Detecting the Burned Area in Volcanic Region by Using Multitemporal Landsat-8 OLI  
(Case Study: Mt. Sumbing, Central Java)

I Prasasti¹, D Triyono² and Suwarsono¹,²

¹Remote Sensing Application Center – LAPAN, Indonesia  
²Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia  
E-mail: indah.prasasti@lapan.go.id¹

Abstract. Biomass burning is one of the natural agents that most change terrestrial ecosystems and has a key ecological role in a huge piece of the Earth's surface. Biomass burning has numerous socio-economic implications, particularly in developed countries where the developing urbanization of forested regions tends to increase accidents related with extraordinary fire occasions. Wildland fire mapping has been a subject vital for the international community over the recent two decades. Since fire is a major threat to forests and wooded areas in the tropical environment of Kalimantan, methodical regional fire observing is a need. Remote sensing methods are recognized as the efficient source of information for mapping burned areas from regional-national up to global scale. This study investigated the use of multitemporal Landsat-8 OLI (Operational Land Imager) data, to identify the burned area, in the tropical region of Indonesia, during 2019 fire season. A pair of Landsat-8 OLI, collected before and after fires, has been used to delineate the boundaries of sample location of burned area. Then, the difference of reflectance and Normalized Burn Ratio were analyzed. Fire incident causes landcover changes from vegetated land to bareland. This changes can affect the reflectance detected from Landsat-8 OLI. The result showed that biomass burning on volcanic region has caused high decreasing values on band 5 and there were high increasing on band 7. The NBR was better used to extracted burned area rather than NDVI or single spectral band. This method based on multitemporal optical data, creates a valuable tool for identifying and interpreting burned area following a fire event on volcanic region.

1. Introduction

Biomass burning is one of the natural agents that most change terrestrial ecosystems and has a key ecological role in a huge piece of the Earth's surface. Biomass burning has numerous socio-economic implications, particularly in developed countries where the developing urbanization of forested regions tends to increase accidents related with extraordinary fire occasions [1]. Wildland fire mapping has been a subject vital for the international community over the recent two decades [2].

Since fire is a major threat to forests and land areas in the tropical environment of Kalimantan, methodical regional fire observing is a need. Remote sensing methods are recognized as the efficient source of information for mapping burned areas from regional-national up to global scale. The utilization of remotely sensed data and the expanding accessibility of imageries, for example, the Landsat TM/ETM⁺ archives of the US Geological Survey (USGS) and of the European Space Agency (ESA) have encouraged scientists to develop more progressively computerized techniques ready to
decrease the cost/effort of the traditionally applied photo interpretation of moderate/high and very high resolution images [3]. Landsat data series, such as Landsat TM, ETM+, OLI, have been generally used to recognized and mapped of forest and land fires [1][3][4][5][6]. In Indonesia regions, forest and land fires mostly took place in lowland regions in Sumatera and Kalimantan. However, during the extreme dry season, along with El Nino, it is also possible that a large fire also occurred in the mountain or mountainous region of Java [7]. This research attempted to identify the burned area that happened in volcano region in Java Island using multitemporal Landsat-8 Optical Land Imager (OLI). This research is expected to develop a method of detecting burned areas in mountainous regions on Java Island based on time series fusion of optical Landsat-8, by taking the case of forest and land fires that occurred in 2019 on Mount Sumbing, Central Java (Figure 1).

![Research location (red rectangle) in Mt. Sumbing, Central Java.](https://www.google.co.id/maps)

**Figure 1.** Research location (red rectangle) in Mt. Sumbing, Central Java.

*Map source: https://www.google.co.id/maps*

### 2. Methods

#### 2.1. Data

The optical data used were a pair of Landsat-8, path / row 120/065. The date of data acquisition was 25 June 2019 and 13 September 2019. Landsat-8 data were obtained from the Remote Sensing Technology and Data Center of the Indonesian National Institute of Aeronautics and Space (LAPAN), through the http://landsat-catalog.lapan.go.id/. The level of Landsat-8 is L1T (terrain-corrected product). The level data is corrected radiometrically and geometrically[8].

#### 2.2. Data Pre-processing

Landsat-8 OLI data have been converted to the spectral radiance of Top of Atmosphere (TOA). The data were converted to TOA reflectance[8]. Instead, to convert Landsat images from TOA reflectance to surface reflectance, DOS1 (Dark Object Subtraction 1) was introduced[9].

#### 2.3. Delineation training samples of burned area, Normalized Difference Vegetation Index (NDVI), and Normalized Burn Ratio (NBR)

Training samples of burned area were delineated from Landsat-8 composite spectral RGB 654. The NBR and NDVI images were processed from Landsat-8 spectral band NIR dan SWIR[11], both pre-fire (25 June 2019) and post-fire (13 September 2019) images. Then the difference NDVI (dNDVI=NDVI\textsubscript{post-fire} – NDVI\textsubscript{pre-fire}) and NBR (dNBR=NBR\textsubscript{post-fire} – NBR\textsubscript{pre-fire}) were calculated. The mean and standard deviation of each single spectral band, NDVI and NBR in training samples of burned area were calculated among pre-fire and pot-fire image, also the dNDVI and dNBR image.
Furthermore, the separability ($D_{value}$)\cite{12} were measured to know the selected variable that can be used to extracted burned area appropriately.

2.4. **Burned area extraction**

Burned area pixels were extracted using the selected variable, both using Landsat-8 and Sentinel-1 imageries by using threshold of mean + 2*Standard Deviation for Landsat-8 and mean + 1*Standard Deviation for Sentinel-1.

3. **Results**

3.1. **The Reflectance, NDVI and NBR values of burned area pixels (pre-fire, post-fire and its changes)**

Table 1 showed the Reflectance, NDVI and NBR values of burned area pixels (pre-fire, post-fire and its changes).

From the spectral response, it can be seen that generally the biomass burning has caused high decreasing values on band 5 (-0.1285) and there were high increasing on band 7 (0.0314). The NBR experienced the highest decreasing values (-0.6715) (Table 1). Also, the NBR had the highest separability rather than others ($D_{value}$=3.606) (Table 2). Based on separability analysis of these data, it can be seen that the NBR is the most appropriate parameter for the extraction of burned areas.

| Table 1. Reflectance, NDVI and NBR values of burned area pixels |
|---|
| Pre-fire |
| Feature | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NDVI | NBR |
| Mean | 0.0170 | 0.0218 | 0.0396 | 0.0461 | 0.1925 | 0.1477 | 0.0864 | 0.6072 | 0.3732 |
| Std.Dev | 0.0025 | 0.0034 | 0.0070 | 0.0081 | 0.0426 | 0.0306 | 0.0172 | 0.0564 | 0.0942 |
| Post-fire |
| Feature | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NDVI | NBR |
| Mean | 0.0152 | 0.0175 | 0.0198 | 0.0331 | 0.0640 | 0.1106 | 0.1178 | 0.3143 | -0.2983 |
| Std.Dev | 0.0038 | 0.0040 | 0.0049 | 0.0067 | 0.0159 | 0.0234 | 0.0222 | 0.0495 | 0.0920 |
| Difference |
| Feature | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NDVI | NBR |
| Mean | -0.0019 | -0.0043 | -0.0198 | -0.0131 | -0.1285 | -0.0371 | 0.0314 | -0.2929 | -0.6715 |
| Std.Dev | 0.0035 | 0.0043 | 0.0081 | 0.0100 | 0.0500 | 0.0293 | 0.0149 | 0.0945 | 0.1686 |

| Table 2. Separability ($D_{value}$) analysis |
|---|
| Feature | 1 | 2 | 3 | 4 | 5 | 6 | 7 | NDVI | NBR |
| D | 0.290 | 0.585 | 1.653 | 0.884 | 2.196 | 0.687 | 0.796 | 2.767 | 3.606 |

3.2. **Burned area extracted from Landsat-8**

Figure 2 showed the Landsat-8, composite spectral band RGB 654 pre-fire and post-fire. From Landsat-8 composite spectral band RGB 654 post-fire date (13 September 2019), it is often founded burned area. The burned area look dark reddish or magenta color. On the same location in the previous image (pre-fire image), the locations were dominated by vegetated land (looks greenish). Figure 3 showed the extracted NBR$_{pre}$ and NBR$_{post}$, where as Figure 4 showed dNBR images and the extracted burned area.
Figure 2. Landsat-8, composite spectral band RGB 654 pre-fire (a) and post-fire (b), around the peak of Mt. Sumbing

Figure 3. NBRpre (a) and NBRpost (b)

Figure 4. dNBR (a) and the extracted burned area (b)
4. Conclusion

Biomass burning on volcanic region has caused high decreasing values on band 5 and there were high increasing on band 7. The NBR was better used to extracted burned area rather than NDVI or single spectral band. The NBR experienced the highest decreasing values, also the NBR had the highest separability rather than others. Based on separability analysis of these data, it can be seen that the NBR is the most appropriate parameter for the extraction of burned areas. The method based on multitemporal optical data, creates a valuable tool for identifying and interpreting burned area following a fire event on volcanic region.

5. References

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