The estimated total area of forest fire in Siak Regency, Riau Province during the early period of COVID-19 outbreak

M H Mustofa¹, L Syaufina¹ and N Puspaningsih¹

¹ IPB University, Jl. Raya Dramaga, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

Corresponding Author: mhmustofa@apps.ipb.ac.id

Abstract. Forest fires in Indonesia are more prominently caused by human factors rather than natural factors. In 2020, the COVID-19 outbreak resulted in social distancing policies which leads to the restriction and limitation of human activities. This research aims to compare the forest fire areas and the number of cases between the early period of the COVID-19 outbreak and the normal period before the outbreak. In this research, we used Sentinel-2 images for further analysis through visual method and Normalized Burn Ratio method. Additionally, the ground check was also carried out in the burnt area. The estimation based on the visual analysis resulted in a total burnt area of 459.71 ha with 4 counts of cases. While based on the NBR result, it was 302.79 ha. For comparison, during the same period in 2019 in the same focus research area, there are 7 forest fire cases with a total burnt area of 1,236.80 ha. These results indicate that in terms of total burnt area and count of cases, there are fewer burnt areas in 2020 compared to the burnt areas in 2019. In conclusion, restrictions on human activity are suspected to be the cause of the reduced area of the fire.

1. Introduction

Forest fire is a problem every year in Indonesia during the annual dry season, especially in Sumatra and Kalimantan [1]. In Riau, one of the provinces in Sumatra, the forest and peat fires mostly happened because of land clearing activities for plantations [2]. Forest fires occur in Indonesia more frequently during El Nino years due to a deficit in rainfall [3]. The losses areas caused by forest and land fires are enormous, in the form of economic, health, and environmental damage [4].

Forest fires themselves are influenced by four factors: fuel, weather conditions, ignition agents, and people. The type of fuel, continuity, structure, humidity, and quantity are important elements of a wildfire [5]. One example of a large disaster due to forest fires was in 2015 during El-Nino, where conditions were drier than normal, causing forest fires that occurred by humans to be out of control in fire-prone areas in Indonesia, including Sumatra, Kalimantan, and Papua. Millions of people were exposed to hazardous air quality for weeks and at its peak, dense pollution from wildfires stretches across the globe on the equator [6]. The frequency of forest fires is influenced by a complex combination of natural and human factors [7].

Mostly, the motive for the forest fire caused by humans is economic motive [8]. Burning peatlands is considered a fast way to conduct a land preparation [9]. As a way of preventing, controlling, and monitoring forest fires in areas with high risk such as peatlands, the researchers used hotspots which are indicators of fire in land and forests, even though hotspots does not mean an actual wildfire, they are useful to identifying transient wildfires patterns by detecting seasonal and annual variations in the
number of wildfires occurrences [10]. The relationship between hotspots and burned areas obtained from Landsat imagery can be quantified in different ecosystems to find information on the occurrence of fires [11].

Remote sensing is the study of information about the earth's land and water surface using images obtained from an overhead perspective, using electromagnetic radiation in several parts of the electromagnetic spectrum that is reflected or emitted from the earth's surface [12]. In this study, sentinel-2 imagery is used as remote sensing that has a function for making thematic designs that are related to spatial planning, ecosystems, and changes in the appearance of the earth. The use of sentinel-2 is also related to the Google Earth Engine (GEE) application which functions to archive all data sets and link them to the cloud computing engine for open source use. Data archives may include those from other satellites, as well as vector data sets based on Geographical Information Systems (GIS), social, demographic, weather, digital elevation models, and climate data layers [13].

Riau Province was chosen as the location of this study because it has 2 fire seasons, which are January-March and June-September. Based on research data by Mubekti [14], the districts that have a large distribution of peatlands are Siak Regency, Indragiri Hilir Regency, Bengkalis and Dumai, Palalawan, Rokan Hilir, and Meranti. Based on data from the Riau Province Forestry Service, the total area of forest and land burned in 2019 is 90,550 ha, greater than in 2018 which amounted to 37,236.27 ha.

COVID-19 outbreak caused the enactment of social distancing policies. As a result, several activities related to forest and land fire control have also been disrupted. It is known that some types of infectious diseases are more easily spread in areas with high temperature [15], and to reduce the spread of the COVID-19 disease, various types of social distancing and lockdown policies have been implemented in various countries. In Indonesia, the implementation of social distancing is manifested in the form of large-scale social restrictions. Social distancing that was done to slow the spread of the coronavirus is already hampering fire prevention programs and could do the same for firefighting efforts when the intensity of the dry season increase. Then, regarding the incidence of COVID-19, in Riau Province, starting from March 2020 to October 30, 2020, a total of 14,671 positive cases were found. The objective of the present study is to compare the forest fire areas and the number of cases between the early period of the COVID-19 outbreak and the normal period before the outbreak.

2. Material and Methods

2.1 Location and material preparation

This study was done at Siak Regency, Riau Province. One of the reasons for Siak Regency to be chosen as a research area is because the majority of its land is peatland. The vast peatlands in Siak Regency increases the possibility that the forest and land fires are caused by human factors. The climatic conditions in Riau Province are bimodal, which means there are two dry season peaks. In this study, the data collection time was planned for July-November 2020, and the data processing and analysis were carried out in November 2020-May 2021.

The tools used in this research included several software such as ArcGIS, Google Earth Pro, Google Earth Engine, and Microsoft Office. The materials used are in the form of certain data from the European Space Agency (ESA), KLHK, BMKG, and Manggala Agni Daop Siak Patrol Report. The framework in this study can be seen in Figure 1.
2.2 Research Method
This research method contains several parameters or variables, data sources, and analysis methods from the previous research conducted in the same regency [16]. The purpose of this study was to estimate the area of forest and peatland fires in Siak Regency, Riau Province, with one of the measured parameters being the burned area in hectares (ha) and the data needed is the burned area data from Sentinel-2 imagery sourced from ESA. The analysis method used is to analyze the Sentinel-2 image to identify the burned area using a visual method based on hotspot data and fire suppression data, and a digital method based on the NBR (Normalized Burn Ratio) model. The research stages of the estimated burned area can be seen in Figure 2.
2.3 Collecting data
Data collection was implemented by estimating the area of burned area based on hotspot data obtained through the data of active MODIS fire that generated based on a contextual algorithm in which a threshold is applied to the middle-infrared temperature and the brightness of thermal infrared were observed by the wildfires that detected by the Terra and Aqua MODIS satellite channels [17]. The active fire was identified from wildfire data sensed remotely by satellites at a spatial resolution of 1 km pixel which was reprocessed by a series of tests, closings, additional corrections, and false alarm rejections to improve prediction accuracy [18]. Hotspot data used is monthly MODIS hotspot data sourced from the website: http://earthdata.nasa.gov. This hotspot data is used to assist in identifying the period of fire occurrence which is then used in selecting Sentinel-2 imagery.

The data of remote sensing satellite image used is Sentinel-2. The channels used are channels 2, 3, 4, 8, and 12 from the Multispectral Instrument (MSI). Channels 2, 3, 4, and 8 have a spatial resolution of 10 meters, while channel 12 has a spatial resolution of 20 meters. In one fire episode, it takes one scene of the recording date image before the fire period and one scene of the recording date image after the fire period. Sentinel-2 measures different frequency ranges along the electromagnetic spectrum in a color, although not always the color visible to the human eye. Each range is called a band, and Sentinel-2 has 12 bands. The Sentinel-2 indicated the red, green, and blue sensors as the number of 4, 3, and 2, and when it is combined, you get true color images.

The data collection technique to estimate carbon emissions is by sampling the random layered referring to SNI 7724 of 2011 that concerning the measurement and calculation of carbon stocks. The largest plot size is 20 m x 20 m, and for each level of vegetation growth the plot sizes are as follows: (a) seedlings with a minimum area of 4 m², (b) saplings with a minimum area of 25 m², (c) piles with a minimum area of 100 m², and (d) trees with a minimum area of 400 m².

2.4 Processing and data analysis
The data analysis was performed to estimate the area of the burned area by correcting Sentinel-2 image data which includes geometric and radiometric corrections. In this processing, the radiometric correction that is carried out is a correction of TOA (Top of Atmosphere) reflectance or peak atmospheric reflectance, which converts the digital value into a peak atmospheric reflectance value. This correction
is useful for producing surface reflectance, reflectance correction to the direction and the slope (slope correction), or atmospheric correction to minimize disturbance by the atmosphere.

The next analysis is to detect burned areas visually which is done by combining several separate images into one data set file (dataset). The data files that are combined are channel data 2, 3, 4, 8, and 12. After that is image sharpening and color composite image creation, image sharpening that included contrast enhancement and spatial enhancement, then is the determination of the selected Sentinel-2 imagery period to identify areas of ex-forest and land fires. Fire hotspot data (vector format) which has been adjusted to the projection system (into the UTM datum WGS84) is compiled with Sentinel-2 imagery, on the date before and after the forest fires. Then, delineation of the burned area visually is done by drawing a line vector which is the boundary between the image pixels which are the burned area, and the unburned area. The method used to identify burned areas is by determining the changes of land cover conditions before and after the burning of vegetated land. The image layer on-off technique is used to make it easier to identify these changes, the identification process is only carried out in areas where there are hotspots, smoke, and burnout data. Visually, the burned area can be identified using 7 characteristics such as tone or color, shape, size, pattern, texture, location, and association.

The next step is detecting the burned areas digitally by combining channel data 8 and 12, then creating an NBR image for all image data, so that the NBRpre (NBR before the fire) and NBRpost (NBR after the fire) images are obtained. The index variables extracted from the Sentinel-2 image are the vegetation index variable from channel 8 and the fire index from channel 12. Channel 8 is a channel that displays data with Near Infrared (NIR) techniques, while channel 12 can display data related to Short-wave Infrared (SWIR). The equation for calculating the two variables [19] is:

\[
NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)} = \frac{(Band 8 - Band 12)}{(Band 8 + Band 12)} \quad \ldots\ldots(1)
\]

Explanation:
NBR = Normalized Burn Ratio
Band 8 = Reflection of channel 8 Sentinel-2 (NIR; 785-799nm)
Band 12 = Reflection of channel 12 Sentinel-2 (SWIR; 2100-2280nm)

After that, it was continued with NBR image fusion, which was combining several separate NBR image data files, namely NBRpre and NBRpost into one dataset, then extracting the burned area pixels. A pixel is stated as a burned area pixel if it meets 2 (two) requirements which are the burned area pixel threshold. Statistically, the threshold value can be measured from the mean value (μ) and standard deviation (σ) of the sample area that representing the burned area in the NBRpost and ΔNBR images. By using the assumption of a normal distribution, the threshold value chosen is the value μ ± 2σ. Furthermore, based on these assumptions and criteria (μ ± 2σ), the α value is obtained from the mean value plus two times the standard deviation of the burned area sample in the NBRpost image. The β value is obtained from the mean value minus two standard deviations from the burned area sample in the ΔNBR image. The estimation of the area of the fire is based on the best model.

3. Result and Discussion

3.1 The condition of burned area
The majority of land in the Siak Regency is peatland, so the forest fires that happened are caused by humans. In 2020, the COVID-19 outbreak resulted in the enactment of a social distancing policy, as a result, several activities related to forest and land fire control were disrupted. The data were collected by taking samples on predetermined area plots. Figure 4 is a sampling of plots in 3 different areas.

There are two major advantages of this research. First, a ground check has been done during the early period of COVID-19 outbreak. Second, this type of research which tries to find the correlation between pandemic and forest fire can be considered new. Meanwhile, this research also has some disadvantages, namely this research does not include the carbon emission calculation and epidemiologic analysis.
Field observations have been done by measuring the total weight of peat and the total weight of litter on three predetermined plots, then taking 2 samples at different depths and analyzing the physical and chemical properties of the soil. Peat samples were obtained directly from the burned area in Sungai Apit District, Siak Regency, then the peat samples were sent to Bogor for further analysis. In the chemical analysis of the three measurement plots, the average pH value was 3.48 and the average C-organic value was 47.69%, then in the physical analysis the average value of bulk density of peat soil with a depth of 30 cm was 0.06 while at a depth of 60 cm, the average value is 0.09 g/cm³.

3.2 Area estimated of the burned area by visual method

In this study, Sentinel-2 imagery was used to monitor burned areas, Sentinel-2 imagery has been used in various studies [20, 21, 22]. The classification of all Sentinel-2 Bands that are common to Landsat-8 has resulted in overall accuracy, which is 5% and 4% better than Landsat-8 [23].

![Figure 3](image)

**Figure 3.** Map of distribution of the location of forest and land fires in Siak Regency, Riau for March-October 2020.

Figure 3 shows that the burned areas were in Mengkapan Village and Lalang Village that was in Sungai Apit District. Three burned areas were found in the Mengkapan Village and one burning area at Lalang Village. According to Manggala Agni, there were also other fire areas with an area of about one hectare in Dayun Village and Merempan Hilir Village, but after matching the coordinates there was no burned area on the satellite imagery. With this in mind, these two areas were excluded from the analysis due to a lack of data.

The period used in finding hotspots or the location of wildfires at a predetermined place is the dry season period that starts from March to October. From the five data of hotspots that have been determined, 4 locations of peat fires are located in Sungai Apit District. The pattern of hotspots associated with the rainy season can become a recommendation in the formulation of strategies for
disaster management of forest and land fires in Indonesia as well as preparations for handling haze disasters caused by forests and land fires.

Sentinel-2 (MSI Level-1C) images were obtained from the ESA Copernicus portal via Google Earth Engine (GEE). As can be seen in Figure 4, the analyzed satellite images have cloud coverage of less than 15%. The determination of the satellite image period has been directly matched and confirmed with official data from Manggala Agni Siak related to forest and land fires during 2020 in Siak District. The Sentinel-2 satellite is similar to the Landsat satellite, especially in terms of making thematic designs that are related to spatial planning, ecosystems, and the changes of the earth sighting.

![Sentinel-2 image and digitization of burned areas at locations A, B, C, and D.](image)

Figure 4. Sentinel-2 image and digitization of burned areas at locations A, B, C, and D.

3.3 Area estimated of the burned area by digital method

The use of the burned area index for mapping burned areas has been widely used. On one hand, by highlighting the charcoal signal in post-fire pictures, the Burn Area Index (BAI) identifies burned land in the red to NIR spectrum in which burned regions are indicated by brighter pixels [24]. On the other hand, NBR uses near-infrared (NIR) and shortwave-infrared (SWIR) wavelengths highlight burned areas in large fire zones greater than 500 acres. NBR and BAI are ways to measure the area burned. In this study, NBR was used to help estimate the burned area and estimate emissions due to forest and land fires. For the mapping of burned areas in this study, NBR is calculated based on equation 1 in subchapter 2.4.
Figure 5. The results of determining the NBR (Normalized Burn Ratio) at locations A, B, C, and D.

The results of the Sentinel-2 image analysis at location A, which is at Lalang area, precisely at the coordinates 0.99936° N 102.21062° E, at this location, the area burned based on the NBR analysis was 187.00 ha. This is equivalent to 11.53% of the total area. Then in area B, which is located around the Kayu Ara River, to be precise at the coordinates 1.08044° N 102.16792° E, at this location, the burned area based on the NBR analysis is 27.00 ha, which is equivalent to 21.09% of the total area. Furthermore, at location C around the Buton area with location coordinates at 0.92233° N 102.18787° E, at this location, the burned area based on the NBR analysis was 2.79 ha, which is equivalent to 11.32% of the total area. And the last location is location D which is located in the area around Koempai with location coordinates at 0.92607° N 102.25860° E. At this location, the area burned based on the NBR analysis was 86.00 ha, which is equivalent to 21.18% of the total area.

Table 1. Data of forest and land fires in Siak District for March-October 2020.

| Code | Location | Hotspot Coordinate | Real Fire Coordinate | Burned Area (ha) | NBR (ha) | NBR (%) |
|------|----------|--------------------|----------------------|------------------|----------|---------|
| A    | Mengkapan Village, Sei Apit District, Siak Regency | 0.9995 102.2120 | 0.9986 102.2140 | 277.28 | 187.00 | 11.53 |
| B    | Lalang Village, Sungai Apit District, Siak Regency | 1.0762 102.1671 | 1.0775 102.1663 | 59.68 | 86.00 | 21.18 |
|      | Mengkapan village, Sungai Apit District, Siak Regency | 0.9463 102.2318 | 0.9227 102.1812 | 2.66 | 2.79 | 11.32 |
| D    | Mengkapan Village, Sungai Apit District, Siak Regency | - | 0.9269 102.2666 | 120.10 | 27.00 | 21.09 |

Total 459.72 302.79

The data in Table 1 are related to the locations of forest and land fires that have been processed. There are 4 cases in 4 locations. All hotspots mentioned have a high confidence level. The first location is Mengkapan Village, Sungai Apit District, Siak Regency, precisely at coordinates 0.9986° N 102.2140° E, the burned area there is 277.28 ha and NBR of 187.00 ha or 11.53% with the hotspot obtained at the coordinates 0.9995° N 102.2120° E which was found via the SNPP/VIIRS satellite and AQUA/MODIS. The second location is Lalang Village, Sungai Apit District, Siak Regency, precisely at the coordinate 1.0775° N 102.16638° E, with a burned area of 59.68 ha and the NBR obtained was 86.00 ha or 21.18%, and the hotspot coordinates obtained are 1.0762° N 102.1671° E via SiPongi and
NOOA-20 satellite. Furthermore, the third location is in Mengkapan Village, Sungai Apit Subdistrict, Siak Regency with the coordinate 0.9227°N 102.1812°E, it was found that the burned area was 2.66 ha and the NBR obtained was 2.79 or 11.32%, and the hotspot was obtained at the coordinates 0.9463°N 102.2318°E which was obtained via SiPongi with a confidence level of 79% obtained through the SNPP/LAPAN satellite. The 4th location is Mengkapan Village, but precisely at the coordinate 0.9269°N 102.266°E with the burned area of 120.10 ha and NBR obtained 27.00 ha or 21.09% with hotspots found through spatial analysis.

The analysis was carried out based on satellite images through the visual method and NBR method. The fire area based on visual analysis is 459.71 ha while the total area of fires based on the NBR results was 302.79 ha.

As a comparison data, the burnt area in 2019 was analyzed. The focus area of analysis used in estimating the burnt area in 2019 is the same as the focus area for the burnt area estimation in 2020. The time period used for the burnt analysis was also the same, which is March to October. As a result, the estimated burnt area in 2019 is 1,236.80 ha with 7 cases.

The results showed that both of them are less compared to the burnt area during the same period in 2019 in the same focus area, which is 1,236.80 ha. Apart from the size of the burnt area, the forest and land fire can be compared based on its count of cases. In 2019 the number of forest and land cases was 7 cases, while in 2020 it was 4 cases. That means there is a fewer count of cases in 2020 than in 2019.

While it is clear that the burnt area in 2020 is less than in 2019, for the forest fire cases in 2020, the locations of the forest fire are largely concentrated in the western region of the Siak District. Specifically, the Village of Mengkapan and the Village of Lalang in the Sungai Apit District. Based on the ground check most of these locations are relatively difficult to access especially during the early COVID-19 outbreak.

Forest fires in Indonesia are mostly caused by human factors. Due to the partial lockdown, human activities are more limited. Subsequently, it can be determined that forest fire areas and cases during the early period of the COVID-19 outbreak are lower compared to the normal period prior to the outbreak because of the limited human activities. This is also in accordance with the findings during the ground check. Future studies should integrate carbon emission calculations and epidemiologic analysis to have a better understanding of the relationship between pandemic situations and forest fire cases in multiple forest fire prone areas.

4. Conclusions
Based on the results of the analysis, it was found that the total area of wildfires based on the NBR results was 302.79 ha. Meanwhile, the wildfire area based on visual analysis was 459.71 ha. The results showed that both of them are less compared to the burnt area during the same period in 2019 in the same focus area, which is 1,236.80 ha. Based on the count of cases, the number of forest fire cases of 2020 is less than that of 2019. Restrictions on human activities are highly suspected to be the cause of the reduced areas and cases of forest fire. Carbon emission calculation and epidemiologic analysis should be included in future research to improve the acquire more insight into the correlation between pandemic situation and forest fire cases in various areas which are prone to forest fire.

References
[1] Kustiyo et al 2015 Detection of forest fire, smoke source locations in kalimantan during the dry season for the year 2015 using landsat 8 from the threshold of brightness temperature algorithm Int. Journal of Remote Sensing and Earth Sciences 12 151
[2] Thah TH and Sitanggang IS 2016 Contextual outlier detection on hotspot data in Riau Province using k-means algorithm. Procedia Environmental Sciences 33 258
[3] Yuliiani N et al 2012 Recent forest and peat fire trends in Indonesia the latest decade by MODIS hotspot data Global Environmental Research 16 pp 105-116
[4] Konecny K et al 2016 Variable carbon losses from recurrent fires in drained tropical peatlands Global Change Biology 22 pp1469-1480
[5] Flannigan M D et al 2005 Future area burned in Canada Climatic Change 72 pp 1–16
[6] Shawki D et al 2017 Long-lead prediction of the 2015 fire and haze episode in Indonesia Geographic Research L 36 pp 9996-10005
[7] Young AM et al 2017 Climatic thresholds shape northern high-latitude fire regimes and imply vulnerability to future climate change Ecography 40 pp 606-617
[8] Japan International Cooperation Agency 2017 Survei Pengumpulan Data Mengenai Pengendalian Hutan & Lahan Gambut dan Restorasi Lahan Gambut di Indonesia (Jakarta: JICA)
[9] Febrie H et al 2017 Karakteristik Tanah Gambut yang Distabilisasi Terhadap Pembakaran Jom Fteknik 4 pp 1-8
[10] Takahata C et al 2010 Remotely-sensed active fire data for protected area management: eight-year patterns in the Manas National Park, India. Environmental Management 45 pp 414-423
[11] Hantson S et al 2013 Strengths and weaknesses of MODIS hotspots to characterize global fire occurrence Remote Sensing of Environment 131 pp 152-159
[12] Campbell J B and Wynne R H 2011 Introduction to Remote Sensing (5th Edition) (New York: The Guilford Press)
[13] Mutanga O and Kumar L 2019 Google Earth Engine Applications Remote Sensing 9 pp 1-4
[14] Mubekti 2011 Studi Pewilayahan dalam Rangka Pengelolaan Lahan Gambut Berkelanjutan di Provinsi Riau. Jurnal Sains dan Teknologi Indonesia 13 pp 88-94
[15] Zhou X et al 2013 High temperature as a risk factor for infectious diarrhea in Shanghai, China J. Epidemiol 23 pp 418-423
[16] Hafni D A F et al 2018 Estimation of carbon emission from peatland fires using Landsat-8 OLI imagery in Siak District, Riau Province IOP Conf. Ser.: Earth Environ. Sci 149 012040
[17] Giglio L, Schroeder W, Justice CO 2016 The collection 6 MODIS active fire detection algorithm and fire products Remote Sens Environ 178 pp 31-41
[18] Fornacca D et al 2017 Performance of three MODIS fire products (MCD45A1, MCD64A1, MCD14ML), and ESA Fire CCI in a mountainous area of northwest Yunnan, China, characterized by frequent small fires Remote Sens 9 1131
[19] Kovács K D 2019 Evaluation of burned areas with Sentinel-2 using snap: the case of Kineta and Mati, Greece, July 2018 Geographia Technica 14 pp 20-38
[20] Westerling A L 2016 Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring Phil. Trans. R. Soc. B 371 20150178
[21] Quintiere J G 2017 Principles of Fire Behavior (New York: CRC Press)
[22] Sannigrahi S et al 2020 Examining the effect of forest fire on terrestrial carbon emission and ecosystem production in India using remote sensing approaches. Science of the Total Environment 725 pp 1-13
[23] Farda N M 2017 Multi-temporal land use mapping of coastal wetlands area using machine learning in Google Earth Engine IOP Conf. Ser.: Earth Environ. Sci 98 012042
[24] Martin M P 2006 Burnt Area Index (BAIM) for burned area discrimination at regional scale using MODIS data Forest Ecology and Management 234 pp 193-197