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Peatland Fire Photo Geotagging using Smartphones as an Investigative Tool

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Abstract. One of the ways to control tropical peat fires is to use a combination of the Global Navigation Satellite System (GNSS) and smartphones for monitoring, reporting, and verification of the location of the fires. The latest smartphones have many sensors, such as a compass, accelerometer, GPS, and a camera, to collect forest activity data from a specific target area. The collected data were then transferred to a cloud server through global mobile communication. This paper discusses a mobile and web application-based approach to collect and analyze user-generated geographical information of human activity data. The paper aims is to promote law enforcement agencies, local government, and fire patrol to consider the use of this low-cost, easy-to-use technology in controlling and reducing the risk of tropical peatland fires. Our mobile application has an easy-to-use mapping technology that allows its users to locate addresses quickly and provides cartographic maps augmented with digital information and high-resolution aerial imagery. This study proposes online citizen reporting as a new approach for law enforcement by aiding local government and fire patrols to conduct monitoring, reporting, and verification to reduce the risk of peat forest fires.

Keywords: Geotagged photo; GNSS; Investigation tool; Peatland fire; Smartphone

1. Introduction

Tropical peatland fires caused by spontaneous combustion, human activity pose critical problems, especially in Indonesia. Tropical peatland fires can cause to significant health, economic, environmental damage and worsen climate damage (Hayasaka et al., 2014; Alisjahbana and Busch, 2017; Purnomo et al., 2017). In Sumatra and Kalimantan Island, many of fire events are detected by satellites. Because the initial detection of peatland fires is of importance for effective burnout, a detection and monitoring system for Indonesian forest fires has been developed (Siegert et al., 2004; Groot et al., 2007; Elvidge et al., 2015; Iizuka et al., 2018; Sandhyavitri et al., 2019). One of the ways to control tropical peat fires is the use of Global Navigation Satellite System (GNSS) and smartphones for effective monitoring and prevention. The latest smartphones have many features, such as a compass, accelerometer, Global Positioning System (GPS), and camera, to collect and measure forest activity data from a specific target area (Masiero et al., 2016; Keefe et al., 2019). The

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collected data are then aggregated to the cloud server through global mobile communication. This system can provide direct reports and analyses of criminal activity patterns resulting in tropical peatland forest fires through smartphone-based citizen reporting.

A lot of monitoring and surveillance systems for tropical peatland fires are currently based on satellites, drones, fire lookout towers, or wireless sensor networks (Teguh et al., 2012; Kadir et al., 2019; Salman et al., 2019). Although these methods are easy to use, they all present serious drawbacks that limit peat and forest fire monitoring effectiveness. Smartphones and GPS can create digital images with spatial information, which are commonly referred to as geotagged photos (Merry and Bettinger, 2019). The geographical positioning is created automatically by the GNSS satellite. The geotagging of photos is possible using digital cameras with a built-in smartphone model (Mamei et al., 2010; Orsi and Geneletti, 2013; Krylov et al., 2018). In this paper, we establish a combination of mobile applications and geotagged photos as a novel method to collect such as fire data, quickly and efficiently for investigating tropical peatland fires. Moreover, this methodology can be used for various environmental investigations.

Using the methodology discussed in this paper, users can employs smartphone-based mobile application to generate geographical information related to criminal activity resulting in forest fires. This paper aims to encourage law enforcement agencies, local governments, and fire patrols to consider this low-cost device and easy-to-use technology for monitoring tropical peatland fires. The GPS technology in smartphones automatically generates and stores the coordinates in an Exchangeable Image File (EXIF) every time a photograph is taken. The EXIF file data also contain information, such as the time/date an image was captured and the basic information about the camera model.

Google Maps is a popular mapping service application that offers a simple location look-up functionality and easily accessible online/offline mapping and cartography for citizen reporting. The cartographic maps provided by Google Maps is augmented with digital information and high resolution aerial imagery. This paper introduces online citizen reporting as a new approach for law enforcement to conduct environmental investigation of tropical peatland fires.

The monitoring peat and forest fire techniques are currently based on satellites, watchtowers, or sensor networks. Although helpful, both technologies present serious drawbacks, limiting their detection capability. In this paper, we propose a method for monitoring, reporting, and verifying tropical peat fires using smartphone technology. Our method is novel, useful, and very quick to perform a timely response to the occurrence of fires in peat and forest areas.

2. Methods

2.1. GNSS Positioning using Smartphones

This paper describes an approach to crowdsource tropical peat fire data using geo-referenced photographs. Figure 1 shows an overview of the system with GNSS positioning used to collect crime data related to a peat fire environment. We developed an application for smartphones based on the Android version and a web-based application for collection and visualization. In this mobile application, the system is built using the Android library to access functions from cameras, GPS, and storage on smartphone devices (Arifin and Axhausen, 2012; Dwiyantoro et al., 2016). The GNSS satellite calculates the distance between the receiver and the satellite based on the signal propagation time if the transmitter and receiver clocks are perfectly synchronized. The smartphones receive signals from fully operational systems, such as GPS, GLONASS, BeiDou, and European

Galileo. The smartphone obtains the location and elevation from the GNSS satellite to determine the positioning accuracy of the device. However, tropical peatland fire management activities are often required in areas where cellular coverage is inadequate. The object image data ability to store use a smartphone as an EXIF file to geotagged close-range objects employing photograph techniques to overcome the accuracy of navigation sensors and supply raw observation to our devices and sent to the cloud server using global mobile communication. Finally, a web-based application was used to visualize the spatiotemporal status of a tropical peatland fire taken from a smartphone. The photo and other related information are simultaneously received by the web server and recorded into the database. This interface has a map displayed on the web service, where decision makers, firelighters, and citizens can see in detail the smartphone position and situation of the fire close to their location. Smartphone facilities, such as GPS, the internet, and cameras, are rapidly establishing themselves as essential elements of our daily lives (see Table 1).

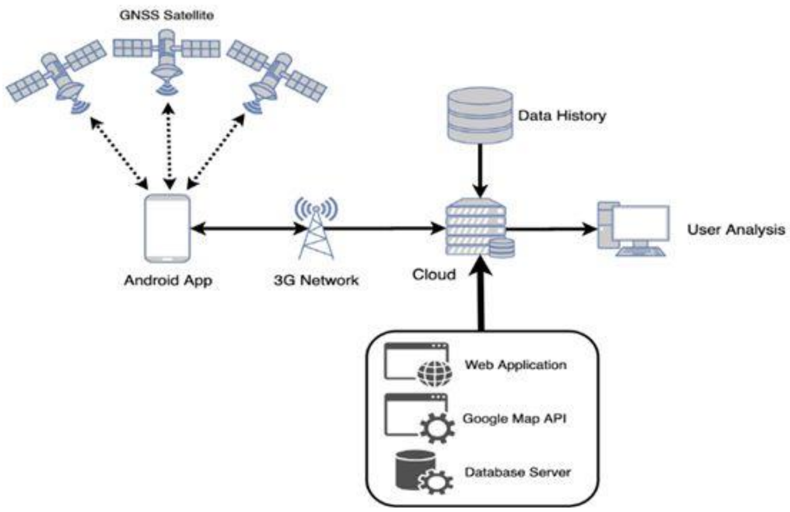

Figure 1 Overview of the tropical peatland fire investigation tool

Table 1 Examples of smartphone facilities

Receiver	VIVO-1807	Samsung Tablet SM-P355
Constellation	GPS, BeiDou, GLONASS	GPS, BeiDou, GLONASS
OS Detail	Funtouch OS 4.5	Android
Network	2G GSM, 3G WCDMA, 4G FDD-LTE, 4G TDD-LTE	2G GSM, 3G WCDMA, 4G LTE FDD, 4G LTE TDD
Sensor	Fingerprint, accelerometer, ambient light sensor, proximity sensor, e-compass, gyroscope	Accelerometer, Hall Sensor, RGB Sensor
Camera	8.0 Megapixel	5.0 Megapixel
Battery	Li-Po 4030 mAh	4200 mAh
Comms	WiFi	WiFi
Memory	32 Giga Bytes	10 Giga Bytes
RAM	3 Giga Bytes	2 Giga Bytes

2.2. Mobile Mapping for the Spatial View of the Crime Scene Data

In this paper, we developed a mobile application to access the facilities in smartphones, such as internet access, GPS position, and data storage. The application was built using an Android-based Google API (Application Programming Interface) service. The georeferenced information can be developed in conjunction with the weather API to obtain the actual weather data, such as temperature, humidity, wind speed, wind direction, and air pressure, simultaneously with the image taken by the camera. Figure 2 shows the interface of the mobile mapping for the spatial view of the crime scene data. Users can see the real-time GPS position (blue circle) and the location of the fire on the map.

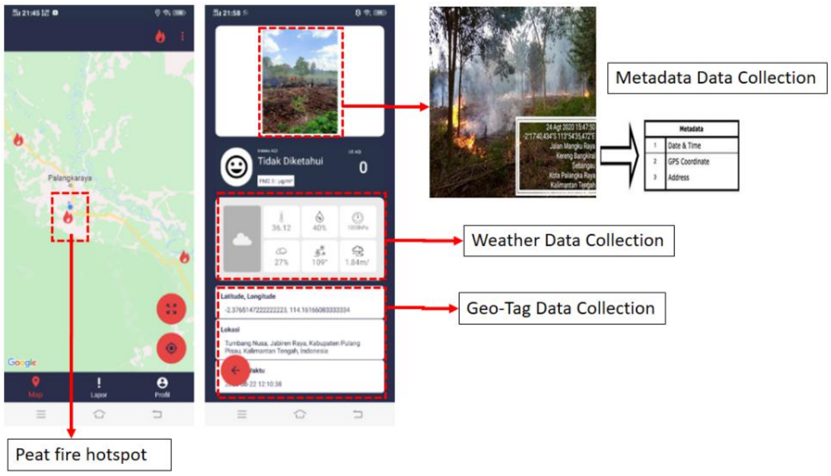

Figure 2 Mobile mapping for the spatial view of the crime scene data

The data collection for this study was performed using an Android-based application system developed in our lab. To facilitate data collection, the Android application needs to be installed on the mobile phone. Each user was encouraged to send photographs of fires they saw around their area. This application has simultaneous photography and positioning functions. When the user takes a photo, the app automatically generates and combines the photo, time, and location information into geotagged metadata of the image. Users can upload or store data on our database server. If an internet connection is not available when a user is taking the photo, the Android system can store the image data and coordinates in the smartphone memory and send it to the server when an internet connection is available. While the user collects the geographic details of a fire through the captured image, this application simultaneously collects weather data, including wind direction and speed. The data collection process and data type are shown in Figure 3.

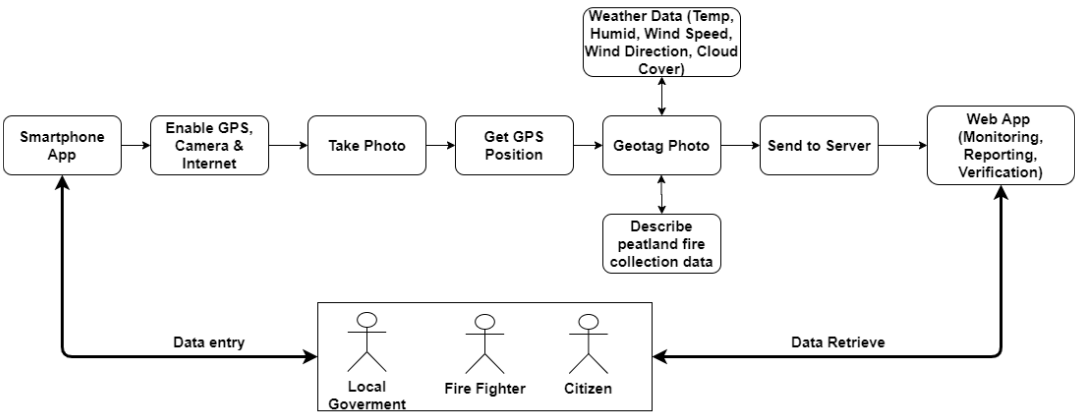

Figure 3 Data collection process for the crime data related to forest fires

2.3. Crime Scene Data Collection

The photograph and the geographical location of the crime scene are important for the spatial and temporal analyses of human activities leading to peatland fires. Hence, geotagged photos have been commonly used as a primary data source in investigation and control of tropical peatland fire events. In a tropical peatland fire event, the visual perspective offered by photographs assist in profiling and documenting the investigation events and the crime scene settings. Moreover, the spatial perspective of the geotagged photos streamlines the process of confirming the location of fire activity and linking it to observations of the crime scene. Table 2 provides the description and name of the records that will be saved or stored in the database as part of the data collection.

Table 2 Details of the peatland fire database

Name of the Record	Description
Latitude & Longitude	Coordinate location photo
Date and time	Date and time photo
Location	Position of the object
Fire stop	Duration of fire stop
Duration	Duration of the fire stop
Time Response	Response time from fire fighters
Burnt Area	Information related to the burnt area
Region	Object location
Fire Speed	Propagation of fire
Soil type	Description of the soil type
Suspect	Object verification (person or company)
Distance from water (m)	Distance of fire from water
Distance from street (m)	Distance of fire from a street
Distance from resident (m)	Distance of fire from the residents
Fuel type	Information related to the fuel type
Temperature & Humidity	Air temperature and humidity
Wind direction & speed	Wind direction and speed at the location
Rainfall (mm)	Information related to rainfall

In this paper, we used geotagged photos as a primary data collection tool. Citizens observed and reported the locations of peat fires. Users also created descriptions of information, such as soil type, burnt area, and the land status. In addition, we included weather data taken from current coordinated positions that were stored and sent from smartphones. The spatial view from the geotagged photos assisted in the process of recording the location of the fire activity and profiling the observations. Figure 2 shows the profile of the crime scene based on geotagged photos of tropical peat fires.

These photos become preliminary evidence of a crime scene in a peatland fire event. Moreover, these photos are a low-cost, paperless approach to data collection that may save time and resources. In an investigation, data derived from visual observations are typically used to study the patterns of spreading, human behavior, and response to peat fire events. The data collection has the potential to help the government design and evaluate the effectiveness of data-driven prevention and monitoring strategies. The official records of fire history and human activity collected by fire ranger patrols are an invaluable tool for investigation and vital to minimizing fire disasters.

3. Results and Discussion

3.1. Crime Sites Data

We collected data related to peat fire events from August to September 2020 using smartphone-based citizen reports. Citizens and firefighter patrols reported potential peat fire they spotted through a mobile app. Table 3 shows the time and location details of the crime site data for a peat fire event. The geotagged photos were then collected as preliminary evidence to identify the fire site and time of occurrence. Using a map on the mobile or web application facility (see Figure 2), the location of the fire can be quickly tracked. All data sent by citizens using smartphones will be collected in a database system. The firefighters and citizens who have registered in the same application can view and retrieve all data directly to their computers or smartphones.

Table 3 The crime data and location

Fire ID	Latitude	Longitude	Date	Time	Location
F1	-2.31228	113.96181	23-07-20	14:01	Sebangau
F2	-2.21685	113.86016	24-07-20	15:42	Jekan Raya
F3	-2.12953	113.80483	26-07-20	13:53	Bukit Batu
F4	-2.18143	113.80041	28-07-20	14:10	Jekan Raya
F5	-2.37651	114.16166	22-08-20	12:10	T. Nusa
F6	-2.13442	113.80222	24-08-20	13:48	Bukit Batu
F7	-2.29444	113.90972	24-08-20	15:47	Sebangau
F8	-2.16056	113.84815	27-08-20	18:25	Jekan Raya
F9	-2.18980	113.86245	30-08-20	12:40	Jekan Raya
F10	-2.27376	113.88093	31-08-20	13:37	Sebangau

Table 4 Description of the fire spread, fuel and soil type, and the status of land

Fire ID	Soil Type	Fire Speed	Fire Type	Suspect	Fuel Type	Land Status
F1	Peat	Slow	Surface	Unknown	Grass	Grassland
F2	Peat	Slow	Surface	Person	Shrub	Farm
F3	Peat	Slow	Surface	Unknown	Shrub	Farm
F4	Peat	Slow	Surface	Unknown	Shrub	Farm
F5	Peat	Fast	Surface	Unknown	Grass	Grassland
F6	Mineral	Slow	Surface	Person	Shrub	Oil farm
F7	Peat	Slow	Surface	Person	Shrub	Farm
F8	Peat	Fast	Surface	Unknown	Shrub	Farm
F9	Peat	Slow	Surface	Person	Shrub	Farm
F10	Peat	Slow	Surface	Person	Grass	Grassland

Figure 3 shows the geographic profiling of the crime data in the peat fire event near Palangka Raya, Central Kalimantan. The red circle indicates the position of the citizen reporting related to fire events. Using such data to monitor and explain peat fire crime problems requires knowledge of how fire activity in protected areas is detected. Furthermore, the visual information provided by each photo was very detailed and provided the fire authorities with a visualization. In Table 3, each crime data evidence has a code identity known as a fire id. Every fire ID is identifiable through descriptive coordinates, location (where), date, time (when), and suspect (who). This information can be used to easily perform a pattern analysis for the geographic profiling of the crime data associated with the peat fire (Figure 3). Table 4 shows the description of the land status, fire spread, fuel and soil type, and the responsible person. The fire photo acts as an effective supporting evidence. Generally, fire ranger patrols can use these photographs as a noninvasive method to investigate fire events and suspects and characterize places and events.

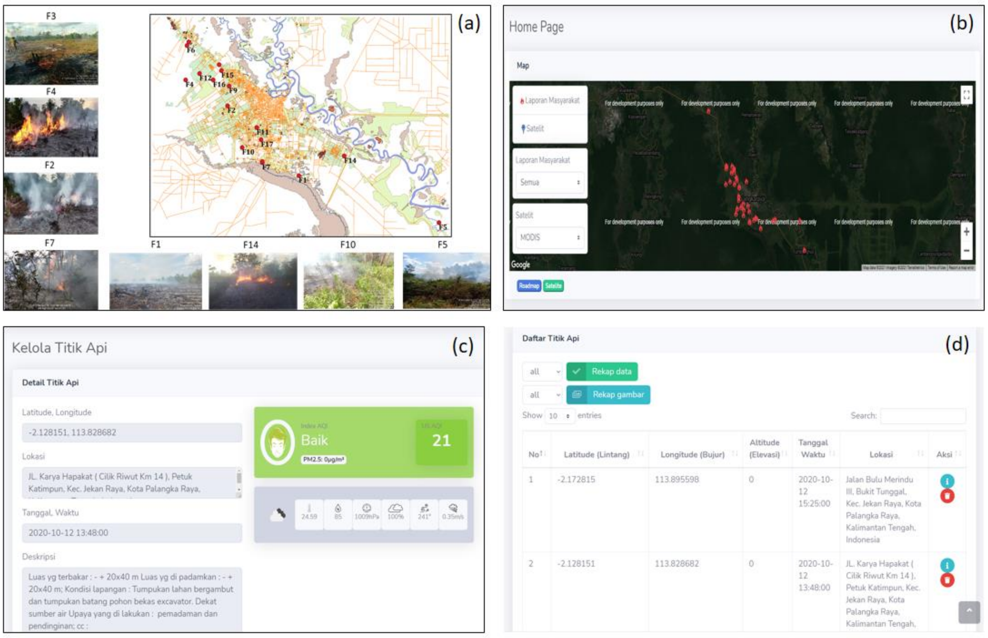

Figure 3 Geographic profiling of the crime data related to the peat fire events during July 23rd - Sept 19th, 2020: (a) Peat fire crime data pattern; (b) dashboard of the web app for Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data and citizen reporting; (c) detailed description of citizen reporting and verification; and (d) the database of the peat fire record

Figure 4b indicates an additional feature in this web application, which includes a comparison with MODIS satellite data. Thus, citizens and firefighters can use MODIS satellite data to validate the data sourced from people who care about the potential to minimize peat fire events. Figure 4c shows the details of fire data reporting and verification. In Figure 4d, the fire data collection was verified on the web application by the authorized officer.

3.2. Weather Data at Sites

The weather data is vital for viewing patterns and the starting point of fire occurrence. At the starting point, fire ignition can be tracked from the position and weather information, such as wind direction and speed. Temperature, humidity, and rainfall can be used as indicators of the drought level at the location at the time taken by mobile apps. Table 5 shows the weather data at different fire sites. The temperatures vary between 28.9-34.5 degree Celsius. The level of humidity (RH) is in the range of 74–89% RH, and the average rainfall was found to be of 0.3–8.6 mm.

Table 5 Weather data

Fire ID	Temperature (°C)	Humidity (RH)	Rainfall (mm)	Wind Direction	Wind Speed (mph)
F1	33	89	0.3	120	2
F2	33	85	0	80	2
F3	31.9	83	0	160	2
F4	32.8	83	0	210	2
F5	34.6	78	0	170	2
F6	34.5	83	0	240	2
F7	33.7	83	0	240	2
F8	32.6	74	0	140	3
F9	32.6	76	0	180	2
F10	33.5	80	0	130	2

3.3. Fire-fighting and Citizen Activities in the Field

Both firefighters and citizens can actively engage in field to provide information on peat fires from close-range and develop strategies to control them. In our mobile application, firefighter patrols can deliver and supply environmental data, such as response time based on the location, time required to stop the fire, discovery of nearby water supply, and the size of the burnt area after the termination of fire by firefighters. Using our mobile map app, firefighters and citizens can check the distance of the fire from the home of a local resident and the road access to visit the location of fire. Figure 4 shows important information related to the fire location to help firefighters find roads and water sources to reach the location and prevent the fire from spreading.

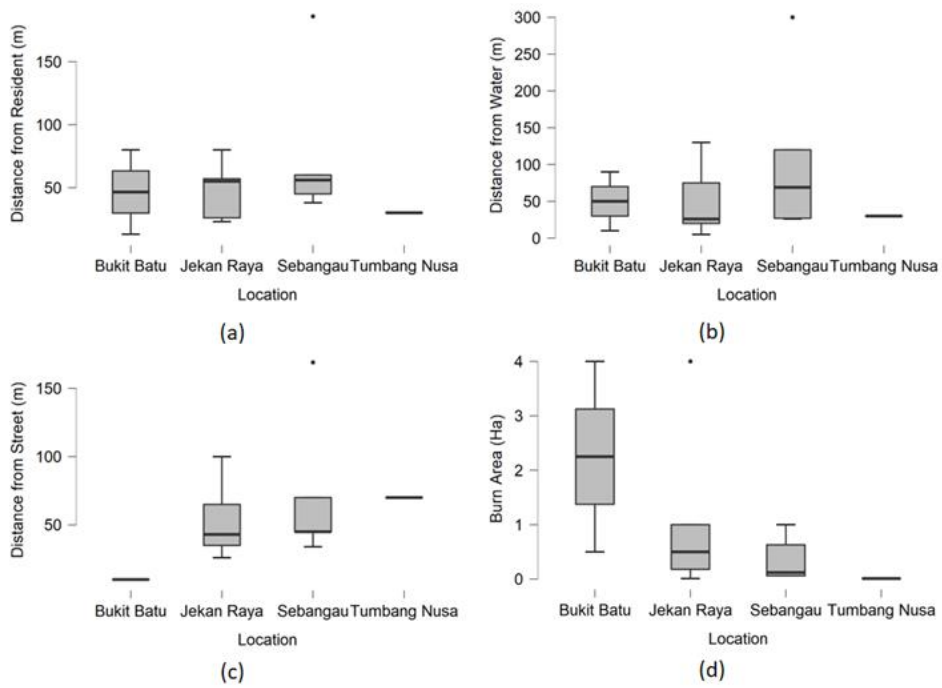

Figure 4 The fire patrol measure object fire from resident (a); distance of water source (b); distance from street (c); and size of burnt area (d)

Figure 5 shows the quantification of the response time based on location and the time required to stop the fire by firefighters and citizens. When a citizen sends the data and the image of a fire event, it will be verified by firefighters. The response time was estimated based on the distance from the position of the firefighters to the tracked location of the fire. This information is helpful for measuring the firefighters' response time after the detection of a fires.

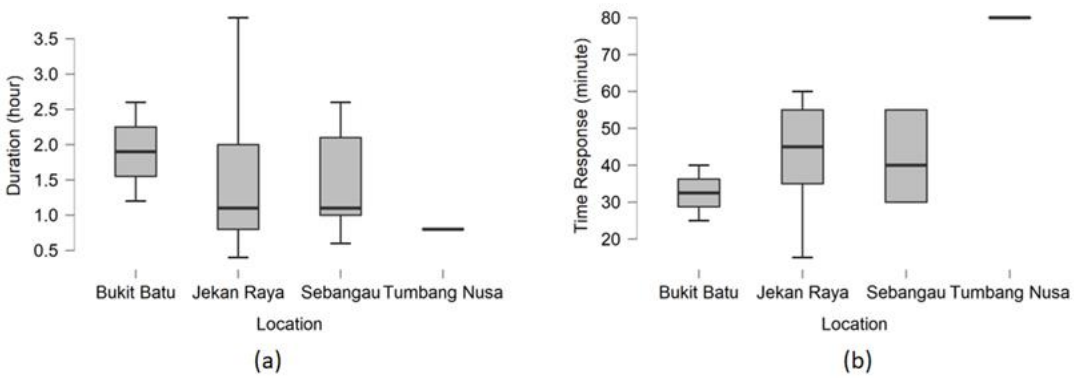

Figure 5 The fire-fighter measure duration for stop the fire (a); and time response (b)

4. Conclusions

We developed a mobile and web application for monitoring and verification of citizen reporting of peat fire sightings. The geotagged photos and descriptions collected from smartphones were sent via a global communication system. Firefighters used the coordinates and crime scene photos as preliminary evidence in the investigation of peatland fire events. The Google Maps services in our mobile app can be used to track the fire location and find nearby water sources and roads. The app also provided measurement of the response time and duration to stop the fire. A record of crime data included the location of the fire event and the soil type (peat or mineral). The characteristic type of fire is still on the surface of the peat.

In this study, smartphone users generated geographical information and a mobile-based web application was subsequently used to collect and analyze activity crime activity data. This is a low-cost device and easy-to-use technology to monitor and control tropical peatland fire. The collected data has contributed to the monitoring, reporting, and verification of peat fire preventive strategies.

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