Utilization of MODIS data to analyze the forest/land fires frequency and distribution (Case Study : Central Kalimantan Province)

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Abstract. Forest/land fire often occurs in Indonesia particularly in Sumatera, Kalimantan, and Papua. This phenomenon has direct impact not only in Indonesia but also transboundary countries. To minimize this impact, remote sensing technology can be used to monitor forest/land fire using hotspot from Terra/Aqua MODIS data which good have 2 equatorial revisit times per day i.e. 10.30 a.m. for Terra and 1.30 p.m. for Aqua in near real time. The objectives of this study was to analyze the frequency and spatial distribution of hotspot in Central Kalimantan Province using Terra/Aqua MODIS. Hotspot is derived from Terra/Aqua MODIS data using algorithm which available daily in LAPAN system. Hotspot classified into three categories of confidence level i.e. low (0-30%), medium (30-80%), high (80-100%). RGB 1-2-18 were used as base map layer to analyze the spatial distribution of three hotspot categories. The result shows that there was hotspots concentrated in Kotawaringin Timur and Pulang Pisau Regency which it was burn peat hydrological unit area. Thus, peat land area that covers with shrubs, etc is hard to extinguish which relate to the frequency of hotspot. High frequency hotspot occurs in September 27th 2018 then decreasing until October 6th 2018 (10 days).

1. Introduction

The phenomenon of forest/land fires in Indonesia have significant impact not only to air quality and human health in Indonesia but also transboundary countries. As the previous case in 2015 there were six provinces encountered, such as South Sumatra, Jambi, Riau, West Kalimantan, Central Kalimantan, and South Kalimantan (bbcindonesia online, 2015). The impact of this haze was felt in North Sumatra Province, West Sumatra, as well as transboundary countries i.e Malaysia, Singapore, Thailand and the Philippines. Indonesia National Disaster Management Agency (BNPB) stated that forest/land fires in 2015 consumed 2,089,911 hectares of forest or 32x DKI Jakarta province (cnnindonesia online, 2015). Forest fires also contribute significantly to climate change, Based on data of NASA, due to forest fires in Indonesia in 2015, around 600 million tons of greenhouse gases were released into the air. That number is the same as the glass gas that released by Germany every year (Viva online, 2015). Forest/land fires can often become uncontrolled, leading to the destruction of large areas of forest, these fires are reported to be a major reason for the rapid degradation of the remaining rainforests in Southeast Asia (Siegert et al., 2004)

In an effort to minimize impact of forest/land fires, early information about forest/land fires is very important. Remote sensing technology can be used to provide information on forest/land fire i.e using MODIS (Moderate Resolution Imaging Spectroradiometer) images which are obtained from the Aqua and Terra satellites. Vetrita et al (2014) stated that based on field validation, MODIS data with various confidence levels provides the best data with some other data. The advantage of data from MODIS data is that it can display daily information where MODIS data has a temporal resolution of 2 times per day. Forest fire analysis is carried out by visual analysis of MODIS images and hotspots data. The research of Zubaidah (2014) showed that the percentage of MODIS FIRMS hotspot accuracy is 64%
with a commission error 18% and omission error 18% the percentage of the accuracy of the MODIS Indofire hotspot was found at 42% with a commission error rate of 20% and omission error of 38%. Further analysis on peatland has obtained a value of 66% hotspot Firms accuracy with a commission error of 19% and omission error of 15%, while the Indofire hotspot was found at 46% with a commission error of 19% and omission error of around 35%. The purpose of this study was to analyze the frequency and spatial distribution of the incidence of forest fires in Central Kalimantan Province from September 27th to October 6th 2018 by utilizing MODIS data through visual analysis of fire fumes equipped with hotspot data.

2. Methods

2.1 Study Area

This study focused on the Central Kalimantan Province, where it was one of the vulnerable area of forest/land fires. According to BNPB data, from January until June 2018, there were approximately 37 cases of forest/land fires. Total area of Central Kalimantan was 153,564,000 hectares of which 4,644,317 hectares are included in the Peat Hydrological Unit (Directorate of Peatland Damage Control, 2015). This study focused on September 27th to October 6th 2018 by considering FDRS (Fire Danger Rating Systems) data from the Remote Sensing Applications Center LAPAN. FDRS is an early warning system for forest and land fires. FDRS provides input on decisions relating to the management of forest and land fires using the weather index fire or Fire Weather Index (FWI) as a parameter (Itsnaini, 2020). FDRS data showed that Central Kalimantan Province in September 27th classified in high and extreme classes especially in the southern region. FDRS consist of FFMC (Fine Fuel Moisture Code), FWI (Fire Weather Index), ISI (Initial Spread Index), and DC (Drought Code).

2.2 Hotspot Data

MODIS data can be used to analyze forest/land fires using hotspot data which indicates high temperature in an area. To produce hotspots from MODIS data, there are 7 spectrums of waves electromagnetic is used, i.e. thermal spectrum 4 μm, 11 μm and 12 μm, and spectrum reflectance 0.65 μm, 0.86 μm and 2.1 μm which are used to minimize cloud disturbance, sunshine reflection on the sea (sun glint), coastal areas, and forest clearing. MODIS band that used to analyze hotspots i.e band 1 (0.65 μm), band 2 (0.86 μm), band 7 (21 μm), band 21 (4.0 μm), band 22 (4.0 μm), band 31 (11.0 μm) and band 32 (12.0 μm) (Giglio et al 2016). Then the data is processed using certain algorithms to produce hotspot information. The following is the band used to obtain hotspot data from MODIS Imagery:

![Figure 1](http://spbn.pusfatja.lapan.go.id/maps/927)

Information:
- Low level
- Medium level
- High Level
- Extreme level
- Central Kalimantan Province

FDRS Central Kalimantan Province
(Source: http://spbn.pusfatja.lapan.go.id/maps/927)
Table 1. The Band Used to Produce Hotspot Data from MODIS Imagery

| Band | Central Wavelength (μm) | Usability |
|------|-------------------------|-----------|
| 1    | 0.65                    | Minimize the error of detection due to reflection of sun glint, coast, and clouds. |
| 2    | 0.86                    | Minimizing errors due to sun glint and coastal conditions. |
| 7    | 21                      | Minimizing errors due to sun glint and coastal conditions. |
| 21   | 4                       | Is a channel that has a high range for fire detection. |
| 22   | 4                       | Is a channel that has a low range for fire detection. |
| 31   | 11                      | For fire detection and minimizing errors of detection from clouds and forest clearing |
| 32   | 12                      | To minimize detection errors due to clouds. |

(Source: Giglio et al. 2016)

The Indonesia National Aeronautics and Space Agency (LAPAN) has utilized the algorithm to produce hotspot data, the data can be accessed on Modis Catalog website (http://modis-catalog.lapan.go.id/). Giglio (2015) in MODIS Active Fire Product User's Guide classified confidence level into 3 types:

Table 2. Confidence Level Classification of Hotspot from MODIS Imagery

| Confidence Level | Classification | Action          |
|------------------|----------------|-----------------|
| 0%-30%           | Low            | Important to noticed |
| 30%-80%          | Medium         | Alert           |
| 80%-100%         | High           | Immediate response |

It is important to note that the number of hotspot not showing the number of occurrences forest/land fires but indicate occurrences of forest/land fires. The indicators of forest/land fires is:

- Hotspots that clustered, large enough of forest/land fires are not detected as only one hotspot because the heat effect spreads, so if the hotspot is clustered then it can be ascertained that there was forest/land fires.
- Hotspots accompanied by smoke. In analyzing hotspots as markers of forest/landfires, it is also necessary to look at RGB combination of band 1, band 2, and band 18.
- Hotspot points occur repeatedly, so there is a possibility of fires in the area. (Deputy for Remote Sensing LAPAN, 2016).

then to get a visual display of forest and land fires can be done with a combination of RGB combination of band 1-2-18, the band data is obtained from Modis Catalog Website (http://modis-catalog.lapan.go.id/). Combination of RGB bands 1-2-18 and hotspot data is then used to identify forest/land fires.
3. Result and Discussion

3.1 Hotspot Frequency
Terra satellite recording in the Central Kalimantan Province is at 10.30 a.m and Aqua satellite 01.30 p.m in near real time, daytime hotspot data from Aqua Satellite is generally more extensive than the hotspot data from Terra satellite. Based on the results of the study, there are fluctuating daily frequency of the hotspot data in Central Kalimantan Province which most of hotspot data classified as medium class and high class in confidence classification.

| Date             | Low (0-30%) | Medium (30-80%) | High (80-100%) | Total |
|------------------|-------------|-----------------|----------------|-------|
| September 27th   | 16          | 165             | 109            | 290   |
| 28 September 2018| 3           | 41              | 20             | 64    |
| 29 September 2018| 10          | 82              | 54             | 146   |
| 30 September 2018| 4           | 46              | 13             | 63    |
| 01 October 2018  | 0           | 16              | 5              | 21    |
| 02 October 2018  | 3           | 39              | 19             | 61    |
| 03 October 2018  | 0           | 4               | 0              | 4     |
| 04 October 2018  | 8           | 156             | 79             | 243   |
| 05 October 2018  | 0           | 3               | 0              | 3     |
| 06 October 2018  | 0           | 20              | 17             | 37    |

The highest number of hotspots occurred on September 27th and decreased the following day until October 3rd with some increased in number on September 29th. Then there was an increase in the number again on October 4th.
3.2 Distribution of Forest/Land Fires

Based on an analysis of forest/land fire indicators, there are forest and land fires in several locations. Some points are in the same location continuously for several days, this is due to forest/land fires occurring on peat land, so the fire lasts a long time.

Table 4. Forest/Land Fires Based on Forest/Land Fires Indicators Using MODIS Image
Central Kalimantan Province
September 27th – October 6th 2018

| Date       | Time | Satellite | Longitude | Latitude | Regency         | Confidence |
|------------|------|-----------|-----------|----------|-----------------|------------|
| September 27th 2018 at 09.55 a.m | | | | | | |
| 9/27/2018   | 09.55| Terra     | 113.313988| -2.592333| Katingan        | 90         |
| 9/27/2018   | 09.56| Terra     | 114.622108| -2.545527| Barito Selatan  | 73         |
| 9/27/2018   | 09.57| Terra     | 114.004860| -3.026157| Pulang Pisau   | 100        |
| 9/27/2018   | 09.58| Terra     | 113.841797| -3.221791| Pulang Pisau   | 100        |
| September 28th 2018 at 12.46 WIB | | | | | | |
| 9/27/2018   | 12.46| Aqua      | 113.827110| -2.3213700| Pulang Pisau  | 100        |
| 9/27/2018   | 12.46| Aqua      | 113.882156| -3.225609| Pulang Pisau  | 100        |
| 9/27/2018   | 12.46| Aqua      | 113.991943| -3.200390| Pulang Pisau  | 100        |
| 9/27/2018   | 12.46| Aqua      | 113.997169| -3.035089| Pulang Pisau  | 100        |
| 9/27/2018   | 12.46| Aqua      | 114.366028| -2.576918| Kapuas         | 100        |
| 9/27/2018   | 12.46| Aqua      | 112.886627| -2.916742| Kotawaringin Timur  | 100    |
| 9/27/2018   | 12.46| Aqua      | 113.569366| -0.714748| Gunung Mas     | 100        |
| September 28th 2018 at 13.30 WIB | | | | | | |
| 9/28/2018   | 13.30| Aqua      | 112.363266| -2.710428| Seruyan        | 86         |
| 9/28/2018   | 13.30| Aqua      | 112.892723| -2.913026| Kotawaringin Timur  | 100    |
| 9/28/2018   | 13.30| Aqua      | 114.003563| -3.047861| Pulang Pisau  | 100        |
| Tanggal       | Waktu   | Plattform | Koordinat       | Desa               |
|--------------|---------|-----------|-----------------|-------------------|
| 9/28/2018    | 13.30   | Aqua      | 113.987305      | Pulang Pisau      | 90   |
| 9/28/2018    | 13.30   | Aqua      | 113.875534      | Pulang Pisau      | 91   |
| 9/28/2018    | 13.30   | Aqua      | 114.700485      | Murung Raya       | 81   |
| September 29th 2018 pada 09.43 WIB |
| 9/29/2018    | 09.43   | Terra     | 112.875084      | Kotawaringin Timur| 97   |
| 9/29/2018    | 09.43   | Terra     | 114.031288      | Pulangka Raya     | 90   |
| 9/29/2018    | 09.43   | Terra     | 114.761261      | Kapuas            | 94   |
| 9/29/2018    | 09.43   | Terra     | 113.955452      | Pulang Pisau      | 100  |
| 9/29/2018    | 09.43   | Terra     | 114.018684      | Pulang Pisau      | 94   |
| 9/29/2018    | 09.43   | Terra     | 113.981827      | Pulang Pisau      | 100  |
| 9/29/2018    | 09.43   | Terra     | 114.016624      | Pulang Pisau      | 99   |
| 9/29/2018    | 09.43   | Terra     | 113.803352      | Pulang Pisau      | 84   |
| September 29th 2018 pada 12.34 WIB |
| 9/29/2018    | 12.34   | Aqua      | 112.869209      | Kotawaringin Timur| 91   |
| 9/29/2018    | 12.34   | Aqua      | 112.892303      | Kotawaringin Timur| 88   |
| 9/29/2018    | 12.34   | Aqua      | 113.856705      | Pulang Pisau      | 100  |
| 9/29/2018    | 12.34   | Aqua      | 114.020576      | Pulang Pisau      | 89   |
| 9/29/2018    | 12.34   | Aqua      | 114.015144      | Pulang Pisau      | 91   |
| 9/29/2018    | 12.34   | Aqua      | 114.413841      | Kapuas            | 70   |
| September 30th 2018 pada 10.26 WIB |
| 9/30/2018    | 10.26   | Terra     | 114.003937      | Pulang Pisau      | 55   |
| 9/30/2018    | 10.26   | Terra     | 113.435829      | Katingan          | 71   |
| September 30th 2018 pada 13.17 WIB |
| 9/30/2018    | 13.17   | Aqua      | 112.867966      | Kotawaringin Timur| 94   |
| 9/30/2018    | 13.17   | Aqua      | 112.888214      | Kotawaringin Timur| 93   |
| 9/30/2018    | 13.17   | Aqua      | 113.752075      | Pulang Pisau      | 91   |
| 9/30/2018    | 13.17   | Aqua      | 114.015312      | Pulang Pisau      | 88   |
| 9/30/2018    | 13.17   | Aqua      | 114.000183      | Pulang Pisau      | 89   |
| 9/30/2018    | 13.17   | Aqua      | 113.967957      | Pulang Pisau      | 87   |
| 9/30/2018    | 13.17   | Aqua      | 114.059822      | Pulang Pisau      | 42   |
| 9/30/2018    | 13.17   | Aqua      | 113.962868      | Pulang Pisau      | 90   |
| October 1st 2018 at 09.30 a.m |
| 10/1/2018    | 09.30   | Terra     | 113.859344      | Pulang Pisau      | 95   |
| 10/1/2018    | 09.30   | Terra     | 113.969055      | Pulang Pisau      | 89   |
| October 2nd 2018 at 10.12 a.m |
| 10/2/2018    | 10.12   | Terra     | 113.880959      | Pulang Pisau      | 94   |
| 10/2/2018    | 10.12   | Terra     | 114.063805      | Pulang Pisau      | 84   |
| October 2nd 2018 at 01.05 a.m |
| 10/2/2018    | 13.05   | Aqua      | 111.952690      | Seruyan           | 89   |
| 10/2/2018    | 13.05   | Aqua      | 112.841408      | Kotawaringin Timur| 94   |
| 10/2/2018    | 13.05   | Aqua      | 112.867561      | Kotawaringin Timur| 100  |
| 10/2/2018    | 13.05   | Aqua      | 113.867249      | Pulang Pisau      | 98   |
| 10/2/2018    | 13.05   | Aqua      | 113.959717      | Pulang Pisau      | 95   |
| October 3rd 2018 at 09.17 a.m |


3.3 Concentration of Forest/land Fires

Based on the data above, the hotspot location on September 27th, September 29th and October 4th spread in Central Kalimantan Province area and there were several points of concentration of hotspots where and continued, several points i.e in Pulang Pisau Regency and East Kotawaringin Regency. From visual appearance RGB 1-2-18 MODIS image can be observed forest/land fires both at the point of Pulang Pisau Regency and Kotawaringin Timur Regency where fires in Pulang Pisau Regency are greater than in Kotawaringin Timur Regency. The following is a visual display of temporal forest/land fires located in Pulang Pisau Regency.

(September 27th, at 00.46 p.m)            (September 28th, at 00.30 p.m)             (September 29th, at 00.34 p.m)

(September 30th, at 01.17 p.m)            (October 1st, at 09.30 a.m)                   (October 2nd, at 01.05 p.m)

(October 3rd, at 09.17 a.m)               (October 4th, at 00.52 p.m)                   (October 5th, at 01.34 p.m)
Figure 4. Time Series Display of RGB Images 1-2-18 and Hotspot Data on Forest/land Fires in Kotawaringin Timur Regency and Pulang Pisau Regency

Forest/land fires in Kotawaringin Timur Regency and Pulang Pisau Regency have decreased since September 27\textsuperscript{th}, until on October 3\textsuperscript{rd} only the remaining smoke of forest/land fires is visible but on October 4\textsuperscript{th}, forest/land fires appear to reappear with high frequency, until finally decreasing until October 6\textsuperscript{th} there were no hotspots or forest/land fire fumes from MODIS data recording. This phenomenon indicates that forest/land fires occur on peatland, where fire burns not only on the surface but reaches deeper ground so that it is not detected by MODIS image recording.

Information:

- Central Kalimantan Province
- Concentration of Forest/land Fires at Pulang Pisau Regency and Kotawaringi Timur Regency

Figure 5. Peatland Hydrological Unit Map in Central Kalimantan Province and Location of Forest/Land Fires that Occurs in Pulang Pisau Regency and Kotawaringin Timur Regency (Source: Geospatial Information Agency in Suwarno, 2017)

Based on the data above, there are locations continuous forest/land fires is on peatland hydrological unit of Kotawaringin Timur Regency and Pulang Pisau Regency. The area of peat land in
Kotawaringin Timur Regency is 361,835 hectare, consisting of very shallow peat area of 19,385 hectare, shallow peat 103,517 hectare, medium peat 88,923 hectare, peat in 129,799 hectare, and very deep peat 20,211 hectare (Wahyunto, 2005), while Regency Pulang Pisau amounted to 64% of 899,700 hectare in the form of peat land (Government of Pulang Pisau Regency, 2015), the condition of peatlands was alarming due to agricultural activities, expansion of plantations and transmigration settlements, in 2016 the population growth of Kotawaringin Timur Regency is 2.37% (BPS Kotawaringin Timur Regency, 2017) while Pulang Pisau Regency is 0.51% (Pulang Pisau Regency BPS, 2017) population growth in Kotawaringin Timur and Pulang Pisau Regency due to the transmigration program, due to increasing population caused changes in land use from forests to settlements, human activities in changing landuse often ignored existing environmental conditions, often clearing forests by burning because it is considered the most effective, besides that the construction of facilities such as irrigation also causes the volume of water stored in peatlands to be reduced so that it is vulnerable to forest fire. In the other side, FDRS value in Kotawaringin Timur Regency and Pulang Pisau Regency on September 27th - October 6th, 2018 is in high to extreme category in majority.

The high FFMC value from September 27th to October 5th shows that the area is classified as "extreme" which shows relatively dry burnt material which caused by the dry season and can also be caused by human activities so that they are flammable, on the October 6th declined at the "low" level to Pulang Pisau Regency and "medium" level to Kotawaringin Timur Regency, this could be due to the presence of clouds and rain on that date so that the relational burnt material was wetter than the
previous date. The ISI value on September 27th to October 4th which is classified as “high” to “extreme” shows the high spread of fire, this indicates that the fires that continue to occur have the potential to enlarge, the decline in value on October 5th can be caused by weather, which in the fashionable image is identified the presence of thick clouds. DC values are an indicator of the potential for fire to flare in a forest/land fire and the potential for smog to occur. DC values on 27th September to October 2nd are relatively stable in the “medium” category, there are fluctuations in DC values caused by fires, when the fire of forest fires decreases, it can leave burning coals, especially on peatlands. The FWI value shows the effect of weather on forest fuels and forest fires. on September 27th to October 5th the value of FWI is “high” to “extreme”, this can be seen from the absence of clouds on that date, on October 6 the value of FWI dropped due to the influence of the weather.

3.3 Obstacles
MODIS imagery from Aqua/Terra satellite recordings can be used to monitor forest/land fires, especially in Indonesia which has a tropical climate and land conditions in the form of peatlands with a fairly good temporal resolution, namely 2 times in 1 day. The obstacle in utilizing MODIS data is in determining the location of the fire, spatial resolution of MODIS Image is 1km x 1 km, for the edge area, the spatial resolution can be 2 km x 2 km, so the location error can reach a maximum of 2 km. The coordinates of the hotspot/hotspot are the midpoints of the MODIS Terra/Aqua satellite image. The source of the fire identified as a hotspot can be in the area of the satellite pixel.

Figure 7. Illustration of Land Fire Using Remote Sensing Data
(Source: Giglio et al 2003)

Another obstacle is to obtain MODIS Figure data, it takes about 30 minutes of recording time due to data processing by the server. In this study only using data processing operations through software, field surveys are needed to validate forest/land fires.

4. Conclusion
Utilization of MODIS data in observing forest/land fires shows a pattern of spreading hotspots and at some points there is a concentration of hotspots, this concentration indicates forest/land fires, visual analysis of forest/land fire fumes and concentrations of continuous hotspots can also be used as a reference to determine forest fires. Concentration of fires is in Kotawaringin Timur Regency and Pulang Pisau Regency, fires in the area of the Kotawaringin Timur and Pulang Pisau Regency showed burning land in the form of peatlands with land cover i.e shrubs, the condition of peatlands caused fires to be extinguished because they burned to the ground, with at least 7 weather conditions and land cover days to extinguish fires on the surface based on analysis of peak frequency on September 27th and decreasing until October 3rd, the increase in frequency on October 4th indicates the possibility of fires occurring in the peat soil propagating back to the surface.
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