Burn Area Detection Using Landsat 8 OLI TIRS

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ABSTRACT- Fires associated with land use conversion activities such as agricultural expansion, palm and pulp plantations, peat land alteration, and industrial deforestation are significant in Indonesia (Jerrod & Alex, 2015). Fires season in 2015 is one of the worst incident in Indonesia since 1997, it made Indonesia at the second position as an emitter country, at least 22 days in September 2015, and generated more than the daily average emission of U.S. economic activity. A study from the National Development Planning Agency (Bappenas) and Asian Development Bank (ADB) estimated that the amount of land affected by fires reaches 9.75 million hectares. It caused losses reached US$4.861 or equivalent to IDR711 trillion or even more based on disruption of economic activities, transportation problems, and health problems. Head of Data Information and Public Relations of National Disaster Management Agency (BNPB), Sutopo Purwo Nugroho, said the economic impact of smog disasters occurring in several provinces in Indonesia in 2015 could exceed 20 trillion per province. The most widespread forest fire area occurred in South Sumatra Province. BNPB released that during 2015 in South Sumatera Province has 35.008 hotspots and the burnt area is 641.964 Ha. The most affected area is in Ogan Komering Ilir Regency. Landsat 8 OLI TIRS has a 30-meter spatial resolution for each band except TIRS band and panchromatic band (USGS, 2016). TIRS band has a 100-meter spatial resolution but are resampled to 30-meter that can be used to identify burned scars area. By using SWIR bands (TM bands 5 and 7 in Landsat 5 and 7 systems) as a NBR (Normalized burn ratio) composite, can be used to detecting and mapping burnt area. TIRS algorithm which was used to detect fire will be seen red and SWIR which was used to detect water stress in vegetation and burned vegetation will be seen green, both of them will become darker when burn happened. This method modifying dNBR (pre-NBR – post-NBR) composite, which only can be used in oil palm plantations area that has same commodities, so can be used in various type of landuse especially the area that has plantation adjoin with forest area.

1. Introduction
Fires associated with land use conversion activities such as agricultural expansion, palm and pulp plantations, peat land alteration, and industrial deforestation are significant in the country of Indonesia [1]. Fires season in 2015 is one of the worst happened in Indonesia since 1997, it made Indonesia at the second position as an emitter country, at least 22 days in September 2015, and generated more than the daily average emission from U.S. economic activity. A study from the National Development Planning Agency (Bappenas) and Asian Development Bank (ADB) estimated that the amount of land affected by fires reached 9.75 million hectares. It caused losses reached US$4.861 or equivalent to Rp.711 trillion or even more based on disruption of economic activities, transportation problems, and health problems [2]. Head of Data Information and Public Relations of National Disaster Management Agency (BNPB), Sutopo Purwo Nugroho, said the economic impact of smog disasters occurring in several provinces in Indonesia in 2015 could exceed 20 trillion per province.

The most widespread forest fire area occurred in South Sumatra Province. BNPB released that during 2015 in South Sumatera Province has 35.008 hotspots and the burnt area is 641.964 Ha. The most affected area is in Ogan Komering Ilir Regency. BNPB also reported that almost 99% forest fire occurred
due to deliberately burned by human [3]. The dry weather conditions and the characteristics of the peat soil areas add to the severity of the affected areas [4].

![Image of Hotspots & Peatlands Distribution in South Sumatera 2015](image_url)

Figure 1. Hotspots & Peatlands Distribution in South Sumatera 2015

The extent of the impact of the fires, made public have right to get the accurate location of the prone area, so public can make a mechanism to cope with disaster and manage the community to prevent the bigger impact. Unfortunately, public in Indonesia doesn’t have any access into the update burned scars map, especially in vector format. Whereas, the update data is a crucial part to deciding the thread’s exact respond. A company can monitor the restoration of burned areas, control land use conversion, and decide special treatment, and design a contingency plan in their concession areas. Government can design an efficient disaster management program. And the most important, public can monitoring the entire activities and incidents in the prone area.

Landsat 8 OLI TIRS has a 30-meter spatial resolution for each band except TIRS band and panchromatic band [5]. TIRS band has a 100-meter spatial resolution but are resampled to 30-meter that can be used to identify burned scars area. There are 9 Landsat scenes covering in South Sumatera Province, those 4 scenes are overlapping with Fire Hotspot Data 2015 in Ogan Komering Ilir Regency. By using image processing software, with composite bands analysis and Normalized Burn Ratio (NBR) methods, raster format of burned composite can be construct as portray as burned area in Indonesia. With GIS software those raster data can be convert into vector format that can be displayed in WebGIS platform as an open data e.g. in Green Peace Indonesia WebGIS or another institutions either Government Organization or Non-Government Organization which have webGIS platform. Along with various maps from The Ministry of Environment and Forestry that shown in Greenpeace Indonesia WebGIS, some analysis can be made to help forest monitoring, such as selective logging activities (HPH), pulp & paper activities (HTI), palm oil companies, coal mining companies activities in their concession. Especially, to support Zero Deforestation in Indonesia.

1.1 The Study Area

One of the largest peat swamp areas in Sumatra is in South Sumatera Province which has covering area approximately 1.42 million hectares. A total of 54.12% of the area is located in Ogan Komering Ilir Regency [6]. Figure 2 showed that mostly the hotspot are above peatlands.
This regency has a population of 798,482 people [7] who is the second largest population in South Sumatera Province. More than 95 of this regency is lowland area and bypassed two major rivers namely Musi River and Mesuji River.

2. Methodology
In the past studies, mapping of detecting burn scars was done by using MODIS Imagery [8]. The empirical technique for remote sensing of burn scars using a single dataset of MODIS NIR channels centered near 1.24 and 2.13 μm. These channels are sensitive to changes in the surface properties induced by the fire and are not obscured by smoke. Therefore, they allow remote sensing of burn scars in the presence of smoke. The problem is MODIS has a low spatial resolution (250 - 1000 m). It cannot detect the small area of forest, plantation and peatland fires and only detect the big area of burned scar. ArcGIS 10.4.1 were used to process image satellite and vector data to produce burnt scars area.

Therefore, this research was begin with collecting data Landsat 8 OLI (Operational Land Imager) TIRS (Thermal Infrared Sensor) imagery which has better spatial resolution than MODIS (30m vs 250m). However, MODIS has a better temporal resolution compared to Landsat TM (daily vs 16 day repeat cycle). Landsat 8 OLI TIRS is not acceptable for monitoring, however, with the spatial resolution makes it a very good data set to detect and analyze the damage after the fire. Further, the data were processed to assess burn scars by composite band analysis and Normalized Burn Ratio (NBR) method.

2.1 Data Collection
In achieving the goal of this research, secondary data are used in assessing the burn scar. Secondary data was needed in this research are Landsat 8 OLI TIRS form United States Geological Survey (USGS) USA, hotspots from Fire Information for Resource Management System (FIRMS) National Aeronautics and Space Administration (NASA) USA, Peatlands map from Ministry of Agriculture Indonesia and basic spatial data from Geospatial Information Agency (BIG).

According to ASEAN Specialized Meteorological Center about transboundary haze in Sumatera and Kalimantan showed fire start reported in May in Sumatera and in July in Kalimantan. Both areas are high in August and September, and start declined in October. Fluctuated data shown on Global Forest Watch Fires report. Fires start raised in May 2015 slowed down in September 2015, but grew back in October and November, then started to diming in December 2015.

From those data, this research took two periods of data collection, which are pre fire/during fire data in March – May 2015 and post fire in November 2015 – January 2016.
2.2 Identified Burnt Scars Using Band Composite

The Shortwave Infrared (SWIR) bands (TM bands 5 and 7 in Landsat 5 and 7 systems) are very useful for detecting and mapping burnt areas because it can penetrate heavy smoke and the areas with active flames happened. Combining Landsat-8 TIRS (brightness temp) and Landsat-8 OLI can detect fire burnt area.

To create NBR (Normalize Burn Ratio) that highlighted burnt area, we were using this formula: [9]

\[ NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)} \]

When:
- NIR (Near Infra-Red) as a Band 5
- SWIR (Short Wave Infra-Red) as a Band 7

The Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) are instruments onboard the Landsat 8 satellite. Those two instrument can be combine to identify burn area. OLI instrument can Emphasized burnt area by compositing false- color (red-green-blue) band algorithms. TIRS (Thermal Infra-Red Sensor) for Band 10 to replace red composite, SWIR (Short Wave Infra-red) for Band 7 to replace green composite, and NBR (Normalized Burn Ratio) to replace blue composite. TIRS which was used to detect fire will be seen red and SWIR which was used to detect water stress in vegetation and burned vegetation will be seen green, both of them will become darker when burn happened. Otherwise, NBR which was used to detecting vegetation index will be seen lighter when it’s burned. The combination will show dark yellow/orange when fire happened.

Below is a workflow diagram of processing data that can be followed to identifying burn scars.
2.3 Supervised Classification
In this type of classification the image analyst "supervises" the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a scene. To do this, representative sample sites of known cover type, called training areas, are used to compile a numerical "interpretation key" that describes the spectral attributes for each feature type of interest [10]. Further, all of these pixels are not as samples will grouped based on the characteristic of pixel value by applying statistical calculations.

Training samples area were taken from the pan sharpened or composite image of the Landsat 8 data which clearly from cloud. It were created for three classes (burnt, unburnt, and water bodies/cloud). A maximum likelihood classification algorithm was used to classify the image. Maximum likelihood is one of the most common classifiers used in remote sensing studies and assumes that the spectral values of training pixels are normally distributed [11]. The maximum likelihood classification tool considers both the variances and covariances of the class signatures when assigning each cell to one of the classes represented in the signature file [12]. Each defined pixel will be grouped based on pixel values that have already been retrieved by applying statistical calculations [13].

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There are some problem related with Landsat 8 data in 2015:
Default projection each bands is UTM Northern Hemisphere, so if the area (path row) is in the southern equator, must be re-projected;
- TIRS data (Band 10 & 11) for the period of December-March was broken. Re-uploaded again by USGS on the Early February sequentially;
- Thick-cloud contamination is a common problem in Landsat images especially in Tropical Country, which limits their utilities in various land surface studies cross check with forest fire report are needed

3. Result and Discussion

3.1 Normalized Burn Ratio (NBR)

Based on analysis using the NBR algorithm, showed that the burnt area has a lower NBR value than the unburnt area. This indicates that burnt area has a lower humidity level than unburnt area. It can be good represented through NBR value using SWIR band which very sensitive to capture water condition of the plants [14].

3.2 Burn Composite & Fire Spots Detection

Based on image data processing using 10 + 7 + NBR composite, it is found that this composite can clearly give a good visualization of burnt area or fire spot detection. Figure 7 shows a comparison of images between burnt area, unburnt area, and on fire area. Land that is on the fire burnt will appear in the image as a bright yellow color, however, the burnt land will show dark yellow closest to orange color. In composite band 653 will be clear the difference of those.

![Figure 6](image_url)

**Figure 6.** NBR value in the burnt area and unburnt area

![Figure 7](image_url)

**Figure 7.** Composite bands for fires burnt area detection

However, in built up area will show a similar color with the burned area because this area has a high radiation value of heat (Figure 8). Built up area consists of roof,
highways, parking lots and sidewalks. This condition dramatically altered the radiation, thermal convective, moisture, as well as emissions properties of the surface, leading to higher atmospheric and surface temperature in urban areas than in surrounding rural areas [15]. This condition will be captured by Thermal Infrared Sensor (TIRS) on Landsat 8. Therefore, this condition need to combine with landuse data to eliminate errors during interpretation.

**Figure 8.** Similar color of burnt area in built up area

### 3.3 Burn Area Extraction

Data extraction using supervised classification method needs to create some training samples area (Region of Interest) in imagery which furthermore all of samples will grouped based on the characteristic of pixel value by applying statistical calculations. Training samples area were taken from composite band image (band 10, band 7, and NBR). Figure 9 shows that total burnt area in Ogan Komering Ilir Regency is 397.087,43 Ha which the burnt area on peatlands is 50,65% area occurred in peatlands area.

| No | Sub District      | Burnt Peatlands | Non Peatlands | Burnt Total |
|----|-------------------|-----------------|---------------|-------------|
| 1  | AIR SURIHAN       | 73,901.5        | 31,136.2      | 105,037.7   |
| 2  | CENGAL            | 8,844.9         | 14,267.0      | 23,211.9    |
| 3  | JELAWI            | 12,998.6        | 12,998.6      |             |
| 4  | KOTA KAYU AGUNG   | 1,320.3         | 3,622.4       | 4,942.7     |
| 5  | LEMPUNIS          | 8,497.0         | 8,497.0       |             |
| 6  | LEMPUNIS JAYA     | 379.8           | 8,427.7       | 8,807.5     |
| 7  | MESUI             | 11,804.0        | 11,804.0      |             |
| 8  | MESUI MAKMUR      | 2,198.2         | 2,198.2       |             |
| 9  | MESUI RAYA        | 6,802.7         | 6,802.7       |             |
| Sub Total              | 84,446.5        | 39,207.7       | 123,754.2   |

| No | Sub District      | Burnt Peatlands | Non Peatlands | Burnt Total |
|----|-------------------|-----------------|---------------|-------------|
| 10 | PAMPANGAN         | 7,452.5         | 12,479.1      | 19,931.6    |
| 11 | PANGKALAN LAPAM   | 16,353.0        | 14,006.3      | 30,359.3    |
| 12 | PEDAMARAN         | 18,622.9        | 7,366.2       | 26,183.7    |
| 13 | PEDAMARAN TIMUR   | 12,350.4        | 7,419.3       | 19,769.8    |
| 14 | SIRAH PULAU PADANG| 2,213.0         | 3,392.2       | 5,605.1     |
| 15 | SUNGAI MENANG    | 2,788.5         | 14,346.3      | 17,134.8    |
| 16 | TANJUNG LUBUK    | 6,266.5         | 6,266.5       |             |
| 17 | TELUK GILAM       | 2,373.2         | 2,373.2       |             |
| 18 | TULUNG SELAPAN    | 68,285.8        | 28,077.5      | 96,363.3    |
| Grand Total            | 201,133.0       | 195,954.4      | 397,087.4    |
Figure 9. Burnt area pre/during, post fire & total fire in Ogan Komering Ilir Regency 2015

4. Conclusion

- Band combination of RGB (TIRS, SWIR, NBR) can be used to detect fire burnt area with the good visualization image. (easy to distinguish burnt & unburnt area)
- Landsat resolution is 30 x 30 m can detect the small area forest, plantation & peatland fires.
- In the areas are dominated urban (built up area), Band combination of RGB (TIRS, SWIR, NBR) sometimes the colour same with burnt area, need to combine with land use data.
- NBR composite can be used to detect burned area especially on oil palm plantations, because it suits for burned oil palm plantations (vegetation), but it will hard to be applied for burned open land/soil.

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