Towards a study of fire occurrences in Indonesia

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Abstract. In the past 5 years, the issue of forest and peatland fires in Indonesia has received a major concern from various parties. As one of the prevention efforts, the Government of Indonesia seeks to prevent the ignition of forest and peatland fires both anthropogenic and naturally as a result of prolonged drought. These efforts could be carried out well through the implementation of remote sensing observations and through predictive technology on the position of the hotspot. However, it should be noted that historical data that have been used in those predictive technology on these hotspots are not yet verified and validated with fire occurrences and burned area footprints. Therefore, in this study, verification of historical fires hotspot will be conducted with the occurrence of wildfires based on land use satellite imagery to validate the events. This verification test will use overlay and spatial statistical methods. Based on the results of the verification test, a number of hotspots were found that were not in accordance with the incidence of forest fires especially in some area that neared agricultural area and factories. Thus, in the implementation of the use of hotspot data for predictions of forest fires, it is necessary to verify the suitability of the land and the incidence of forest fires.

1. Introduction

In the past 5 years, the issues of forest and peatland fires in Indonesia has received a major concern from various parties. As one of the prevention efforts, the Government of Indonesia seeks an alternative to prevent the ignition of forest and peatland fires both anthropogenic and naturally as a result of prolonged drought. These efforts could be carried out well through the implementation of satellite observation, also through predictive technology on the position of the hotspots. Both of technologies were intended as the part of the development of fires early warning systems in Indonesia which based on the concept of European Forest Fire Information System (EFFIS) [1].

While in order to develop the fires early warning systems in Indonesia, it is imperative and necessary to have historical fire database as it means to have a more realistic features of fire incidents in the fire models [2]. There have been a lot of proposed methodologies to develop fire database such as San-Miguel-Ayanz et al. [1], Prasetyo et al. [3], Prayoto et al. [4], and many other researches. Nevertheless, it should be noted that the hotspots which is in this case is active fires data, are not yet verified and validated with fire occurrences and burned area footprints. Further, to implement the interrelation in the fire cycle as EFFIS concept [1] and the needs of fire models, this study tried to refine the hotspots data...
as part of historical active fires database with aggregated land use change in 2017. It needs to be underlined that the goal of this study is to build fire preparedness as part of fires early warning system.

2. Fire Hazard Preparedness
The knowledge of the future fire dangers is needed to increase the preparedness. However, the improvement of the preparedness needs more time as there is a need of fire mitigation planning and preventive actions. Furthermore, there is a need to combine such a lot of knowledge dimensions such as indigenous knowledge in designing the fire mitigation planning especially in Indonesia’s indigenous community forest area. Therefore, there should be a knowledge of what the appropriate response to each different fire situations, that depending on the land cover (e.g. vegetation or agriculture vegetation), meteorological factor (i.e. wind), the community around the fire situations, and what the plan action is.

Therefore, in order to improves the preparedness and increase the control over fires situation, an early warning system become a dire need. The early warning system could use the remote sensing (i.e. satellite) information which provide the information about land cover and land use change, droughts, and moisture fuel conditions [5]. Those provided information could be transformed into fires danger ratings that later could provide the early warning system with the rating information. The fire indices could be made, by using the satellite information about precipitation, temperature, wind, and relative humidity which indicate dryness, fuel availability (in the form of litter), and potential spread of fire [5]. Satellite data are used as input for a forest fire models or as calibration data. Input data include precipitation, temperature or relative humidity data for a certain moment. Change detection or information over a time period can be used for calibration of a forest fire model. This is done by comparing the earth observation with the model results. The combinations of models and satellite data form predictive tools supporting preparedness and mitigation efforts [5].

3. Fire Monitoring Using Satellite
A quick hazard response starts with locating the hazard as soon as possible. Fire monitoring is one of the main applications of satellite information and aims to detect a forest fire as soon as it starts. Current fire activity, also called fire hotspots, can be observed by thermal infrared bands on satellite platforms like MODIS [5]. Hotspots can be retrieved from MODIS band which detect thermal differences per pixel. If a pixel has a significantly higher temperature than the surrounding pixels, this is likely to be a fire hotspot. When fire hotspots are noticed and calculated by the MODIS Rapid response system, they are registered by the Fire Information for Resource Management System (FIRMS) of MODIS [5]. Additional information will be saved such as latitude and longitude (centre point location), confidence percentage, acquisition date, time of the overpass of the satellite, satellite name, scan and actual spatial resolution of the scanned pixel, also the brightness temperature (BT) of either channel in Kelvin [5].

The confidence percentage could be between 0 and 100% and one of the three fire danger classes will be assigned: low-confidence, nominal confidence or high-confidence [5]. Meanwhile, MODIS does not only monitor fire hotspots but also patterns such as burn scars, smoke emissions or vegetation composition and condition. This information can help making predictions about the fire behaviour. Additionally, the fuel (litter) consumption combined with the rate of the fire spread can determine the fire intensity. The radiative energy of the fire, which is measured by satellite sensors, can predict the fuel consumption and emissions. All this information contributes to fire behaviour forecasts and to a quick and accurate response.

However, the active fire that have been used by FIRMS are not yet filtered whether the fire occurred over the forest land use or agricultural land. This condition deliberately worsened the community trust over forest fire management by Indonesian’s government. Therefore, this study will try to filter the active fire data with the land use map. Henceforth, the applied algorithm in this study could be implemented further in the development of fire early warning system.
4. Methodology

4.1. Mapping the Land Use Aggregate 2017
A map of land use after a severe fire between 2017 was created using post-fire Landsat 8 images, acquired from January to December 2017. Landsat 8 has a spatial resolution of 15 × 15 m [4]. The images from the period with less than 50% cloud cover were used. Satellite images were downloaded from the US Geological Survey National Center for Earth Resources Observation and Science via the Global Visualization Viewer (GLOVIS) data portal (http://glovis.usgs.gov/). This study was conducted with Landsat 8 pre-processing (atmospheric correction), land cover classification, and an accuracy check of land cover classification [4].

Atmospheric correction was conducted to reduce atmospheric distortion. Later, Geographical Information Systems (GIS) was used by transforming radiance at the sensor into surface reflectance values [4]. Physics-based derivation of surface and atmospheric properties of hyperspectral and multispectral data was presented by image enhancement process. This is based on atmospheric radioactive transfer, input of atmospheric parameters, and calibration of the instrument accuracy. Spectral differences were enhanced with the algorithm that divided spectral band (numerator) by another band (denominator) [4]. A supervised classification through maximum likelihood algorithm method in to classify land use into 7 types (Table 1) was used.

| Colour | Forest | Swamp and Bush | Agricultural Land | Savanna & Open Field | Industrial Area and Settlement | Pond and Water Bodies | Other (unclassified) |
|--------|--------|----------------|-------------------|----------------------|-------------------------------|----------------------|---------------------|

This classification was used to simplify the overlaying over the active fire data. By using the classification, it hoped that it will give a significant difference for analysis later. The result of classification could be seen in figure 1. From figure 1, spatially analysed, Indonesia dominated by the forest area, followed by agricultural land, also swamp and bush as top three of the largest land use in Indonesia. Logically speaking, the fire occurrence over Indonesia area should be dominated over forest area. This hypothesised logic will be proven using spatial and statistical analysis in Result and Discussion.

Figure 1. Indonesia’s Land Use Aggregate 2017.
4.2. Mapping the Active Fire Data in 2017

To elucidate a relationship between fire occurrence and land use type, pre-fire land use was identified for areas burned by the active fire in 2017. The former burned area was identified by the presence of active fire from Moderate Resolution Imaging Spectroradiometer (MODIS) fire hotspots. Hotspot data were downloaded from the National Aeronautics and Space Administration via Fire Information for Resource Management System (FIRMS) data portal. MODIS fire hotspot data shows the coordinates of the centre of a $1 \times 1$ km pixel where persistent fire was detected from a MODIS image using an algorithm [4]. The total number of fire occurrence for each month are shown in figure 2, while the spatial active fire data shown in figure 3.

![Figure 2. Fire Occurrence in Indonesia along 2017.](image)

In figure 2, it is shown that the fire occurrence in Indonesia reach its peak in September 2017, while the lowest at March 2017. This condition seemly related to monsoonal wind that carried moisture as the spell of rain season over the Indonesia area around October to March and the drought season from April to September [18]. Furthermore, the was suspected that the fire around rain season was contribute by agricultural activities [19].

5. Results and Discussion

From the spatial active fire map in figure 3, it is shown that the active fire hotspot was distributed almost evenly in each large island in Indonesia. Furthermore, it should be noted that the active fire data was occurred in Java Island which known the highest density area of settlement and agriculture land. This condition could become the first premise to verified that not every active fire monitoring from remote sensing that in this case was the MODIS and VIRS data could be used directly in fire monitoring especially with the purposed forest fires early warning system in Indonesia. This condition also suspected to around the development area such as industrial and settlement.
Further, after overlay process spatial count over the distributed land use, it was found as shown in figure 4, that over the 2017, the active fire found distributed over the agricultural land with proportion of 38%, followed by the forest area with 23%, swamp and bushes with 21%, savanna dan open field with 10%, industrial area and settlement with 1.8%. Meanwhile, for pond and around water bodies with 0.5% and finally other land use or unclassified with 6% from total percentage of active fire over the land use aggregate in Indonesia.

![Figure 3. Indonesia’s Active Fire Along 2017.](image1)

In accordance of figure 2 and related to figure 4, there is an interesting case that could be exploited further as shown in figure 5.

![Figure 4. Pie Chart of Active Fire Data over Land Use Aggregate in 2017.](image2)
From the figure 5, it shown that over the year, the active fire data was distributed over the agricultural land, followed by forest, finally by swamp and bushes as top three largest land use classification that have fire occurrence in 2017. Those conditions become the second premises, that prove the hypothesis logic “the fire occurrence over Indonesia area in 2017 should be dominated over forest area” in could not be used as generalized term that fire occurrence monitoring could be used directly for fire monitoring and took as direct measurement for statistical forest fire modelling and determined the trend of forest fire occurrence in Indonesia.

6. Conclusion
From the explanation above, this study has explained the dire need of fire early warning system as part of increase the fire preparedness and improve the fire response through the fire monitoring as part of fire information cycle of fire early warning concept. The designed fire early warning system intended to use the remote sensing as such satellite data for fire monitoring in Indonesia. This study further implemented the satellite data (i.e. MODIS and VIRS) that have been taken from FIRMS, to fulfil the criteria of fire monitoring in Indonesia. However, this study is not yet found any basis for using the remote sensing data directly as part of monitoring system. Therefore, with overlay method, this study tried to prove the usefulness of the remote sensing for fire monitoring.

It was hypothesised in this study, that the fire occurrence over Indonesia area should be dominated over forest area. However, this hypothesis was proven could not be accepted with two premises. First, that the active fire data was occurred in Java Island which known the highest density area of settlement and agriculture land such as that have been shown in figure 3. Furthermore, after this study overlay with land use map, the second premise, such as have been counted in by spatial statistic, it was found that 38% of fire occurrence happened in agricultural land, followed by forest with 23% and 21% by the swamp and bushes. Both of the premises could be concluded that the satellite data could not be used as generalized term that fire occurrence happened in Indonesia without filtering with land use and the satellite data could not be used directly for fire monitoring and took as direct measurement for statistical forest fire modelling and determined the trend of forest fire occurrence in Indonesia.

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The Authors hoped that this research could be used as foundation of development of Fire Early Warning System in Indonesia.

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