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# Detection of Forest Fire Used Multi Sensors System for Peatland Area in Riau Province

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**Abstract.** Forest fire is one of the major issue in Indonesia, especially in Riau province because forest fire very dangerous impact on environments and people because of haze and carbon emits from the fire. The most technology to detect fire hotspot so far is using satellite image then process to determine number hotspot and the location. Some weakness in this technology which is in bad weather or cloudy then satellite system cannot penetrate. In this research propose ground sensor system which is using multi sensors related to the parameters of fire, especially fire in peatland area with a special case of fire. Common parameter of the fire such as temperature, smoke, haze, and carbon dioxide applied in this system then measure the indicator used the special sensor. Results of every sensor analyze by apply to intelligent computer programming and algorithm to determine fire hotspot and location. Results show based on integrated multiple sensors, determination of fire hotspot location and intensity more accurate comparison to the use of single sensor determination. Data collected from every sensor keep in an internal database and in some of the period generate a graph for a report as well as for record.

*Keywords—Forest fire, Multi sensor, Peatland, WSNs*

# Introduction

Forest fires in Indonesia seem to become a regional and global disaster, the fire impact spread to neighboring countries and gases combustion emitted into the atmosphere (Co2) has the potential to cause global warming. Initial forest fires were thought to occur naturally because of dryland and hot environmental, but it is likely that humans have a role to play in starting fires in the last decade, hunting and opening up patches of agriculture in the forest. Although fires have been a feature of forests in Indonesia for hundreds of years, fires that occurred initially must have been smaller and more dispersed in terms of frequency and time than in the past two decades, these initial fires were not a cause of significant deforestation.

The first major fire which was the result of a combination of improper forest management and the El Nino climate phenomenon destroyed millions of hectare, of which a few millions hectare were tropical forests (Schindler et al. 1989). According to the National Development Planning Agency (BAPPENAS) together with the Asian Development Bank (ADB) estimated 9.75 million hectares of the forest fire. Furthermore, Indonesian forest fires continue every year though area burned and losses it is relatively small and generally not well documented. Data from the Directorate

General of Forest Protection and Nature Conservation shows that forest fires that occur every year from 2000 to 2002 recorded ranging from 42 thousand to 2.6 million hectares. One of the impacts that occurred due to forest fires the presence of fog. The haze caused forest fires in Riau province, Indonesia has been troubling and bring disease to residents. A number of hospitals, especially clinic in the suburban and urban area are flooded with patients Acute Respiratory Tract Infection (ARI), especially children and elderly people physical endurance is very weak and must breathe the air that is not already healthy due to smoke from forest fires. The haze itself had struck almost all regions in Riau since mid of January, along with the rampant forest fires. The haze is felt at days and night with hot temperatures. The haze gradually fades in the morning along with sunrise and this keeps repeating every day since the forest fire occurred.

The impact of fires that are felt by humans in the form of economic losses is a benefit from forest potentials such as forest trees that are commonly used by humans to meet their needs for building materials, food ingredients and medicines, and animals to meet the needs for animal protein and recreation. Other disadvantages include ecological losses, namely the reduction of forest area, the unavailability of clean air produced by forest vegetation and the loss of the function of the forest as a water regulator and preventing erosion. The direct impact of forest fires is as follows. First, the emergence of acute respiratory infections for the community. Secondly, socially and economically the community is disadvantaged because of the reduced efficiency of work, offices, and schools are closed and transportation is disrupted. Third, immaterial and material losses to the local community even cause transboundary haze pollution (cross-boundary smoke pollution) to the region of neighboring countries such as Singapore, Malaysia and Brunei Darussalam. This research discussed one of preventing effort the forest fire by design a new sensing system to detect and estimate the potential of fire in Riau Province, Indonesia. The special type of land which is peatland is one of challenging with new design of sensor and system that difference to others researcher.

# Related Works

In this research of forest fire detection used the multi-sensor to achieve accurate information about the potential of forest fire happen. Some literature review on previous works as discussed in [1-3] the use of probabilistic neural networks (PNN) data fusion algorithm to detect the potential of fire based on texture features from the fire scene. Some of the information on the environmental temperature and smoke concentration was collect to be processed by the trend of algorithm separately to the data processed. In [4, 5] elaborate on the design and implementation of a web-based communication module of a multi-sensors, in order to detect fire, a system with a notification system designed. A Global System for Mobile Communication (GSM) technology used which GSM module to send data of fire alerts to representative officer and notification based on the web but subsystem in real-time. The purpose design of web-based notification system is for remote notification and alert of fire.

In [6, 7] discuss on the processing method of the essentially different from the traditional signal. The multi-sensor system information fusion can be merged at different levels. The use of Wi-Fi system to detect fire is applied in [8-10] but the application for indoor as a Wi-Fi signal with the analysis used the fuzzy logic system. The used of Wireless Sensor Network (WSN) system easily reconfigure its topology in the communication of data. The system applies several numbers of sensor such as temperature, gas concentration, and visibility. The adaptive method based on a multilayer perceptron for the processing of measurement results in a multi-sensor system [11, 12]. The development of the multi-sensor system in the detection of fire apply the algorithms to increase the sensitivity in the detection of fire and some devices implement to reduce nuisance alarms [13, 14].

Wireless multi-sensors for fire detection in WSN node and algorithm is implemented to determine the probability of fire. Fire detection is formed of the low-power electrochemical carbon monoxide sensor, photoelectric smoke detector, and semiconductor temperature sensor. Algorithm for the program in an embedded system is applied as samples of the algorithm were used to derive from the fire detection standard room of the State Key Laboratory of Fire Science of China [15, 16]. Furthermore, a research conducted by the previous researcher is the detection of forest fire in prediction model based on two-stage adaptive duty, then the results obtained be able to detect but some of spot inaccurate. The discussion on the used Internet of Things (IoT) technology in the detection of forest fire as elaborate in [17, 18], this section applies IoT as alerts and broadcast information through IoT system that currently widely used.

## Forest fire

Forest fire in Indonesia very often in summer session because of dry environment, many places in Indonesia with rising temperature in summer then easy to get fire on land and forest area. Land and forest fire in Indonesia as a disaster in most provinces, especially in Sumatera and Kalimantan Island because of the peatland area. Table 1 shows the data of forest fire in Indonesia based on province, where Riau province is one of the high and very often getting forest fire.

**TABLE 1.** Forest Fire Data in Indonesia Year 2014-2019

| No | Province | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Total (ha) |
|----|----------|------|------|------|------|------|------|-----------|
| 1 | Aceh | 155.66 | 913.27 | 9,158.45 | 3,865.16 | 1,284.70 | 141.78 | 15519.02 |
| 2 | Bali | 30 | 373.46 | - | 370.8 | 206.54 | - | 980.8 |
| 3 | Bangka Belitung | - | 19,770.81 | - | - | 2,055.67 | - | 21826.48 |
| 4 | Banten | 2 | 250.02 | - | - | - | - | 252.02 |
| 5 | Bengkulu | 5.25 | 931.76 | 1,000.39 | 131.04 | 8.82 | 1.47 | 2078.73 |
| 6 | DKI Jakarta | - | - | - | - | - | - | 0 |
| 7 | Gorontalo | - | 5,225.89 | 737.91 | - | 158.65 | 27.7 | 6150.15 |
| 8 | Jambi | 3,470.61 | 115,634.34 | 8,281.25 | 109.17 | 1,390.90 | 4.18 | 128890.45 |
| 9 | Jawa Barat | 552.69 | 2,886.03 | - | 648.11 | 4,104.51 | - | 8191.34 |
| 10 | Jawa Tengah | 159.76 | 2,471.70 | - | 6,028.48 | 331.67 | - | 8991.61 |
| 11 | Jawa Timur | 4,975.32 | 7.966,79 | - | 5.116,43 | 7.279,76 | - | 4975.32 |
| 12 | Kalimantan Barat | 3.556,10 | 93,515.80 | 9,174.19 | 7,467.33 | 68,311.06 | 2,273.97 | 180742.35 |
| 13 | Kalimantan Selatan | 341 | 196,516.77 | 2,331.96 | 8,290.34 | 98,637.99 | 52.53 | 306170.59 |
| 14 | Kalimantan Tengah | 4.022,85 | 583.833,44 | 6.148,42 | 1.743,82 | 41.521,31 | 27,00 | 0 |
| 15 | Kalimantan Timur | 325.19 | 69,352.96 | 43,136.78 | 676.38 | 26,605.57 | 5,153.07 | 145249.95 |
| 16 | Kalimantan Utara | - | 14,506.20 | 2,107.21 | 82.22 | 625.82 | 792.11 | 18113.56 |
| 17 | Kepulauan Riau | - | - | 67.36 | 19.61 | 320.96 | 4,969.85 | 5377.78 |
| 18 | Lampung | 22.8 | 71,326.49 | 3,201.24 | 6,177.79 | 14,963.87 | - | 95692.19 |
| 19 | Maluku | 179,83 | 43,281.45 | 7,834.54 | 3,918.12 | 14,131.33 | 180.03 | 69345.47 |
| 20 | Maluku Utara | 6.5 | 13,261.10 | 103.1 | 31.1 | 69.54 | 56.79 | 13528.13 |
| 21 | Nusa Tengara Barat | 3.977,55 | 2.565,71 | 706,07 | 33.120,81 | 14.352,26 | 29,10 | 0 |
| 22 | Nusa Tengara Timur | 980.87 | 85,430.86 | 8,968.09 | 38,326.09 | 55,207.64 | 99.13 | 189012.68 |
| 23 | Papua | 300 | 350,005.30 | 186,571.60 | 28,767.38 | 87,676.88 | - | 653321.16 |
| 24 | Papua Barat | - | 7,964.41 | 542.09 | 1,156.03 | 120.63 | 58.36 | 9841.52 |
| 25 | Riau | 6,301.10 | 183,808.59 | 85,219.51 | 6,866.09 | 37,220.74 | 27,683.47 | 347099.5 |
| 26 | Sulawesi Barat | - | 4,989.38 | 4,133.98 | 188.13 | 978.38 | 56.77 | 10346.64 |
| 27 | Sulawesi Selatan | 483.1 | 10,074.32 | 438.4 | 1,035.51 | 1,741.27 | 441.07 | 14213.67 |
| 28 | Sulawesi Tengah | 70.73 | 31,679.88 | 11,744.40 | 1,310.19 | 3,890.95 | 215.92 | 48912.07 |
| 29 | Sulawesi Tenggara | 2,410.86 | 31,763.54 | 72.42 | 3,313.68 | 8,121.35 | 16.42 | 45698.27 |
| 30 | Sulawesi Utara | 236,06 | 4.861,31 | 2.240,47 | 103,04 | 125,07 | 9,98 | 0 |
| 31 | Sumatera Barat | 120.5 | 3,940.14 | 2,629.82 | 2,227.43 | 2,421.90 | 60.68 | 11400.47 |
| 32 | Sumatera Selatan | 8,504.86 | 646,298.80 | 8,784.91 | 3,625.66 | 13,019.68 | 236.49 | 680470.4 |
| 33 | Sumatera Utara | 3,219.90 | 6,010.92 | 33,028.62 | 767.98 | 3,678.79 | 152.55 | 46858.76 |
| 34 | Yogyakarta | 0.27 | - | - | - | - | - | 0.27 |
| | **TOTAL (ha)** | **32,438.97** | **2,012,184.19** | **429,268.22** | **125,399.82** | **447,285.81** | **42,674.34** | **3,089,251.35** |

Peat deposits are generally light brown to dark brown to blackish dark, very soft, easily pricked, dirty hands, if squeezed out the dark liquid and leave remnants of plant waste, obtained from the surface of the earth up to several meters thick. Surface peat deposits can be overgrown with various types and species of plants ranging from moss, bush to large trees. Darker peat usually shows a stronger decay rate. In megascopic tropical peat generally consists of remnants of roots, stems, leaves, and fibers in quantities that are abundant, on the contrary, peat moss (moss peat) is dominated by remnants of moss plants as found in Finland (Northern Europe). Figure 1 shows the area in Indonesia with a high spread of peatland.
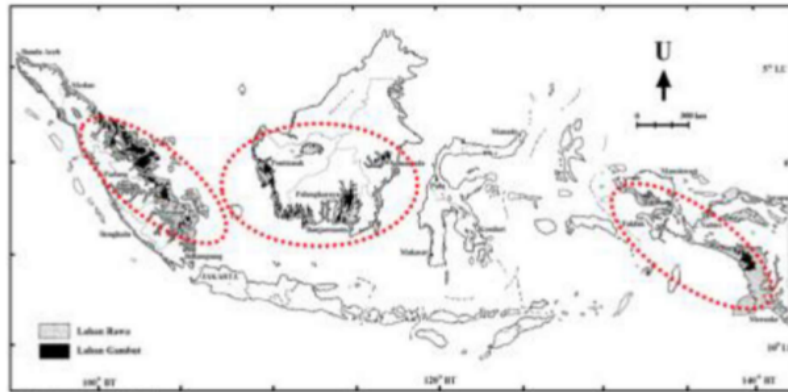
**FIGURE 1.**Peatland map area in Indonesia.

## Proposed Multi Sensor System

Wireless Sensor Networks (WSNs) technology applicable into many applications, such as in industrial automatic control, remote environmental monitoring, target tracking, and remote sensing. The use of WSN system application in an environmental monitoring system which is for detection forest fires in a real-time applied in this research. WSN consists of a numerous number of small nodes in most common situations, which is small nodes deployed in remote and inaccessible hostile environments or over large geographical areas. The deployment of a large number of small sensor nodes to sense environmental changes then report the detection results to sensor base station, then through a gateway to transfer all the data to the server which is the deployment and maintenance should be easy and scalable. Figure 2 shows a block diagram of the design forest fire sensor with multiple sensors.
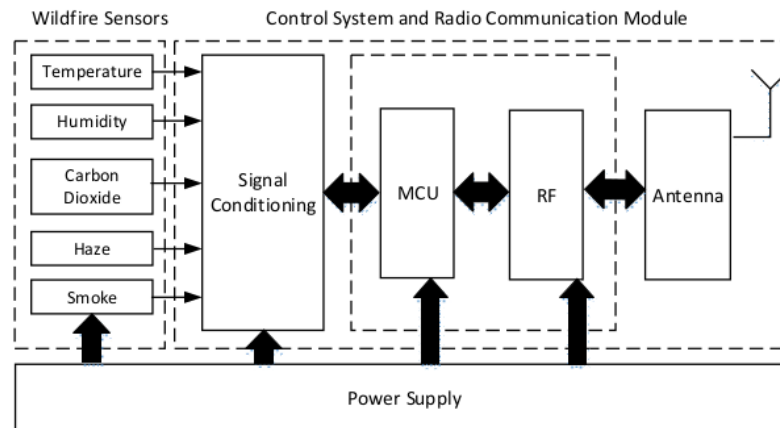


**FIGURE 2.** Block diagram of forest fire sensor used multiple sensors.

The information detected from the sensors keep in an internal memory of sensor before sending to the monitoring system (backend system), because of the distance between sensor base station to monitoring is very far which in the rural area and up to 200 km. The solar system used for power supply to power up the sensing system. The latest technology of communication system applied in this sensing system which is 4G technology or even 5G technology for future in order to achieve real-time data to display to a monitoring system. Figure 3 shows the block diagram of data communication to the backend system for monitoring.
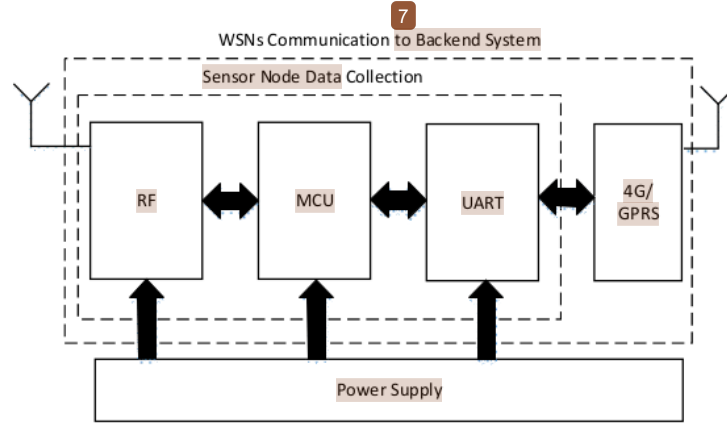
FIGURE 3. Block diagram of communication to backend system.

The design of sensor node for forest fire detection using WSNs system application in peatland area is a new method for ground sensing technology. The data collected base of forest fire parameter and multi sensors to detect abnormal condition. Based of sample data analysis then the design multi sensors system to approach forest fire and material or chemical emit from the forest fire is proposed.

## Forest fire modeling in peatland area

In the forest, the total hotspot coverage area can be assuming a set of multiple WSN sensors distributed over a geographical region in the area to be monitor, coverage function $P$ is given as:

$$P = f(x, y, t) = \{(x_1, y_1), \dots (x_n, y_n)\},$$
$$(x_k, y_k) = f(t), k = 1, 2, 3, \dots, n \tag{1}$$

where $(x, y)$ are coordinates of sensor installed within the coverage monitored area of a fire detection region. In this research, the case network is static without mobile sensor of WSN, but the sensor positions are time-dependent, since the sensor nodes are expected to stop operation in some time. If the case assumes to define the coverage index is $IP$ as a scalar value representing the percentage of coverage area for the detection under the monitoring at a specific time as:

$$IP = \frac{\text{area covered with sensors}}{\text{the total area of the surveillance region}} \cdot 100\% \tag{2}$$

The basic model component is a multiple WSN sensor nodes defined as a vector:

$$S = (d, E(t)) \tag{3}$$

where $d$ is a range of sensor transmitting or radius of transmission area, then the range of covered by radio signal for data exchange with a neighboring node. $E(t)$ is energy available as a power supply for the sensors. Assume a homogenous sensor network with n unified type sensors and one hub-sensor for communication with a dispatcher node.

Network parameters are described as a vector:

$$M = (n, f_0, \Delta E) \tag{4}$$

where n is the number of sensors, *fo* is the frequency of regular transmissions, and ΔE is energy consumption per transmission. Assume that sensor nodes periodically transmit the data collected to the neighboring nodes. Energy consumption ΔE includes also energy spent in sensing and data processing. Each node has two roles:

- sensing environmental data and its transmission.

- receiving data from neighboring nodes and forwarding.

The object under surveillance is modeled as four-side stationary polygon defined as a set:

$$O = (A, B, C, D) = \left\{ (x_A, y_A), (x_B, y_B), (x_C, y_C), (x_D, y_D) \right\}$$

(5)

where *A, B, C,* and *D* are polygon points with coordinates of *(x, y)*.

# Results and Discussion

The proposed new design of forest fire detection application for peatland area has been tested. The sensors are able to detect all parameters that indicator potential fire in the peatland forest area. The design of the sensor system consists of four sensors which temperature, humidity, smoke, and carbon sensor. Figure 4 shows assembled multiple sensors for detection fire hotspot that consist sensor which related to fire parameters.
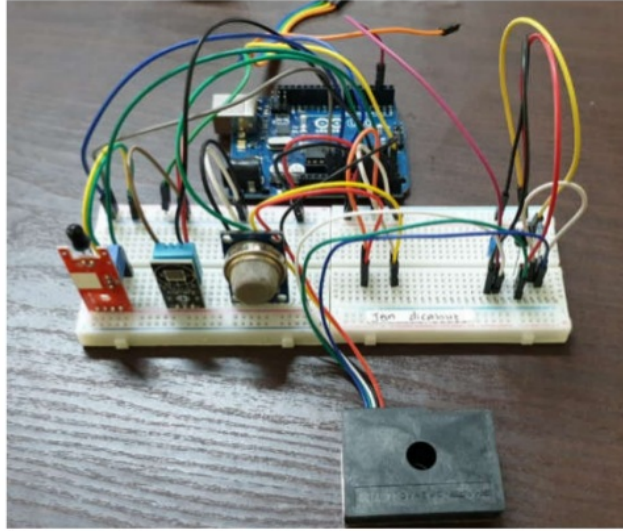


FIGURE 4. Assembled sensor node for fire detetction.

The detection data from the sensors keep in the Arduino memory and some filtering has been in this module to avoid waste data. All the data collected from the sensor analyze with an intelligent programming system to determine whether data receive is potential to be a fire, this programming be able to differentiate normal fire and forest or land fire which becomes a wildfire. There are many parameters as discussed in the previous one of the parameter of environmental potential to fire is environment temperature. Beside environment temperature, humidity gives an impact as well to the potential of fire. Measurements of humidity done using sensor and integrated to a temperature sensor in a processing module which is Arduino. Figure 5 shows the assembled and tested of reading humidity in the laboratory environment, the reading of temperature and humidity shows in as LCD display then all the data will log in a data logger inside the module for the record. In a period of time, all the data collected by the Arduino module with filtered data send to the monitoring system that all the data to analyze and permanently record.
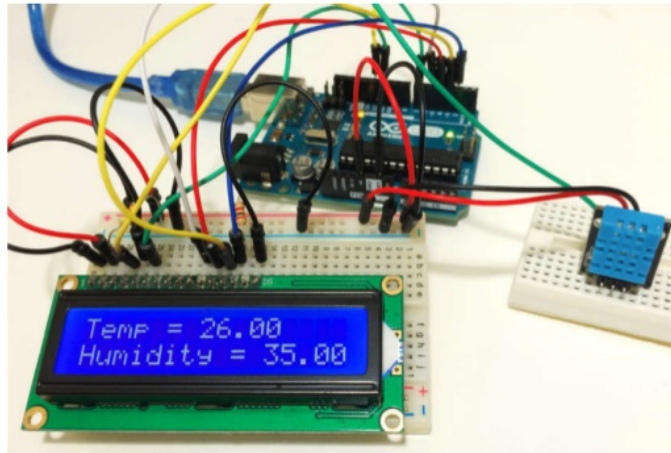
**FIGURE 5.** Results of testing humidity measurement.

The testing conducted in the real environmental foresty area in dry session. The parameter of basic environmental which temperature and humidity can be group as shown in table 2. The low temperature which 25°C to 27°C is in the night time where the area in tropical region day and night time is the same length. While temperature 35°C to 37°C is most in the day with the hot sun from 12 pm to 3 pm noon.

**TABLE 2.** Forest Environmental Parameter

| NO. | Temperature | Humidity |
|---|---|---|
| 1 | 25–27 °C | 85–90% |
| 2 | | 90–95% |
| 3 | 27–29 °C | 85–90% |
| 4 | | 90–95% |
| 5 | 33–35 °C | 70–75% |
| 6 | | 85–90% |
| 7 | | 90–95% |
| 8 | 35–37 °C | 80–85% |
| 9 | | 85–90% |
| 10 | | 90–95% |

Sensor reading for environmental parameters has been tested in a few time, the basic parameter of environmental tested and the data log in the monitoring system. Figure 9 shows a graph based on data collected for temperature and humidity, based on results shows the relation of temperature versus humidity in forest area is very close thus increasing temperature one of caused forest fire in peatland area. Furthermore, carbon dioxide and haze emitted from a forest fire are some of the indicators that very closely related to cause of fire in peatland area.
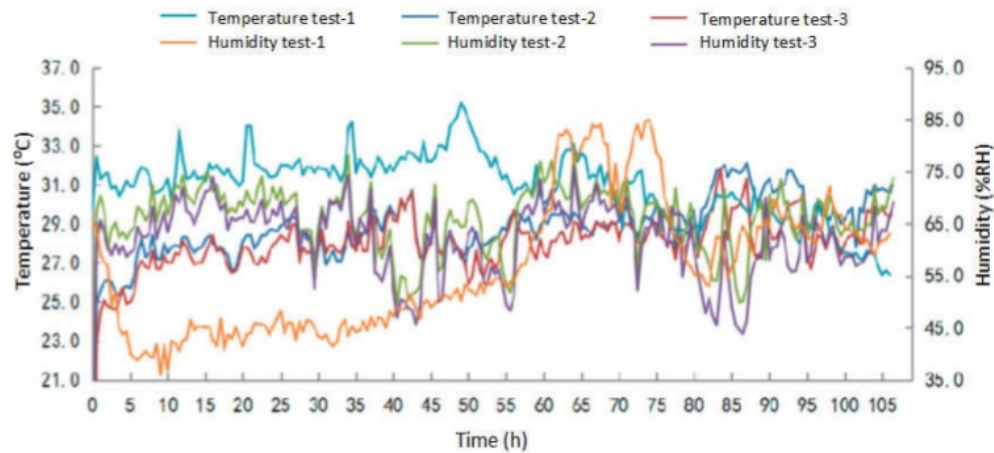
**FIGURE 6.** Testing results for a period of time in real environmental.

# Summary

The design of multiple sensors for forest fire detection and monitoring has been proposed, the results show designed sensor be able to detect basic environmental parameters as the main parameter then some of the additional parameter of forest fire especially in peatland area which different to others normal land or area. The graph shows a strong correlation between increasing temperature versus humidity as well as the reading of carbon emits from the fire and haze concentration one of indicator to justify fire happen. All the reading and detection from the sensor keeps in a data logger for the records. Further enhancement and improvement of the sensing system, as well as data analysis with intelligent programming and algorithm, is one of the targets for future work in this research. Finally, at the end of the project aim to set monitoring system with the mobile report and alert to the community around the forest area as prevention action, notification for authority is a must in this system for action taken.

# Acknowledgments

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