Identification of land cover trajectories before and after forest and land fires in Jambi Province in 2019

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Abstract. Jambi Province has a very extensive forest area. However, the forest area in Jambi Province continues to decline due to forest and land fires which result in changes in land cover every year. There have been large-scale forest and land fires in Jambi Province in 2019. The objectives of this study to determine the temporal and spatial distribution of hotspots in Jambi Province and to find out changes in the land cover before and after forest and land fires in 2019. The method used in this study was an analysis of the temporal and spatial distribution of hotspots and satellite imagery processing of land cover at locations with the highest hotspot density. The period of increasing hotspots in Jambi Province in 2019 occurred from August to December and reached a peak in September. The highest hotspot density was in Muaro Jambi District. Land cover that experienced forest and land fires was dominated by palm oil plantation and swamp shrubs. The forest and land fire incidents generally occur at the same location over the years.

1. Introduction
Indonesia forest occur degradation years to years. The extent of degraded forest in Indonesia cannot be separated from the phenomena that occur, one of which is forest and land fires [1]. One of the causes of forest and land fires in Indonesia, especially in Sumatera and Kalimantan, is the increasing socioeconomic pressure and changes in land use [2].

Jambi Province has an extensive forest area. However, the forest cover in Jambi Province continues to decline. According to a study [3], the decrease in the forest cover in Jambi Province is partly due to the conversion of forest land to plantation land, frequent illegal logging, and forest fires.

In Jambi Province, Forest and land fires happen almost every year. The most considerable burnt areas in Jambi Province are peatlands and they often occur during the dry season [4]. There had been two large-scale forest fires in Jambi Province in the past ten years and they had caught the government’s attention. According to data [5], these forest and land fires occurred in 2015 with a burned area of 114,634.34 ha and in 2019 with a burned area of 39,638 ha. The burned area of forest and land was dominated by peatlands. It is known that peatlands are fragile ecosystems. When the peatlands dry up, it will be very susceptible to burning [6]. Yet, forest and land fires can be detected by knowing data on hotspots in Jambi Province.

Identification to examine land cover is necessary to conduct in Jambi Province before and after forest and land fires in 2019 using remote sensing technology. The results of this study are expected to provide information on the distribution of hotspots throughout 2019 in Jambi Province and the identification of land cover can be a reference and overview of forest and land fire disaster management.
in the future. This study aimed to determine the temporal and spatial distribution of hotspots in Jambi Province and to find out changes in the land cover before and after forest and land fires in 2019.

2. Materials and methods

2.1. Study area

This study was implemented in Jambi Province. It was conducted for six months, from January 2020 to July 2020.

![Study area map](image)

**Figure 1.** The study area map

2.2. Data analysis

We were used primary and secondary data in this study. The data collected were the distribution of hotspots in 2019 which were obtained from the Terra/Aqua satellite with a Moderate-resolution Imaging Spectroradiometer (MODIS) sensor which can be accessed from the NASA Active Fire Data website via [https://firms.modaps.eosdis.nasa.gov/download](https://firms.modaps.eosdis.nasa.gov/download), administrative boundary maps obtained from Development Planning Agency at Sub-National Level (BAPPEDA) and Landsat 8 OLI and Sentinel 2A imageries of Jambi Province which can be downloaded from [https://earthexplorer.usgs.gov](https://earthexplorer.usgs.gov). Field survey was conducted on September – October 2019.

Fire incidents that occur in the field can be seen from the level of confidence of the hotspot which is monitored from satellite data. The high and low level of confidence shows the potential for a fire to occur [7]. The level of confidence ranges from 0 to 100% and is used to classify whether the hotspot is weak or strong. A level of confidence above 50% indicates that the hotspot is a fire incident [8].

Analysis of the data used in this study was the analysis of the spatial and temporal distribution of hotspots. At the stage of analysis of the temporal distribution of hotspots, the hotspot data were grouped in months. This analysis was carried out to see the fluctuation from time to time. At the stage of spatial
distribution analysis, the densest distribution of hotspots was examined by calculating the number of distribution of hotspots compared to the area.

2.3 Satellite imagery processing
Based on the results of data analysis, it obtained the data of the regencies or cities that had the densest distribution of hotspots and experienced fires continuously. These areas were the focus of land cover identification before and after the fires. The land cover identification was carried out based on a comparison of image from Landsat 8 OLI and Sentinel 2A Imagery of Jambi Province taken in 2013, 2015, 2016, and 2019.

3. Results and discussion

3.1 Distribution of hotspots in Jambi Province in 2019
Hotspots indicate that an area has a higher temperature than others and is monitored through remote sensing. Hotspot data are useful for early warning detection of forest and land fires [9]. Based on hotspot data taken from NASA MODIS sensors, it obtained the distribution of hotspots in Jambi Province in 2019

The number of hotspots in Jambi Province, in which there were 5521 hotspots. The hotspots in Jambi Province in 2019 had increased since August and reached the highest peak in September, with a total of 2,861. The number of hotspots in August to December showed an increase in their number. Meanwhile, the number of hotspots from January to July was small.

The period of forest and land fire incidents was associated with the dry season. The study [10] stated that August, September, and October were the months with the most frequent fires in Indonesia which occurred during the dry season or during the transitional period. This is because rainfall during the dry season tends to decrease. When rainfall decreases, the number of hotspots generally increases. Thus, rainfall greatly affects the water content of the fuel, especially on peatlands [11].

Spatially, the distribution of hotspots in Jambi Province was not evenly distributed in all districts. Of the 5521 hotspots in Jambi Province, most of them were distributed in Muaro Jambi District, with a total of 2871 hotspots.

Forest and land fires in Muaro Jambi District mostly occurred in peatlands. This is because peatlands are irreversible, so that when they experience drought, they cannot be reversed to the initial condition and this becomes a potential for a fire to occur [12]. Besides, the study [8] stated that peatland fire is also difficult to extinguish and fires can spread out through ground layer so that they can spread uncontrollably. Dry peat with very low humidity in the dry season will be a highly flammable fuel.

Based on Figure 3, it obtained that Muaro Jambi was also the District with the densest hotspots of 0.5305 hotspots/km². The hotspots in Muaro Jambi District were also distributed throughout the districts. The hotspot density in each district had a different value. The density was calculated based on the ratio of the number of hotspots to the area of the district. The hotspot density as an indication of fire activity was determined by the presence of peatland, land cover, accessibility, and human activities [11].

Over the years, the hotspots in Indonesia are distributed in Muaro Jambi District. According to the study [13], from 2001 to 2006 and from 2007 to 2014, the hotspots were spread over 53 regencies in Sumatera with a total distribution area of peatlands reaching 78,673.53 km². The locations that had the most hotspot distribution from 2001 to 2017 were Riau Province (Rokan Hilir, Bengkalis, Siak, and Indragiri Hilir Regencies), South Sulawesi, Sumatera Province (Ogan Komering Ilir District), and Jambi Province (Muaro Jambi District).

Spatially, it can be seen that based on the hotspots in Muaro Jambi District, there were 3 districts with the highest hotspot density, including Kumpeh District of 1.28 hotspots/km², Kumpeh Ulu District of 0.59 hotspots/km² and Sungai Gelam District of 0.31 hotspots/km² (Figure 4). The three locations with the highest density were a reference for comparison of land cover change, either before, during, and after forest and land fires. Number of hotspots of the 2,871 distributed in Muaro Jambi District, there were 2,447 hotspots in Kumpeh Sub-district, 226 hotspots in Kumpeh Ulu Sub-district, 165 hotspots in
Sungai Gelam Sub-district, 28 hotspots in Muara Sebo Sub-district, 2 hotspots in Mestong Sub-district, 2 hotspots in Sungai Bahar Sub-district and 1 hotspot in Jambi Luar Kota Sub-district.

Forest and land fires cause changes in land cover. There are several main types of land cover changes in Sumatera, including agricultural development, land cover changes due to oil palm plantations which were previously forest and converted because of forest fires or human activities, and temporary changes in oil palm plantation [14].

Figure 2. The trajectory of land cover change in Sungai Gelam District from shrub swamps to burning land (a) in 2013, (b) 2015, (c) 2016, (d) 2019, completed with the hotspots in 2019 (black circles)

There were several types of land cover in Sungai Gelam District (Figure 2), including shrub swamps, mixed dryland agriculture and plantations, and secondary swamp forest. In 2015, part of the plantation and mixed dryland agricultural lands were turned into open fire areas marked by a smoky image. A massive fire also occurred in 2015, in which based on the data [5], the area of burned land in Jambi Province was 115,634.34 ha.

In 2016, there were more green colors (Figure 5c), indicating that the land that was burnt in 2015 was overgrown with plants. While in 2019 (Figure 5d), all shrub swamps, secondary swamp forest, and dryland agriculture turned into open land due to the forest and land fires, indicated by color changes and dense hotspots on the land cover.

Figure 3 shows the change in land cover on plantation land, marked by a regular line pattern showing the access road for plantation in 2013. The plantation land was open land and it showed land preparation for planting. On the right of the image, the land cover was shrub swamp. Further, in 2015 (Figure 3), the shrub swamp was burnt, marked with the appearance of smoke. Shrub swamp is a land that is very susceptible to burning, which based on the statement of [8], shrub swamps is a fire-prone area because it provides a lot of flammable load fuel in the dry season which is included in the category of fine fuels. For plantation land, there was no significant change. However, the land that was not ready for planting
was processed in 2015. In 2016 (Figure 3c), the image shows that the land that was burned in 2015 was already overgrown with shrubs, marked with a greenish color.

![Figure 3](image-url)

**Figure 3.** The trajectory of land cover change in Kumpeh District from oil palm plantation to burnt land (a) in 2013, (b) 2015, (c) 2016, (d) 2019, completed with the hotspots in 2019 (black circles)

In 2019 (Figure 3d), the area of oil palm plantations and shrub swamp was all burnt, marked with the image color. Based on the results of the ground check, the burned land in Kumpeh District occurred in oil palm plantation land cover. A study [15] showed that, in Jambi Province, fires generally occurred on a bush or unmanaged land for land clearing activities.

Kumpeh Ulu District is an area dominated by oil palm plantations and shrub swamp. In 2013, it was clearly seen that there was regular access to plantation roads. Compared to 2015, there was no significant change in land cover (Figure 4b). Compared to 2015, the land cover in 2016 (Figure 4c) did not change much.

In 2019, the plantation land and shrub swamp was burned and turned into open land, marked by reddish color and the densest hotspots were also found in plantation and shrub swamp land covers. This is similar to the study [16] in North Labuhanbatu District, in which the highest hotspots were in the type of plantation land cover. Besides, in the type of bushland cover, it was detected that the hotspots were stable every year.

The results of the analysis of this study show that forest and land fires that occurred in these three locations generally recurred in the same locations. The spatial distribution of hotspots was also dominated by peatlands. Peatlands became flammable after experiencing repeated fires [8]. In the case of forest and land fires in Jambi Province, it was dominated by plantation land. In line with the study [15], forest and land fires in Jambi Province tended to occur on peatland every year, either during El Nino or La Nino periods. The land cover before the fire was mostly swamp shrubs and disturbed secondary swamp forest. The fires were also used by companies (oil palm plantations and forests) for land preparation.
Figure 4. The trajectory of land cover change in Kumpeh Ulu District from plantation to burnt land (a) in 2013, (b) 2015, (c) 2016, (d) 2019, completed with the hotspots in 2019 (black circles)

4. Conclusions
Hotspots in Jambi Province in 2019 began to increase in the period of June to October and experienced a peak in September with a total of 2,861 hotspots. The period of forest and land fires in Jambi Province occurred during the dry season. Spatially, the hotspot density in Jambi Province in 2019 was in Muaro Jambi District. Muaro Jambi District was one of the districts that experienced forest and land fires which were quite extensive in 2019 and they occurred on peatlands. The three sub-districts that had the highest hotspot density in Muaro Jambi District were Kumpeh, Kumpeh Ulu, and Sungai Gelam Districts.

The land cover in the three districts with the densest hotspots was dominated by oil palm plantation land and shrub swamp. Changes in land cover in Jambi Province occurred in shrub swamp and oil palm plantations into burned land. The forest and land fires in Jambi Province also occurred repeatedly in the same locations.

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