Inaccuracy of hotspots data for early warning land fires incidence

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Abstract. Severe and expansive land fires in Indonesia have been occurred since 1982 due to the human activities and got more severe because of El Nino phenomenon. The impact of this catastrophe has always been notorious. The land fires in 2019 burned down a total of 850,000 hectares of which 200,000 hectares were peat land. The National Disaster Mitigation Agency (BNPB) stated that 85% of the land fires incidence did not occur in concession land, on the contrary, The Ministry of Environment and Forestry claimed that 85% of the land fires were related to oil palm plantation or oil palm businesses. These contradictory statements of both government institutions have led to the public’s bafflement, therefore the aim of this study was to seek the actual condition regarding the land fires in 2019. The results show that the BNPB statement was based on satellite data and actual field observation data while extinguishing the fires. Meanwhile, The Ministry of Environment and Forestry released their statement according to the land fires hotspots data. This research showed that there are many land fires cases actually detected from real time burn scar of Sentinel L1C and L2A, but are not detected from the MODIS C6 hotspots data. This fact related to the fire flow that fire was initiated mostly in areas with low biomass vegetation such as shrubs. This type of vegetation provided highly combustible fuel for fires so that fire continuously swept the whole similar areas and eventually approached areas with higher biomass vegetation, such as oil palm plantation. Once fire reaches and burns higher biomass vegetation, it lasts for a longer period, and will be recorded as hotspots data. Referring to the regulation of The Ministry of Environment and Forestry Number P.8/ MENLHK / General Secretariat / KUM.1 / 3 / 2018 article 8, land fires without hotspots recorded will not be the priority to be checked and controlled. Consequently, the fire will be only detected and then checked after reaching the area with higher biomass vegetation, such as oil palm plantation. There will be a significant delay for inspecting and controlling initial fires. This study also showed that as the result of this monitoring system, The Ministry of Environment and Forestry tended to assume that the land fires are mostly initiated and occurred on oil palm plantations or on concession areas. Therefore it can be concluded that hotspots data cannot be the only source for early warning land fires incidence. An alternative method which is more accurate and susceptible should be invented.
1. Introduction

Indonesia's land fires are an annual problem and have occurred since 1982. Land fires occurred due to human activities and got more severe because of the El Nino phenomenon. Land fires in many places such as Australia and Amazon rainforest were caused by human activities and spread rapidly because of long dry periods. In 2019, Australia experienced land fires that burned around 11 million hectares meanwhile Amazon experienced land fires that burned three million hectares because record-breaking temperatures and months of severe drought fuelled the fires. For south-eastern Australia, continued periodic bushfire conflagrations under drought conditions, particularly associated with El Nino Southern Oscillation (ENSO) events, may be anticipated to be the norm [1], [2].

Indonesia experienced the worst land fires for the last decade where Riau and South Sumatera got the most severe impact in 2015. The 2015 land fires, which raged through 2.6 million hectares in Sumatra and Kalimantan cost the country more than US$16 billion. Between July and December 2015 the estimated burned area during El Nino in South Sumatra was 422,718 ha, of which 163,143 ha in mineral soil and 260,575 ha in peat soil. The grassland fires were larger than other land use categories as the grassland is prone to burning because of abundant fuel and flammable. Human activities influenced grassland fires indirectly [3].

Land fires in 2015 had led the central government to enforce tougher regulation about land fires incidents. The Ministry of Environment and Forestry (KLHK) as a government institution issued regulation Number P.8/MENLHK/General Secretariat/KUM.1/3/2018 in 2018. This regulation regulates fixed procedure for field check for hotspots or/and land and forest fires information. It is clearly proven that hotspots on satellite imagery can be used to confirm land fires incidence.

In 2019, Indonesia experienced land fires again due to the long dry season that dried out vegetation, provided highly combustible fuel for fires and allowed them to spread faster and farther. According to satellite imagery, land fires in 2019 occurred in various land use, such as National Park in Berbak National Park, plantation areas in Seruyan-Sebangau, and even in capital cities such as Palangkaraya. The National Disaster Mitigation Agency (BNPB) stated that 85% of the land fires incidents occurred outside concession areas, such as oil palm plantation and industrial forest plantation. In contrast, The Ministry of Environment and Forestry (KLHK) claimed that 85% of the land fires were utilized or utilized to be plantation areas, in addition 99% of them occurred on purpose because related to oil palm plantation expansion or oil palm businesses. These contradictory statements of both government institutions have led to the public’s bafflement, therefore the aim of this study was to seek the actual condition regarding the land fires in 2019.

2. Materials and Methods

2.1 Study Area

The study area (Figure 1) was focused on a floodplain located in the South Kalimantan province, Indonesia. Administratively, the study area belongs to South Kalimantan Province which most of them are the area of Tapin and Hulu Sungai Selatan Regencies; and a small part in the southern part of Barito Kuala and western part of Kapuas Regencies. This study focused on floodplain (Figure 2) that has seasonal flood in the rainy season, (up to 2 meters), hence it is difficult to plant annual crops without application of modern technology. The land cover on the study area is dominated by shrub and gelam forest therefore local people only utilize this land for seasonal crop in dry season.
2.2 Historical data of hotspots and sentinel satellite
Modis (Terra and Aqua satellite) data set temporal was used for hotspots identification process from January to September in 2019. This data set was downloaded as the Moderate Resolution Imaging Spectroradiometer (MODIS) Collection 6 Active Fire Product data from the official website of Fire Information for Resource Management System (FIRMS) NASA [4]. Sentinel imagery was used for hotspot accuracy validation every five days (time series), thus hotspot data was also accumulated on the same time series. Then, the hotspot was observed since the initial land fires occurred. Sentinel imagery used on this study was Sentinel 2A and 2B L1C which were downloaded from European Space Agency.

2.3 Data Pre-processing and Analysis
Pre-processing and spatial analysis were done using ArcGIS version 10.6.1. The technical steps before temporal and spatial analysis were downloading and extracting of hotspots data and Sentinel 2 imagery of the study area. Then geometric correction, projections, and transformations were done on those dataset. There are three band compositions that were used, they are band 4, band 11, and band
that produced false colour. Burn scars were identified by using SWIR sensors with band composition 12, 8A, and 4. Overlay analysis was done by overlapping Sentinel 2 imagery and hotspots data to show the large scale fires occurrence which were not detected as hotspots that became the main focus in this study. Buffer analysis with 1 km radius on hotspots data was done to identify if the hotspots were clustered.

Dataset hotspot used in this study was extracted and divided into 2 main groups, (1) hotspot with 30-79% of confidence level (yellow point), and (2) hotspot with confidence level ≥ 80% (red point). This grouping process was adjusted to The Ministry of Environmental and Forestry regulation No P8/MENLHK/SETJEN/KUM.1/3/2018. The article number 9 of this regulation states that the main priority for hotspot checking targets are hotspots that detected at confidence level ≥ 30% and the hotspots are clustered and/or indicated with smoke in the satellite imagery and/or recurring hotspots (at least 3 days consecutively). If there is a land fire incident without fulfilling these requirements, then it will not be a major priority to be checked and the local government cannot use their budget for early fires extinction.

The hotspot data was compared with the burn scar from Sentinel imagery 2A and 2B L1C to analyse the inaccuracy of the hotspots (Terra and Aqua satellite). The accumulation of hotspot data was done every five days adjusted to the acquisition of sentinel imagery. So, the results of the analysis and observation in the study area were done per five days.

3. Results and Discussion

The number of hotspots detected by Terra and Aqua satellite throughout 2019 is presented in Figure 3. There was not any hotspot detected in the study area during the rainy season from January to June. The hotspots distribution is mainly accumulated during the dry season in the end of July to the end of September. This fact indicates that the most crucial time for land fires in the study area is particularly between July to September. This finding is in line with [5] because June to September is the driest months in Kota Baru and surroundings based on normalized annual cycle (of precipitation). According to [6] fires in Indonesia occur especially in Sumatra and Kalimantan during dry season months of June to September and more frequent and severe during El Nino years due to a pronounced rainfall deficit. Hotspots with 80% of confidence level were mostly detected in September during El Niño Southern Oscillation where the precipitation level is at its lowest.

There are three classes of confidence level. They are 0%-30% classified as low class, 30%-79% classified as nominal class and confidence level more than 80% is classified as high class. Users requiring fewer false alarms may wish to retain only nominal and high confidence fire pixels, and treat low confidence fire pixels as clear, non-fire, land pixels [7].

The initial hotspot in the study area was detected on 15 June 2019 with a confidence level of 30-79% and located outside the concession area, in an area close to local communities as presented in Figure 4a. This single hotspot was not the main priority to be checked according to the regulation, because the hotspot was not clustered and the confidence level was less than 80%. However, these fires burned the land and created a burn scar on Figure 4b. Based on the burn scar evidence, fires almost reached the plantation area but then stopped at the concession area boundaries (Figure 4b). The company succeeded in preventing fires from coming to their plantation. This initial hotspot was likely located in a low biomass vegetation area near the plantation, where the vegetation is quickly and completely burned out without being detected by the sensor as a hotspot.
Hotspots with confidence level below 80% emerged around the initial hotspot location (Figure 4c) and burn scar was expanding and distinctly noticeable. The fires continuously occurred until the end of July but mostly detected as hotspot with confidence levels below 80% (Figure 4d and 4e). Even though fires could be seen clearly in Figure 4d, the sensor did not detect it as a hotspot. This occurred mostly because the burned material in this area was low biomass vegetation and produced “small fire” that could not be detected as hotspots by satellite. In this case, to detect those fires, hotspots with confidence level less than 30% should be used. However if the government uses all three classes of hotspots to do field observation, it will produce a higher incidence of false alarm.

The first clustered hotspot was found in the beginning of August (Figure 4f). There were two clustered hotspots with confidence levels less than 80% found in the study area. Five days later those fires were extinguished and only two hotspots detected, one hotspots with confidence level 30-79% and the other’s 80% (Figure 4g).
On the midst of August, hotspots started to spread around the study area and the number of hotspots were notably increasing until the end of August (Figure 4h, 4i and 4j). On 3rd of September, hotspots started to be clustered for either 30%-79% or 80% confidence level. Those hotspots were identified nearby the plantation area (Figure 5a). Outside the plantation area, locations that were covered by *gelam* forest and shrubs were still burning with a lot of “small fires” on it. Thus there were no hotspots detected on that location even though the squared area was zoomed, the fires were easily observed and the burn scar expanded (Figure 5b).

Figure 6 shows the condition of the study area on 13 September 2019. This satellite imagery showed that many hotspots were detected nearby the plantation area and fires were extinguished before entering the plantation. In the squared area, there were three unclustered hotspots and fires found. The number of hotspots that were detected nearby the plantation area on this date suggests the reason for The Ministry of Environment and Forestry statement that most land fires incidents occurred nearby the plantation area. On the other hand, the BNPB extinguished the initial fires and did the ground check on the land fires at the squared area, explaining their statement that land fires occurred outside the concession area. Therefore it can be understood the reason behind different statements of these government institutions. The land fires around the study area were completely extinguished on 23rd of September.
Figure 5. Overlapping burn scar and hotspots at the great fires: (a) acquisition date of sentinel 03 September 2019; (b) zooming of figure 5a (red square)
Figure 6. Overlapping burn scar and hotspots at the great fires: (a) acquisition date of sentinel 13 September 2019; (b) zooming of figure 5a (yellow square); (c) zooming of figure 5a (red square)
Figure 7 shows that land fires left obvious scars on the study area. The plantation company areas did not have any fire incidents in this study area because they implemented good fire management, prevention and control of land fires which was funded by the company itself. A bigger land fire could have occurred if the company let the fires enter their oil palm plantation area. Companies should do prevention since most of the land is covered by shrubs, especially those adjacent to plantation areas need to be wary of as a potentially high areas of fires occurrence [8].

The largest land fires (Figure 7) did not occur in areas near plantations (high biomass vegetation), but in areas with low biomass vegetation which was mostly utilized by local farmers. Early monitoring and controlling of land fires in these areas cannot be done if only sourced from hotspots data.

4. Conclusion
Hotspots can detect land fires incidence on plantation areas or secondary forests. However, hotspots slow in detecting fires (inaccurate for early warning land fires incidence) on shrubs or bushes. Hotspots cannot detect fires in low biomass vegetation areas.

5. Suggestion
An accurate method should be invented for land fires early warning systems.
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