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Multiple Sensor System for Land and Forest Fire Detection Application in Peatland Area

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ABSTRACT

Forest fire very dangerous impact on environments and people because of haze and carbon out because of 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 several sensors related to the indicator 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 implement intelligent computer programming and applied an 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 a database and in some of the period generate a graph for a report as well as for record. In case of sensor read with parameters potential for fire and hotspot detected then report will forward to the representative department for action taken.

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1. 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. Figure 1 shows the area in Indonesia with many numbers of fire hotspot.

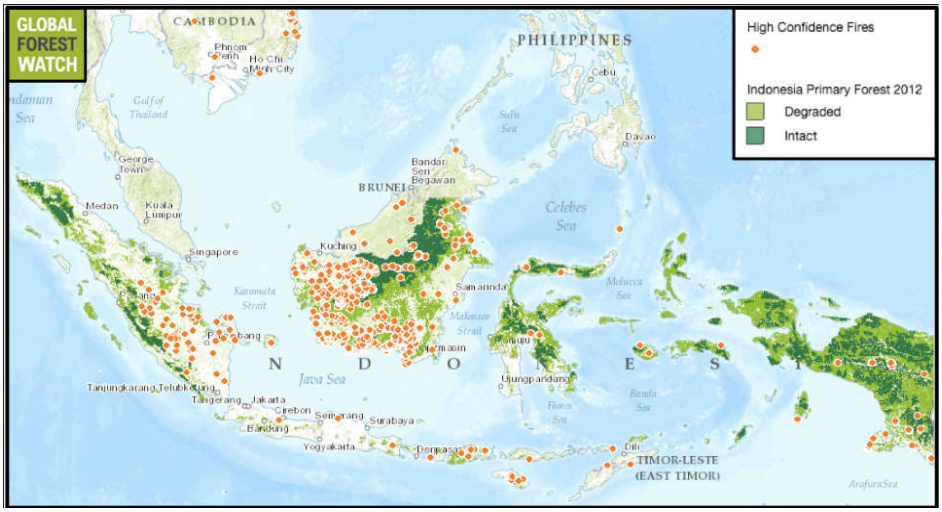

Figure 1. A scene of forest fire scatter in Indonesia

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.

2. 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. Detection of forest fire used atmosphere system to check radiative fire as discussed in [8] but this system only did in simulation. The use of Wi-Fi system to detect fire is applied in [9-11] 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 to 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 [12, 13]. 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 [14, 15].

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 [16, 17]. 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 [18]. The discussion on the used Internet of Things (IoT) technology in the detection of forest fire as elaborate in [19, 20], this section applies IoT as alerts and broadcast information through IoT system that currently widely used.

3. MULTI SENSOR FOR PEATLAND FIRE DETECTION

Current technology to detect forest fire mostly used satellite image and analyze to determine fire hotspot. Multi-sensor system for fire detection introduced by some researcher but only a few parameters of forest fire used. In this research proposed a multi-sensor system for forest fire detection, especially in peatland area because has the unique and different parameter of fire. The design of sensor consists of several sensors related to the soil parameter which is peatland, the impact of fire from the soil analyzed to determine the type of sensor used and method to analyze the data from the peatland fire. Four types of sensors used which temperature and humidity as basic parameters of environmental then additional sensor related to the peatland which carbon and haze.

3.1. Peatland

Peatland formation at the Beginning of Quaternary is an ice age (diluvium), resulting in a decrease in sea level (regression) which causes strong erosion upstream of the river and produces coarse rock deposits such as gravel and gravel called "old alluvium" deposited in over tertiary sediments that form the basis of the peat basin. At the end of the regression phase, which takes place in the "warm" period, i.e at the end of the “Pleistocene” to the Holocene beginning, with the melting of the ice. The increase in seawater is accompanied by an increase in temperature and rainfall in the regions of Sumatra and Kalimantan, which causes rocks along the “*Bukit Barisan*”, Swaner and Meratus to experience strong chemical weathering and produce fine clay deposits on the coastline in the East Coast of Sumatra and south Kalimantan so that the coastline progresses towards the sea, then formed river embankments, meanders, and swamps which are soon overgrown by swampy plants such as “*Nipah*” and mangroves. Figure 2 shows a story of formation peatland in Indonesia.

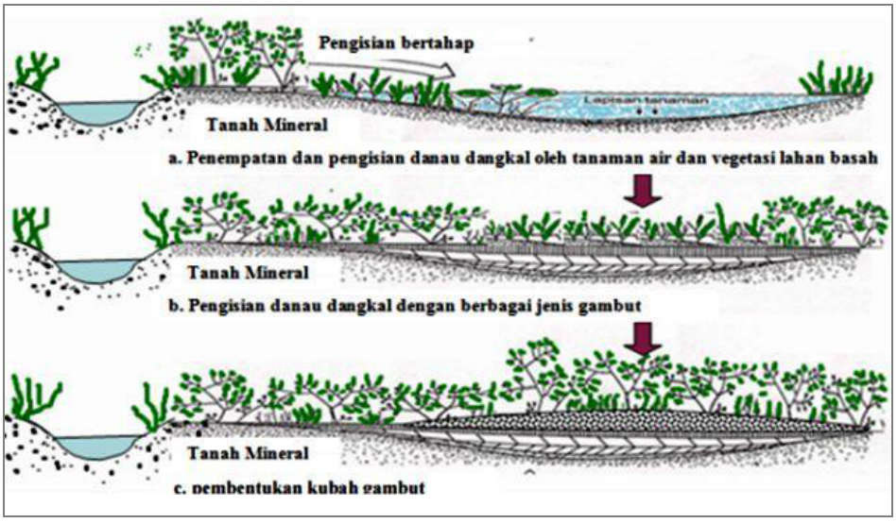

Figure 2. Example of formation peatland

The characteristics of peatland are based on the initial process of its formation are largely determined by the following elements and factors:

- Types of plants (evolution of flora growth), such as mosses, grass, and wood.
- Humification process (temperature or climate); and
- Its depositional environment (paleogeography).

All distribution of peat deposits is in the quaternary alluvium sedimentary group in the quaternary period. The location is relatively near the beach to tens of kilometers inland. The maximum thickness that was ever known reached 15 meters in the Riau area. Basically, because peat deposits are above the earth's surface, peat deposits can be known and differentiated "*megascopically*" in the field. One way to recognize megascopic peat deposits is that peat deposits are generally characterized by very soft physical properties resembling 'soil', 'mud' or humus from a combination of decaying plants such as leaves, stems, twigs, and roots of various species and species. The level of decay of plants is generally determined and influenced mainly by the depositional environment (anaerobic or aerobic) and the composition of the organic material (the content of *lignin, cellulose, cinn, humic* acid, etc.).

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 3 shows the area in Indonesia with a high spread of peatland.

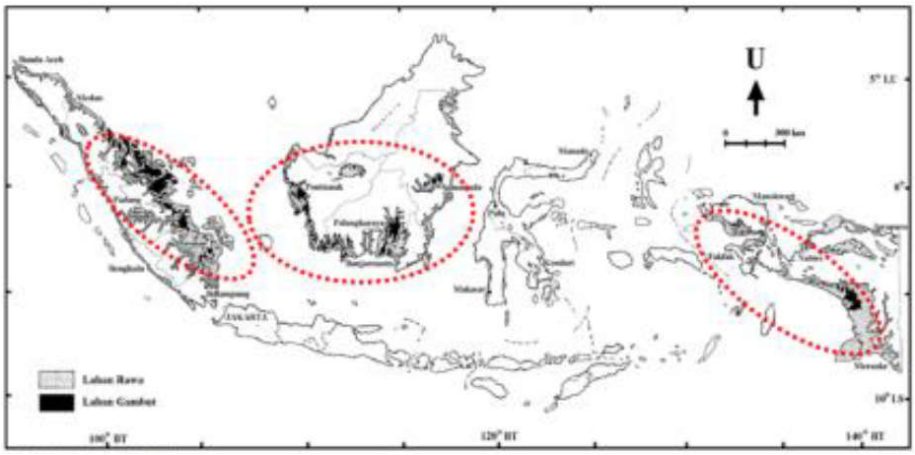

Figure 3. Peatland map area in Indonesia

3.2. Proposed Multi Sensor System

WSNs technology is can be apply in many application, for example in remote environmental monitoring, industrial automatic control, remote sensing and target tracking. In this case proposed an application of WSNs to the environmental monitoring for detection of land and forest fire which apply in real time. Ideally, a WSNs system consist of a few number of sensor nodes in a system that connected each other with communication system. Proposed multi sensors system in this research is required because of various parameters consist in a forest fire, thus all the parameters should measure and monitored. The parameters monitored in this proposed research such as temperature, humidity, carbon dioxide, smoke and haze. Figure 2 shows a block diagram of propos designed system for land and forest fire sensing system with multiple sensors. Data detected from all the sensor collected in internal memory system in sensor node then forward to the WSNs gateway system for large capacity of data memory. In the gateway system data filtering for unused data is done to minimize large number of data to be send to backend system.

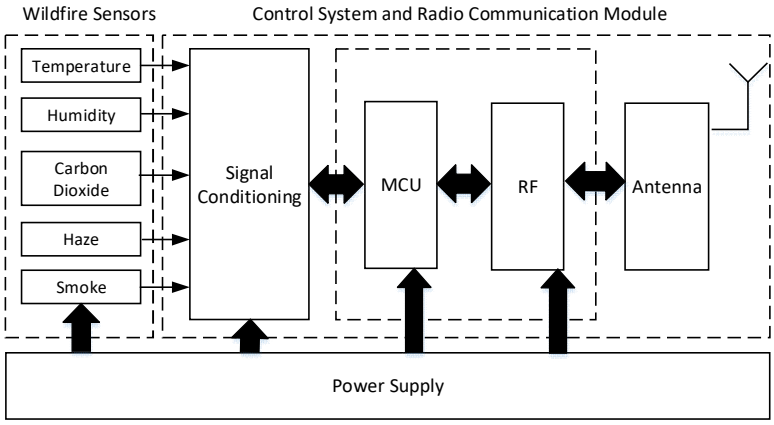

Figure 4. Block diagram of forest fire sensor used multiple sensors

The information detected from the sensors keep in an internal memory of sensor before sending to the monitoring system (backend system), because of the location monitoring system (sensing node) very far away to the backend system up to 200km, which no facility of power supply thus a solar panel system is apply for the sensing node in order to get powered. The latest technology of communication system applied in this sensing system which is Fourth Generation (4G) technology apply in this communication system form sensing nodes to backend system. Figure 3 shows the block diagram of data communication to the backend system for monitoring.

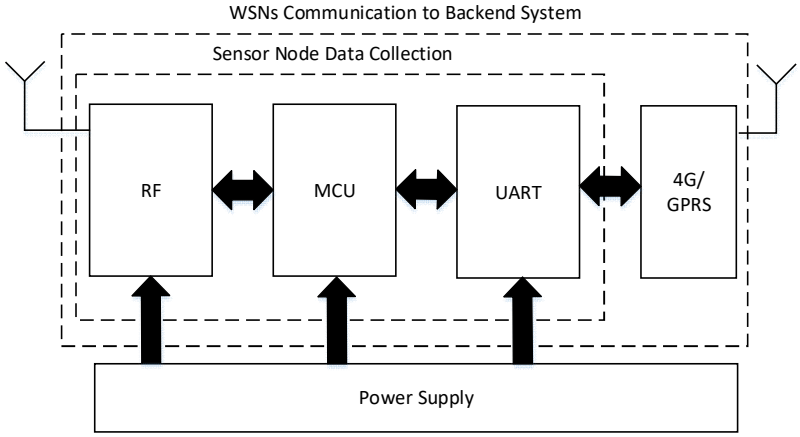

Figure 5. Block diagram of communication to backend system

The proposed design of sensing 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.

3.3. Forest fire modeling in peatland area

Forest fire hotspot is different in each of area, some very high and many fire hotspot and some others area with low number. In order to estimate the total hotspot with common geographical by assuming a set of number with multiple WSNs sensor deployed in a region of the area to be monitor, the function of coverage P is given as (1).

$$P = f\,(x, y, t) = \{(x_1, y_1)\,\ldots.(x_n, y_n)\},$$

$$(x_k, y_k) = f(t), k = 1,2,3,..n \quad (1)$$

(x, y) is represent the coordinate of the sensing system where installed on the ground of forest with the large of coverage area to be monitored. In this case the scenarios of WSNs system is static which mean the sensing node is fix in the location. Since the sensing node is expecting to collect more data in actual condition and stop operating just sometime. Assumes to calculate the case define by the coverage of the index area is IP as a scalar value represent the amount of percentage coverage area to be monitor within a specific of time then the IP can be calculated as (2).

$$\text{IP} = \frac{\text{area covered with sensors}}{\text{the total area of the surveillance region}} . 100\% \quad (2)$$

The model of WSNs system based on basic components in a multiple sensor node can define as a vector in (3).

$$S = (d, E(t)) \quad (3)$$

which d can be defining as a distance of sensing power transmitting in radius of range area, and the distance of covered area by a number of sensing nodes for exchange and communicate each other of neighboring nodes. E(t) is availability of energy in sensing node. The parameter of network can be describing as a vector as write in (4).

$$M = (n, \mathrm{f}_0, \Delta E) \quad (4)$$

while n is the number of sensor in the area of forest, fo is transmissions of the frequency in regular, and ΔE is consumption of the energy per transmission. Consumption of energy as ΔE as well as energy spent in a sensor node and processing of data. In each node has 2 roles:

(a) sensing of environmental data and its transmission.
(b) receiving data from every neighboring nodes and forwarding to the gateway station.

The number of object in sensing node surveillance modeled as four side stationary in polygon defined as a set as in (5).

$$O = (A, B, C, D) = \{(\mathrm{x_A}, \mathrm{y_A}), (\mathrm{x_B}, \mathrm{y_B}), (\mathrm{x_C}, \mathrm{y}_C), (\mathrm{x_D}, \mathrm{y}_D)\} \quad (5)$$

while A, B, C, and D is the polygon of sensing points with coordinates of (x, y).

4. 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 6 shows assembled multiple sensors for detection fire hotspot that consist sensor which related to fire parameters.

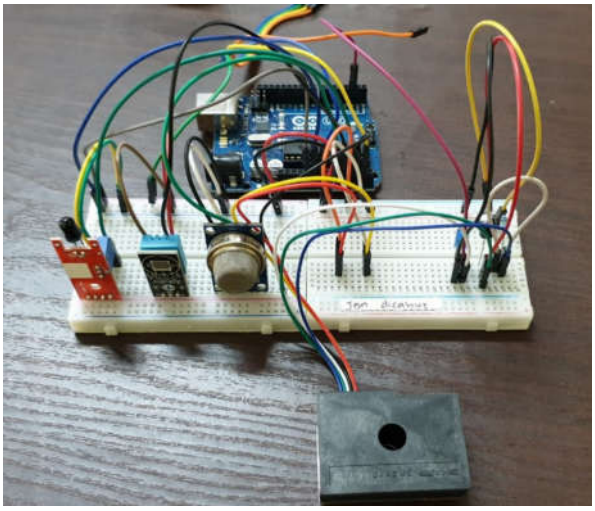

Figure 6. Assembled sensor node for fire detetction.

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. Figure 7 shows testing of measurement temperature of environmental using temperature sensor and all reading keeps in the internal data logger.

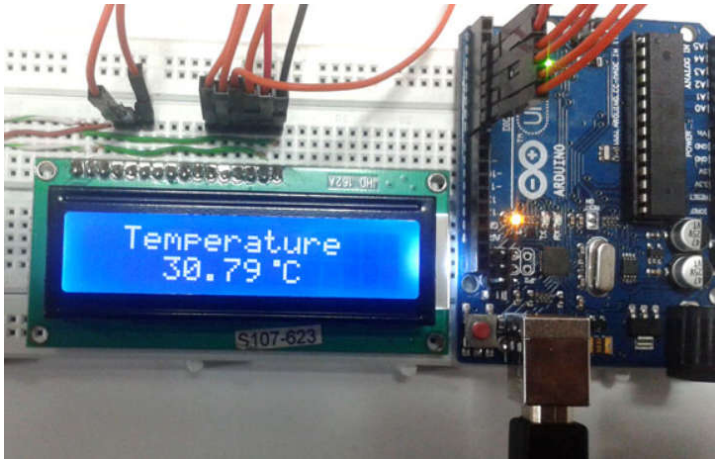

Figure 7. Results of testing temperature measurement.

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 8 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.

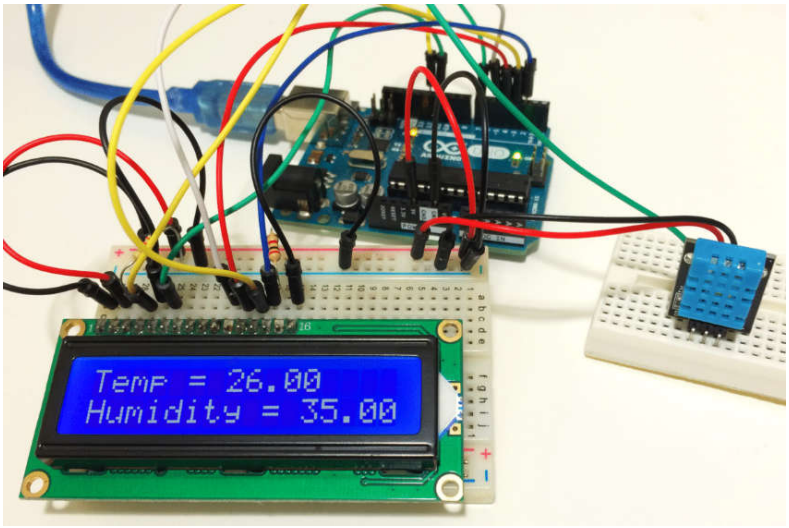

Figure 8. Results of testing humidity measurement.

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 1. The low temperature which 25ºC to 27ºC is in the night time where the area in tropical region day and night time is the same length. While temperature 35ºC to 37ºC is most in the day with the hot sun from 12 pm to 3 pm noon.

Table 1. 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. Based on multiple parameters in the sensing system become a strong justification to make a decision that indication forest fire will happen is one of aim in this research and a recommendation to the authority.

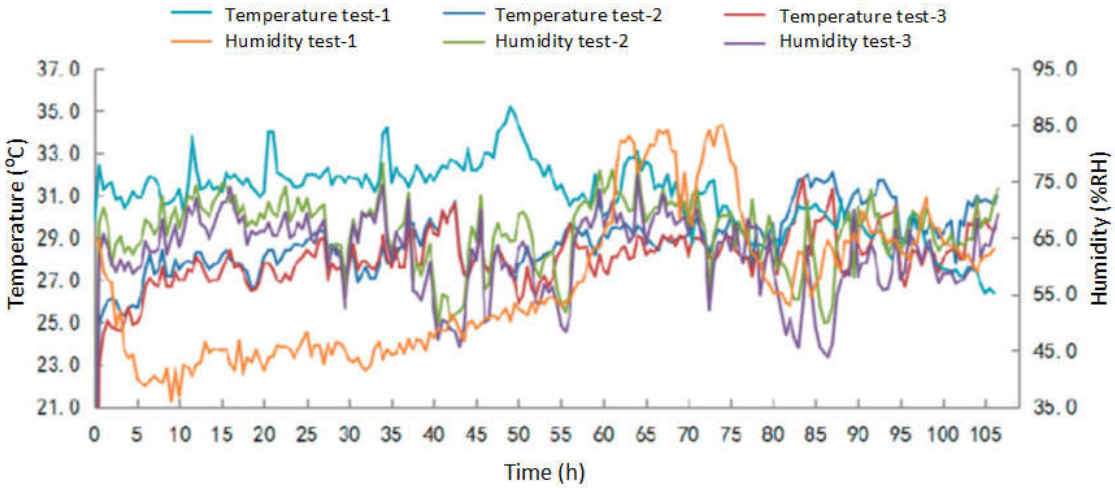

Figure 9. Testing results for a period of time in real environmental.

5. CONCLUSION

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.

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Evizal Abdul Kadir received his Master of Engineering and PhD in Wireless Communication at Faculty of Electrical Engineering, Universiti Teknologi Malaysia in 2008 and 2014 respectively. He is currently as Lecturer and Researcher in Islamic University of Riau (UIR) Indonesia as well as Director of research institute and community services and get promoted to Associate Professor. He has experience and worked in several companies that provide a system solution in Wireless Communication and Radio Frequency (RF) as well as Radio Frequency Identification (RFID), currently is continuing his research activities related to the Wireless Communication System, Antenna, Remote Sensing, Radio Frequency Identification (RFID), Wireless Sensor Network (WSN), Wireless and Mobile Monitoring System and IoT.

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