

Reduced False Alarm for Forest Fires Detection and Monitoring using Fuzzy Logic Algorithm

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Abstract—The purpose of this research was to detect forest fires in efforts to minimize the incidence of false alarms. The research method used is divided into several stages, namely planning, analysis, design, implementation, testing, and maintenance. Arduino acts as a data collector on the field, which will later be used to detect forest fires and false alarms. Fuzzy logic is used as the essence of the algorithm and will provide a higher level of accuracy for forest fire detection and false alarms. In testing the fuzzy program, the fuzzy output between Arduino and the fuzzy on the monitoring dashboard has a small difference of 0.99%. It can be concluded; the application can minimize the occurrence of false alarms to reduce the user's workload.

Keywords—False alarm; fuzzy logic; forest fires detection; sensor; microcontroller

I. INTRODUCTION

Forests are the lungs of the world because forests will absorb carbon dioxide (CO₂) in the air and release oxygen (O₂) which is very useful and creates a balance of ecosystems for living things. Therefore, forest fires are something that must be prevented and minimized their impact. The primary sources for ecological degradation currently are the Forest Fires [1]. Huge losses and serious threats to ecosystems are a common consequence of forest fires [2]. Indonesia is one of the countries with the largest forest area in the world. With forested land area throughout Indonesia's mainland is 94.1 million hectares or 50.1% of the total land area. However, although the forest area owned by Indonesia is quite high, the number of forest and land fires (Karhutla) in Indonesia is also quite high. Based on data quoted from the Directorate of Land and Forest Fire Control, Ministry of Environment and Forestry of the Republic of Indonesia, forest, and land fires in Indonesia in 2019 alone reached 1,649,258 hectares [3]. Forest fires are one of the big problems in Indonesia because forest fires are very dangerous impact on the environment and people due to smoke and carbon emissions from fires [4]. The most technology to detect fire Hotspots have been using satellite imagery and then processed to determine the number of hotspots and their locations. Some drawbacks in this technology that in bad weather or cloudy then the satellite system cannot penetrate [5][6]. In this research, it is proposed sensor system that uses multiple sensors related to fire parameters, especially fires on peatlands with special specifications fire case. Common fire parameters such as temperature, smoke, fog and carbon dioxide are applied in this system then measure the indicator using a special sensor [7]. This high number of forest and land fires is the source of several problems. Among them are disturbing human health as well as flora and fauna, hindering community activities such as

flights and school activities, destroying the earth with CO₂ content released during forest and land fires, and the clean water crisis caused by water that should be filtered by rocks in the ground, instead being mixed with post-fire soil [8]. The number of forests and lands that burn every year in Indonesia is one of the reasons why early detection of forest and land fires can help humans in handling forest and land fires. Therefore, the proposed solution to this problem is by utilizing the technology that is currently popular, namely Arduino which is one of the Internet of Things (IoT) [9]. Currently IoT Devices and sensors enable monitoring various environmental variables, such as temperature, humidity, etc. [10]. Arduino based platform IoT enabled fire detector and monitoring system is the solution to this problem [11] [12]. To implement this research, we will use GSM which is used to deliver WhatsApp to the user via the number given in the simulation program. Based on data from the Indonesia IoT Forum, there are 400 million sensor devices installed. However, use in the agricultural sector is only 4 percent. This low number can be interpreted by the wide space for IoT innovation in the agricultural sector. This monitoring dashboard is used to improve response to forest fires. So that the impact of forest and land fires can be minimized as much as possible. previous research there are several research on algorithms to calculate the probability of fire occurrence [13], forest fire models and warnings based on GIS grid platform [14] studying fire alarms and based on methods based on infrared technology [15]. However, the shortcomings of this study have not been able to reduce false alarms.

II. METHODOLOGY

The method used in this research is an experimental method. The system is built through the design stage hardware, software, implementation, and testing.

A. Hardware Design

Hardware design carried out based on the block diagram in Fig. 1. System. It consists of input, process, and output. Block diagram of a forest fire detector prototype using a power bank as a resource for the microcontroller and sensors. Starting from the input or input, the input block diagram is in the form of smoke sensors, fire sensors and temperature sensors which are used as input from the tool to start the fire detection process or not. For the microcontroller used is Arduino Uno Rev3 which functions as the main processing component and components that can connect input with output. In the output section there is no component to print the output, but it can be seen from the website and WhatsApp notifications using the mobile phone of forest guards.

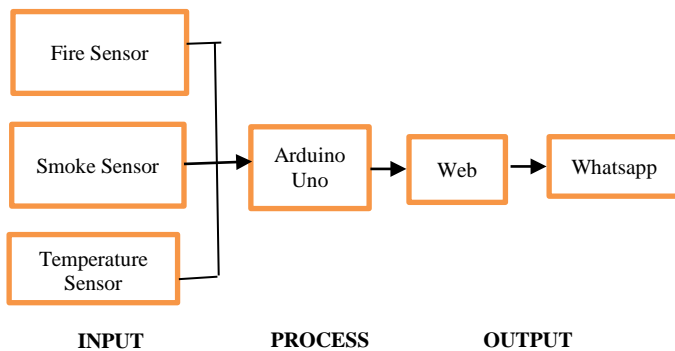


Fig. 1. Block Diagram.

There are three sensors used in this research, namely:

1) *Smoke detection sensor*: The smoke detection sensor used is the Gravity Analog Infrared CO2 Sensor. This sensor works by sucking air around the sensor, then the sensor will determine the gas concentration of the inhaled air [16]. The sensor will get the gas concentration result in Parts-per-million (ppm). For example, if the result is 1,000ppm CO2. So that means there are 1,000 CO molecules and 999,000 other gas molecules. Fig. 2 shows the physical form of the smoke detection sensor used.



Fig. 2. Gravity Analog Infrared CO2 Sensor.

2) *Fire detection sensor*: The fire detection sensor used is a 5 Channel Flame Sensor. This sensor uses infrared rays in 5 directions with a range of 120 degrees and in the wave range of 700 nm – 1100 nm, with a detection distance of less than 1 meter and a response time of about 15 microseconds. The fire detection sensor works by detecting infrared radiation generated by the fire, then the sensor converts the detection into analog and digital signals for further processing. Fig. 3 shows the physical form of the fire detection sensor used.

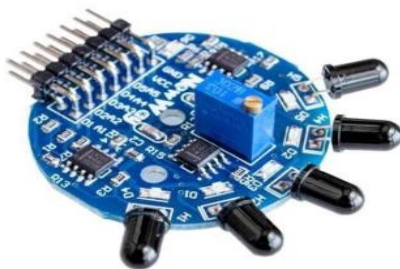


Fig. 3. Sensor Flame.

3) *Temperature detection sensor*: The temperature detection sensor used is the DS18B20 Temperature Sensor, this sensor has a sensor that is quite precise and does not require external components to work. This sensor can measure temperatures from -55°C to +125°C with an accuracy of ±0.5°C. Fig. 4 shows the physical form of the temperature detection sensor used.



Fig. 4. DS18B20 Temperature Sensor.

B. Software Design

The analysis is carried out in the form of observations of the surrounding environment. When a forest fire occurs it cannot be detected by forest rangers, forest guards only know that if a forest fire occurs, smoke will raise in the sky and the fire conditions are largely handled by the firefighters because the fire was too big. The detection process is carried out manually which makes fires difficult to control because the fires are getting bigger, burning forest areas, and the process of forest fires is relatively long. Therefore, an application is needed to monitor and detect forest fires that are useful for minimizing the incidence of false alarms and responding to forest fires handling. The business process of this application is that this application receives sensor data from the microcontroller, then the application will determine the fire status based on the sensor data received by utilizing fuzzy logic, and then the application will send a notification to the forest ranger via WhatsApp, if the fire status is a hazard, then this information also sent to firefighters. Application design business processes to monitor and detect forest fires can be seen in Fig. 5.

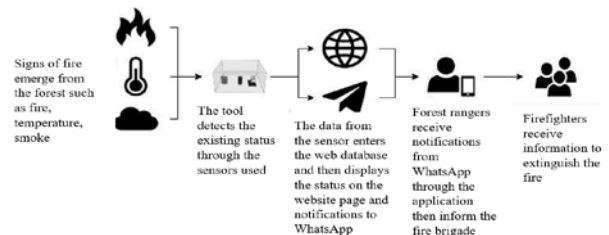


Fig. 5. Design Business Processes.

The flowchart of the system created is described by the sequence of processes in detail from one process to the next so that the system flows easy to understand. Fig. 6 shows the

flowchart of the system that has been made the classification procedure begins with the receipt of sensor data sent by the microcontroller via the API. After that the application will process the data using fuzzy logic to determine the fire status. Fuzzy logic works by receiving data received from the sensor, then classify each data based on the membership function and generate the degree of membership of each sensor data. After that the value of the membership degree will be processed using the rule and will produce the fire status membership degree, which is then entered into the membership degree graph to determine the fire status. If the fire status is declared dangerous, then the application will send a notification message to all contacts WhatsApp stored in the database and displays the status of the fire as a hazard on the monitoring dashboard. Meanwhile, if the fire status is safe or alert, the application only displays the status of a safe or alert fire on the monitoring dashboard.

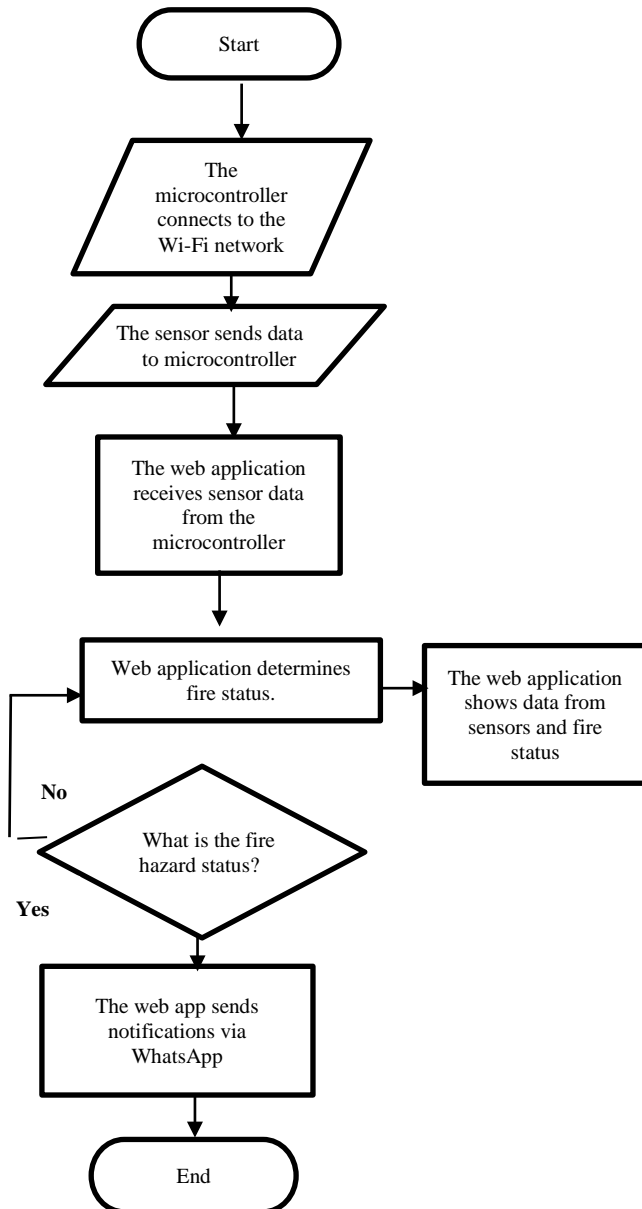


Fig. 6. Flowchart System.

In Fig. 7, the fuzzification sub-system will process input data when doing data reading [17]. The data is in the form of firm values or crispy. In this research using Sugeno Fuzzy for inferencing [18]. The following are the stages of the process of Sugeno Fuzzy Inference:

1) *Fuzzification*: The fuzzification sub process will change the firm value that exists in the membership function or degree of membership. Based on the analysis carried out, the fire status is divided into three, namely, safe, caution, and danger. Where the three statuses are determined based on the variables of Temperature, Smoke, and Fire. Each of these variables has its own status classification. Temperatures are classified into three states, namely, Normal with temperatures less than or equal to 30°C, Warm with temperatures between 30°C and 60°C, and Hot with temperatures greater than or equal to 60°C.

The temperature membership set can be seen in Fig. 8, the membership set function is divided into three ranges, namely, normal [15, 30, 45], warm [30, 45, 60], and hot [45, 60, 75].

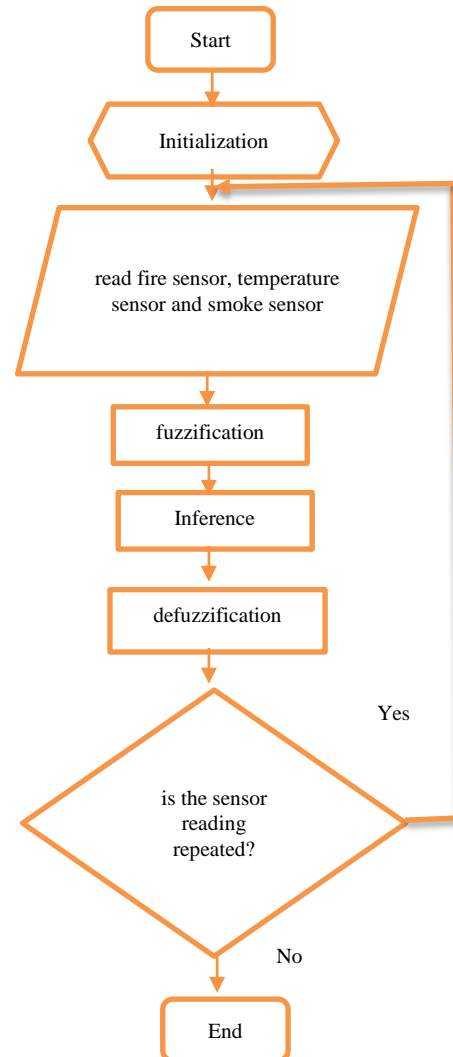


Fig. 7. Fuzzy Design.

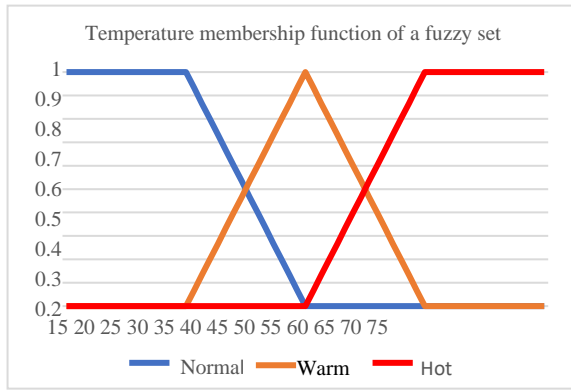


Fig. 8. Temperature Membership.

The smoke membership set can be seen in Fig. 9, in the membership set function is divided into three ranges, namely, thin [200, 600, 1000], medium [600, 1000, 1400], and dense [1000, 1400, 1800].

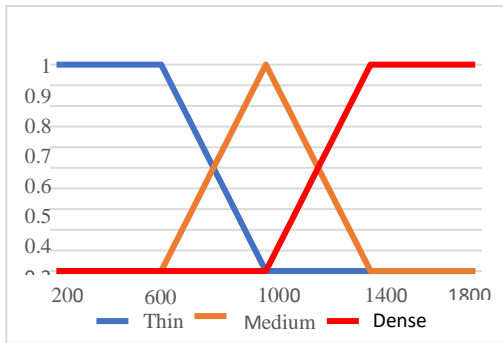


Fig. 9. Smoke Membership.

Fire membership set can be seen in Fig. 10, fire membership set is divided into two ranges, namely, true and false.

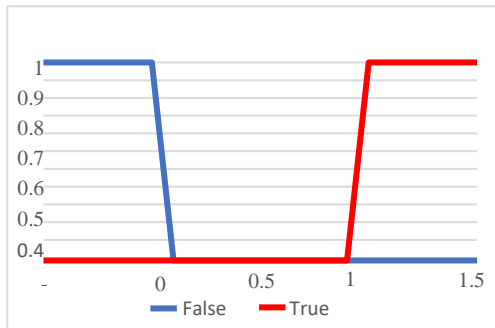


Fig. 10. Fire Membership.

The membership sets above will be used to get the output value by going through the implication stage.

2) *Inference*: At this stage each rule or rule in the fuzzy knowledge base will be associated with a fuzzy relation. The general form of this function is If x is A then y is B. Based on the results of the linguistic variables determining the fuzzy set, the following rules or rule implications can be seen in Table I and set of fire status can be seen in Fig. 11.

TABLE I. FIRE STATUS RULES

Number rule	Temperature	Smoke	Fire	State
1	Normal	Thin	True	Caution
2	Normal	Thin	False	Safe
3	Normal	Medium	True	Danger
4	Normal	Medium	False	Safe
5	Normal	Dense	True	Danger
6	Normal	Dense	False	Danger
7	Warm	Thin	True	Danger
8	Warm	Thin	False	Safe
9	Warm	Medium	True	Danger
10	Warm	Medium	False	Safe
11	Warm	Dense	True	Danger
12	Warm	Dense	False	Danger
13	Hot	Thin	True	Danger
14	Hot	Thin	False	Safe
15	Hot	Medium	True	Danger
16	Hot	Medium	False	Caution
17	Hot	Dense	True	Danger
18	Hot	Dense	False	Danger

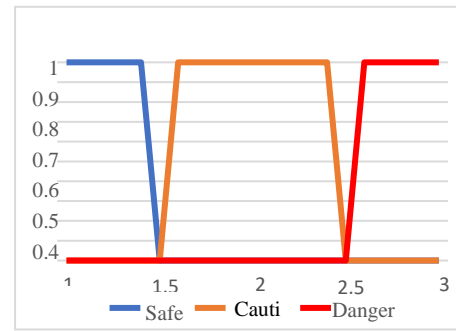


Fig. 11. Set of Fire Status.

At this stage the function used is the minimum calculation, namely by taking the lowest value from the fuzzy set of temperature, smoke, and fire based on the rules that have been made.

$$\alpha_i = \mu A1 (X) \cap \mu B1 (X) = \text{MIN} \{ \mu A1 (X), \mu B1 (X) \} \quad (1)$$

The fire status variable is used to determine the status of the fire status with the Implication function, which consists of safe, alert, and danger with a range as depicted in Fig. 11. That is, safe defuzzification value is 1 – 1.5, Alert 1.5-2.5, and danger 2.5 – 3. Defuzzification

This stage is done by taking the maximum value obtained from taking the minimum value from each rule that has the same rule output.

$$\text{Usf} [Xi] = \text{MAX} (\text{Usf} [Xi], \text{Ukf} [Xi]) \quad (2)$$

- Usf [Xi]: value of the i-th order fuzzy solution.
- Ukf [Xi]: value of the i-th order fuzzy solution.

After that, the composition of the maximum value is obtained as follows:

Safe = MAX (rule 2, rule 4, rule 8, rule 10, rule 14)

Caution = MAX (rule 1, rule 3, rule 6, rule 7, rule 16)

Danger = MAX (rule 5, rule 9, rule 11, rule 12, rule 13, rule 15, rule 17, rule 18)

Then Defuzzification is done by entering the maximum value of each output rule into the weighted average formula:

III. RESULT AND DISCUSSION

In Table III, the temperature is stable below 30°C, Smoke is stable in the range of 428ppm to 456ppm and Fire is not detected at all. So based on the rules in Table II, the fire status is Safe.

TABLE II. TEST RESULTS WITH NO FIRE CONDITIONS

Minute	Temperature (°C)	Smoke (ppm)	Fire	Fire Status
1	28.31	440.63	False	Safe
2	28.19	428.13	False	Safe
3	28.19	428.13	False	Safe
4	28.13	428.13	False	Safe
5	28.13	428.13	False	Safe
6	28.25	428.13	False	Safe
7	28.25	440.63	False	Safe
8	28.19	428.13	False	Safe
9	28.19	456.25	False	Safe
10	28.06	428.13	False	Safe
11	28.13	440.63	False	Safe
12	27.94	428.13	False	Safe
13	27.94	428.13	False	Safe
14	28	440.63	False	Safe
15	28	428.13	False	Safe

In Table III there are three types of fire status that appear. In minutes 1 – 4 there is a fire alert status caused by temperatures exceeding 30°C, smoke in the range of 440ppm to 471ppm, and detected fire. Meanwhile, at minute 5, the status of the fire that occurred was Safe, which was caused by not detecting the fire. This is evidenced by the data at 6 minutes when the fire was detected again, and the fire status returned to Alert. At 9, 13, and 15 minutes there was a Danger fire status, this was caused by a temperature exceeding 45°C, Smoke exceeding 440ppm and a detected fire.

TABLE III. TEST RESULTS WITH 50CM FROM THE FIRE

Minute	Temperature (°C)	Smoke (ppm)	Fire	Fire Status
1	32.06	471.88	True	Caution
2	32.13	440.63	True	Caution
3	31.63	471.88	True	Caution
4	35.31	440.63	True	Caution
5	36.56	471.88	True	Safe
6	35.19	440.63	True	Caution

7	37.19	456.25	True	Caution
8	49.25	440.63	True	Caution
9	53.25	609.38	True	Danger
10	48.5	471.88	True	Caution
11	44.63	440.63	True	Caution
12	51.56	440.63	True	Caution
13	47.75	1159.38	True	Danger
14	50.94	428.13	True	Caution
15	53.56	440.63	True	Danger

In Table IV, it can be seen that the farther the distance from the fire source causes the slightly lower temperature detected.

TABLE IV. TEST RESULTS WITH 100CM FROM THE FIRE

Minute	Temperature (°C)	Smoke (ppm)	Fire	Fire Status
1	31.63	428.13	False	Safe
2	31.69	428.13	False	Safe
3	31.94	440.63	False	Safe
4	32.13	440.63	False	Safe
5	32.25	440.63	False	Safe
6	32.44	1128.13	False	Safe
7	32.56	440.63	False	Safe
8	32.75	440.63	False	Safe
9	32.88	440.63	False	Safe
10	33.06	440.63	False	Safe
11	33.06	1190.63	False	Caution
12	33.19	471.88	False	Safe
13	33.13	487.5	True	Caution
14	33.25	471.88	False	Safe
15	33.31	487.5	False	Safe

The test results with burning mosquito drugs are shown in Table V.

TABLE V. TEST RESULTS WITH BURNING MOSQUITO DRUGS

Minute	Temperature (°C)	Smoke (ppm)	Fire	Fire Status
1	31.63	428.13	False	Safe
2	31.69	428.13	False	Safe
3	31.94	440.63	False	Safe
4	32.13	440.63	False	Safe
5	32.25	440.63	False	Safe
6	32.44	1128.13	False	Safe
7	32.56	440.63	False	Safe
8	32.75	440.63	False	Safe
9	32.88	440.63	False	Safe
10	33.06	440.63	False	Safe
11	33.06	1190.63	False	Caution
12	33.19	471.88	False	Safe
13	33.13	487.5	True	Caution
14	33.25	471.88	False	Safe
15	33.31	487.5	False	Safe

TABLE VI. TEST RESULTS WITH 15 PORTABLE STOVES

Minute	Temperature (°C)	Smoke (ppm)	Fire	Fire Status
1	30.38	428.13	FALSE	Safe
2	30.38	440.63	FALSE	Safe
3	30.31	456.25	FALSE	Safe
4	30.25	440.63	FALSE	Safe
5	30.44	440.63	FALSE	Safe
6	30.38	440.63	FALSE	Safe
7	30.38	1159.38	FALSE	Safe
8	30.44	440.63	FALSE	Safe
9	30.44	440.63	FALSE	Safe
10	30.44	440.63	FALSE	Safe
11	30.44	440.63	FALSE	Safe
12	30.5	428.13	FALSE	Safe
13	30.5	428.13	FALSE	Safe
14	30.63	428.13	FALSE	Safe
15	30.5	428.13	FALSE	Safe

The test results are shown in Table VI, it can be concluded that the false alarm detection accuracy is 100%.

Fuzzy logic testing is done by comparing the fuzzy output value on a series of systems with fuzzy output values found in web. Test performed 10 times is shown in Table VII.

TABLE VII. TEST RESULTS WITH 10 PORTABLE STOVES

Input			Output		Difference	Error
Temperature (°C)	Fire	Smoke (ppm)	Arduino	Web		
23.4	48.8	26.5	2	1.28	0.72	5.62%
29.25	774	1.31	2	2	0	0%
24	50	20	2	1.4	0.6	4.28%
25	25	280	4	4	0	0%
35	25	300	5	5	0	0%
15	500	25	1	1	0	0%
25	200	100	2.73	2.73	0	0%
25	350	200	3	3	0	0%
10	800	20	1	1	0	0%
15	200	500	4	4	0	0%
Average					0.13	0.99%

IV. CONCLUSION

Based on the web-based and WhatsApp-based Forest fire monitoring dashboard detection application that has been done, it can be concluded that: applications can be used by forest halls and forest rangers, the application is implemented by utilizing Arduino along with Arduino sensors to get real time data, the application implements Sugeno Fuzzy Inference for classify fire status and detect false alarm based on data received from Arduino.

Based on the results of tool design and testing, it can be concluded that the performance of the tool as an early fire detector, also functions as a monitoring system for room conditions against potential fires, is able to represent the results of reading all multisensory data and can classify the condition of the room being monitored properly. According to the input data received by the hardware and software. In testing the fuzzy program, the fuzzy output between Arduino and the fuzzy on the monitoring dashboard has a small difference of 0.99%. This shows that fuzzy logic control on multisensory data reading has a high level of accuracy.

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