Burned area monitoring based on multiresolution and multisensor remote sensing image in Muaro Jambi, Jambi

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Abstract. Forest and land fires are one of the disasters that occur regularly every year in the dry season. In 2019, it is estimated that the spread of forest and land fires will continue to expand due to the weak el-nino potential faced by Indonesia. Monitoring burned area is important to be done quickly and accurately to find out the distribution and extent of the burned area to be followed up by relevant parties. This study aims to monitor burned area in Muaro Jambi, Jambi Province based on remote sensing imagery from optical sensors and radar sensors, namely Landsat 8, Sentinel 2, and Sentinel 1 satellite imagery. The method of identifying the burned area is based on the hotspot location and the different land cover images before and after the fire. Hotspot data used are Terra / Aqua MODIS, SNPP VIIRS, and NOAA 20 with confidence level high, medium, low while the satellite imagery used is Landsat RGB 6 5 4, Sentinel 2 RGB 11 8a 4, and Sentinel 1 RGB VV VH VV / VH. Based on this monitoring, the results of multisensor and multiresolution image show that the burned area continues to increase during the fire period from 30 July (217 Ha) - 5 August 2019 (1027 Ha).

1. Background

Forest/land fire usually occur in Indonesia in dry season and increasing when el-nino happen [1]. This year weak el-nino happen in Indonesia make dry season longer. Dry season caused the ground water level decreased and fire potential increased especially in peat land area [2]. In Indonesia, mostly peat land area located in Sumatera (6.44 million Ha) and Kalimantan islands (4.78 million Ha) [3]. In peat land area, the fire burn in the bottom of the surface [4], hence the surface looks burnout while the fire still and it resulted long period of smoke. Post fire burn, it left the burned area which was one of the causes of environmental degradation. Remote sensing satellite image give opportunity to monitor burned area and could be used to restore environment quickly.

Hotspot is one of the parameters to identified fire events [5]. It has three categories of confidence level: low confidence level (low CL), moderate confidence level (moderate CL), and high confidence level (high CL). Each CL refers to possibility of fire events, the higher CL the higher possibility of fire. Hotspot from LAPAN shows the number in Jambi Province from January and July 2019. Based on Figure 1 below hotspot significantly increased in July 2019, so it need more observation to the hotspot location. In this phenomena, fire events could be identified using hotspot and smoke distribution from RGB image [6] and after disaster which is burned area location, vastness, and distribution.
Due to weak el-nino, the fire event increasing so do the effect of it which is burned area over vegetation in peat land area. To identified the location and vastness of the effect need effective detection and monitoring. Burned area of forest/land fire could be identified using remote sensing image, optical [7] and radar sensor[6]. Remote sensing has advantage which fast detection and monitoring using temporal image compilations.

Optical data could identify burned area but has limitation in cloud and cloud shadow coverage to identified using visual or digital interpretation. The data under cloud or cloud shadow could not be interpreted. Radar data which could penetrate cloud in the atmosphere give opportunity to interpret object under cloud and cloud shadow. Study of [8]integrated optical and radar data for burned area mapping in Mediterranean region. This study try to integrate optical and radar data in Muaro Jambi, Jambi Province especially in peat land area. This study has objective to detect and monitor the distribution of burned area based on remote sensing images from optical sensors and radar sensors in Muaro Jambi, Jambi Province.

2. Data and methods

2.1 Data

Data used in this study are hotspot (Terra/Aqua MODIS, SNPP, and NOAA20) range from 25 July – 15 August 2019 from LAPAN. This data as indicator of forest/land fire which have 3 categories of confidence i.e. high confidence level (CL > 79%), moderate confidence level (30% < CL < 79%), and low confidence level (CL < 30%). The higher the confidence the higher probability of fire happens. Meanwhile, hotspots of middle and low confidence usually seen as fire in peat land area [9]. Hence, in this study used 3 hotspots categories.

Remote sensing images from optical and radar sensors were used to monitor the expansion of the burned area. Optical data are Landsat 8 and Sentinel 2, while radar data is Sentinel 1. Table 1 show the recording time of the image.

| Data        | Sensors | Pre fire date | Post fire date |
|-------------|---------|---------------|----------------|
| Landsat 8   | Optic   | 14 July 2019  | 30 July 2019   |
| Sentinel 2  | Optic   | 01 May 2019   | 4 August 2019  |
| Sentinel 1  | Radar   | 23 July 2019  | 5 August 2019  |
| Hotspot     | MODIS/ SNPP/NOAA20 | 25 July – 5 August 2019 |
Comparisons of bands Landsat 8 and Sentinel 2 [10] are shown in Table 2 below. This table compare the bands from each images based on the wavelength range which will be used in this study to know the best composite to identify burned area.

| Band                  | Wavelength range (nm) | Resolution (m) | Band                  | Wavelength range (nm) | Resolution (m) |
|-----------------------|-----------------------|-----------------|-----------------------|-----------------------|-----------------|
| 1 Coastal aerosol     | 433 - 453             | 30              | 1 Coastal aerosol     | 433 - 453             | 60              |
| 2 Blue (B)            | 450 - 515             | 30              | 2 Blue (B)            | 458 - 523             | 10              |
| 3 Green (G)           | 525 - 600             | 30              | 3 Green (G)           | 543 - 578             | 10              |
| 4 Red (R)             | 630 - 680             | 30              | 4 Red (R)             | 650 - 680             | 10              |
| 5 Near infrared (NIR)| 845 - 885             | 30              | 5 Red edge 1 (RE1)    | 698 - 713             | 20              |
|                       |                       |                 | 6 Red edge 2 (RE2)    | 733 - 748             | 20              |
|                       |                       |                 | 7 Red edge 3 (RE3)    | 773 - 793             | 20              |
| 5 Shortwave infrared  | 1360 - 1390           | 30              | 8 Near infrared (NIR) | 785 - 900             | 10              |
| / Cirrus              |                       |                 | 8a Near infrared narrow (NIRn) | 855 - 875 | 20              |
| 6 Shortwave infrared  | 1560 - 1660           | 30              | 9 Water vapour        | 935 - 955             | 60              |
| 1 (SWIR1)             |                       |                 |                       |                       |                 |
| 7 Shortwave infrared  |                       |                 |                       |                       |                 |
| 2 (SWIR2)             | 2100 - 2300           | 30              | 12 Shortwave infrared 2 (SWIR2) | 2100 - 2280 | 20              |
| 8 Panchromatic        | 500 - 680             | 15              |                       |                       |                 |

2.2 Methods

Fire spot identifications based on hotspot and smoke locations. Location and categories of hotspot were plotted in Muaro Jambi, Jambi Province as shown in Figure 1 bellow. Then, it is overlayed with high resolution image of SPOT-7 to know the general characteristic of land cover of the hotspots location at period of 22 days. Figure 1 show that many hotspots were found in Muaro Jambi in one locations, this locations confirm as fire spot.

![Figure 1. Hotspots location in Muaro Jambi, Jambi Province from 25 July – 15 August 2019](image)

Burned area identifications used pre and post fire images which overlay with hotspot locations. First image is optical data from Landsat 8 image. Pre-processed Landsat 8 images were used to identify burned area. Composite RGB image of bands 654 are appropriate to identified burned area [11]. This composite applied to pre fire and post fire images. Burned area were visually analysed when there are hotspots and land cover change between pre and post fire. Usually land covers change from vegetation to burned area which visualized as green pixels change to dark pixels.

Second image also optical data but from different satellite image is Sentinel 2. Based on Tabel 2, composite of 11-8a-4 Sentinel 2 is similar to 654 Landsat 8. Identified burned area from Sentinel 2 use those composite image with land cover analysis of pre and post fire images overlay with fire spot.
locations from hotspots. Third images are Sentinel 1 radar data which used composite of VV-VH-VH to identify the burned area locations. The monitoring uses 3 data with different date to know the expansion and direction of the burned area. Flowchart method of this study shows in the Figure 2 bellow.

![Flowchart of this study](image)

Figure 2 Flowchart of this study

3. Result and discussion
Figure 3 show the hotspot distribution over Muaro Jambi from 25 July until 5 August 2019. It is overlaid with SPOT 6 images recorded 27 December 2018. SPOT 6 image has 1,5 m resolution each pixel could identified land use/land cover of the hotspot location before the fire happen. Hotspot located in the light green area which is dominated with shrub. While the other located in the darker green is plantation area which indicated from pattern of boundary and similar vegetation.

![Land use/land cover of hotspot location from SPOT 6 image](image)

Figure 3 Land use/land cover of hotspot location from SPOT 6 image
Beside hotspot, smoke of forest/land fire is another parameter to identified fire event. Smoke also detected in the hotspot location from 29 July until 3 August 2019 as show in the Figure 4 below. Everyday smoke detected from Terra/Aqua MODIS twice a day (morning and evening) could confirm the hotspot is real fire. The smoke has distribution to northwest appropriate with wind direction for 6 days. The smoke is distributed over the area and last for several days.

![Figure 4 Smokes image detection of hotspot locations](image)

Burned area detected from Landsat 8 composite 654 shows in Figure 5 (a) and (b). Figure 5 (a) display pre fire 14 July 2019 while (b) display post fire 30 July 2019. There is difference in land cover before and post fire. There are dark pixel of post fire image while before not exist in the pre fire image (dark pixel in red circle). Besides that, also found smoke which mixed with cloud in the northwest of dark pixel same as smoke direction in Figure 4. Dark pixel in the red circle classified into burned area. From visual interpretation, the burned area estimation is 217.3 Ha. The calculation has limitation by the influenced of smoke and cloud cover. Burned area under cloud and smoke could not be identified.

![Figure 5 Landsat 8 images (a) pre fire 14 July 2019 and (b) post fire 30 July 2019.](image)

Sentinel 2 composite 11-8a-4 optical image also could detect burned area. Figure 6 (a) explain pre fire image of 1 May 2019 while Figure 6 (b) show post fire of 4 August 2019. Burned pixel show with dark pixel same with Landsat 8 image since it from optical image and same wavelength range. Also the dark pixel release smoke to northwest which is fire smoke. Burned area of 5 August 2019 is estimated 424.0 Ha and has limitation in estimation under the smoke.
Figure 6 Sentinel 2 images (a) pre fire 1 May 2019 and (b) post fire 4 August 2019

Sentinel 1 radar image with composite VV-VH-VV/VH could identify burned area. Figure 7 (a) show pre fire image. Each pixel explains each objects such as vegetation as green, water as dark blue. In post fire image, burned area also show as dark blue but it has significant change between pre and post fire while water has no significant change pre and post fire. Burned area is estimated 1027.1 Ha of 5 August 2019.

Figure 7 Sentinel 1 images (a) pre fire 23 July 2019 and (b) post fire 5 August 2019

Monitoring of the burned area distribution and expansion could be conducted from Landsat 8, Sentinel 2, and Sentinel 1 images. The area is widespread from 30 July until 5 August 2019. The burned area expand to north-east from initial fire. The land use is dominated with dry shrubs which make the fire easily spread and the peat land area make the fire last longer in the ground.

4. Conclusion
Utilization of multiresolution and multisensor satellite data (Landsat 8, Sentinel 2 and Sentinel 1) is good enough to be used in detecting burned area, monitoring its distribution and estimating its extent. However, limitation of burned area detection in this study is smoke and cloud cover of optical image and water object in radar image. Based on the analysis during the monitoring period from 30 July to 5 August 2019 the distribution of burned area in Muaro Jambi tends to the northeast. The expansion factors are land use, land characteristic and weather condition.

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