BURNED AREA IDENTIFICATION USING LANDSAT 8

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Abstract. Forest and land fire is a catastrophic event that always happens every year in Indonesia. In 2015, forest and land fires occured in many islands of Indonesia especially in Sumatera, Kalimantan, Sulawesi and Papua island. Therefore, it is necessary to monitor forest fires using satellite data to obtain the latest information of burned area in a large scale area. This research aims to develop a method for burned area mapping that happened between two Landsat 8 data recording on August 13rd and September 14th 2015. The information of hotspot distribution during the period August - September 2015 was used to help visual identification of burned area on the Landsat image and to verify the burned area resulted using the method. Samples were taken at several land covers to determine the spectral pattern differences among burned area, bare area and other land covers, and then perform the analysis to determine the suitable spectral bands or indexs and threshold values that will be used in the model. Landsat recorded on August 13rd 2016 was extracted for an bare area, while Landsat recorded on September 14th was extracted for burned area. Multi-temporal analysis was done to get the burned area occurring during the period August 13rd to September 14th 2015. The results showed that the clouds could be separated by using a combination of ocean blue and cirrus band, the burned area by using a combination of NIR and SWIR band, while bare area by using ratio SWIR / NIR. Burned area Obtained in this study had a high correlation with the hotspot density and visual appearance of burned area in the Landsat images.

Keywords: Burned area, Landsat 8, bare area, hotspot distribution

1. Introduction

Forest and land fires is one of the disasters in Indonesia that occur repeatedly each year with the large-scale damage. The impacts caused by fires are the benefit loss of forest potential, (such as: loss of forest standing trees) that can be used by humans to meet the various needs of life, and the smoke pollution produced by the fires which affect human`s health and daily activities (Rashid, 2014). Forest and land fires occurred in many parts of the Indonesian archipelago in 2015, mainly in Sumatera, Kalimantan, Sulawesi and Papua islands. National Disaster Management Agency (BNPB) said that based on information from MODIS Terra data until October 20th 2015, the total area of burned area of forest and land reached more than 2 million hectares, equivalent to four times the Bali island. Although the area of forest and land fires in this year had not exceeded the area of forest and land fires in 1997, but the forest and land fires in this year was more severe compare to previous years. BNPB noted that the fires on peat land was most happened in Kalimantan, and followed by Sumatra and Papua, nevertheless 75% of forest fires occurred in non-peatland forest (http://www.cnnindonesia.com/).

Forest and land fire monitoring and burned area mapping are very important system to provide information about current fire conditions and extensive damage caused by the fire. This information will be used by the related institutions to take proper precautions (Early warning) and quick estimation about the damage condition in the disaster area. One technology that can be used to support forest and land fire prevention activities is remote sensing satellite technology. This technology possess several advantages such as broad scope area and high revisiting time, so that information about forest and land fires can be quickly updated from time to time.

Utilization of remote sensing data has been done to monitor hotspot (as indication of the forest fire occurence) by utilizing the band thermal from NOAA AVHRR and MODIS Terra/Aqua (Pacheco, 2014; Handayani, 2014). The hotspot monitoring method based on low resolution satellite data has been widely used for operational system to identify and monitor the number and distribution of forest and land fires in various regions, including Indonesia area. Utilization of remote sensing technology for the mapping of burned area has also been carried out intensively using optical satellite data and synthetic Aparture Radar (SAR). Nakayama (2011) compared the SAR data capabilities of ERS-1/2 data and JERS-1 data to map burned areas and verify the results with the optical satellite of Landsat data, while Chavez et al. (2002) was more focused on using the C band data of ERS and gained the result that the data was very potential for global scale mapping of burned area. The next generation of ERS-2 was also used by Ruecker and Siegert (2000) for mapping burned area in East Kalimantan Indonesia with accurate estimation of burned area reached 90%. Another research was also done by Polychronaki et al. (2013) using ALOS PALSAR data for mapping burned area with an accuracy up to 82%. Based on the previous researches, SAR data is very potential to be used on burned area mapping, but the continuity of SAR data is still a big problem for long term operational use.

The burned area mapping was also carried out using optical satellite in various spatial resolution, such as using low spatial resolution NOAA AVHRR data and MODIS Terra data with 1 km spatial resolution (Bastarrika et al., 2011; Suwarsono et al., 2009; Suwarsono et al., 2012), and using medium spatial resolution Landsat TM / ETM + with 30 m spatial resolution (Bastarikka et al., 2011) and IRS AwiFS with 50 m spatial resolution (Sedano et al., 2012). Several research studies regarding the method of burned area mapping using low spatial resolution MODIS Terra data had been conducted in Indonesian National Institute of Aeronautics and Space. Suwarsono et al. (2009) was using the spesific change of Normalized diference Vegetation Index (NDVI) to identify the burned area. The method was improved by using another index (Normalized Burn Ratio or called NBR), and determine the spesific change of NBR index before and after the fire to map the burned area with an accuracy of about 63% (Suwarsono et. al, 2013). The research is still conduting now to improve the accuracy of the mapping. LAPAN used the burned area mapping based on NBR method to estimate the burned area occured from July 1st to October 20th 2015 for whole Indonesia area and got the result that the estimated burned area based on MODIS Terra data reached 2 million hectare.

Information of burned area from MODIS Terra data produced by LAPAN needs verification and validation to know accuracy level of the information. One method to verify such information is by comparing the information of burned area extracted from MODIS Terra data with the same information extracted from higher spatial resolution satellite data. The higher spatial resolution of satellite data can give the appearance of burned area more detail and accurate. The aim of this research is to develop the method for identifying and mapping burned area by using Landsat 8 data. Landsat 8 is the latest satellite of the Landsat satellite program with 15-30 meters spatial resolution and it can record wide area satellite image, so it is very suitable to be used to identify and map burned area in national scale, and also can be use as reference data to verify the burned area information produced from MODIS Terra.

2. Material and Methods

The study area is located in South Sumatra Province in Sumatra Island. South Sumatera is one of the provinces that suffered extensive forest and land fires in 2015. The satellite data in this research was Landsat 8 data with 30 meter spatial resolution (Figure 1). To identify and map burned area between two Landsat 8 data recording on August 13rd and September 14th 2015, it wasused multi-temporal Landsat 8 before the forest and land fire event (July 28th and August 13th 2015) and after the event (September 14th2015). Other data used was hotspot distribution data during the period August 1st to September 13rd2015 extracted from MODIS Terra data. The hotspot distribution data was used to help visual identification of the burned area in the image, and the datawould also be used to verify the burned area produced from Landsat 8 data.

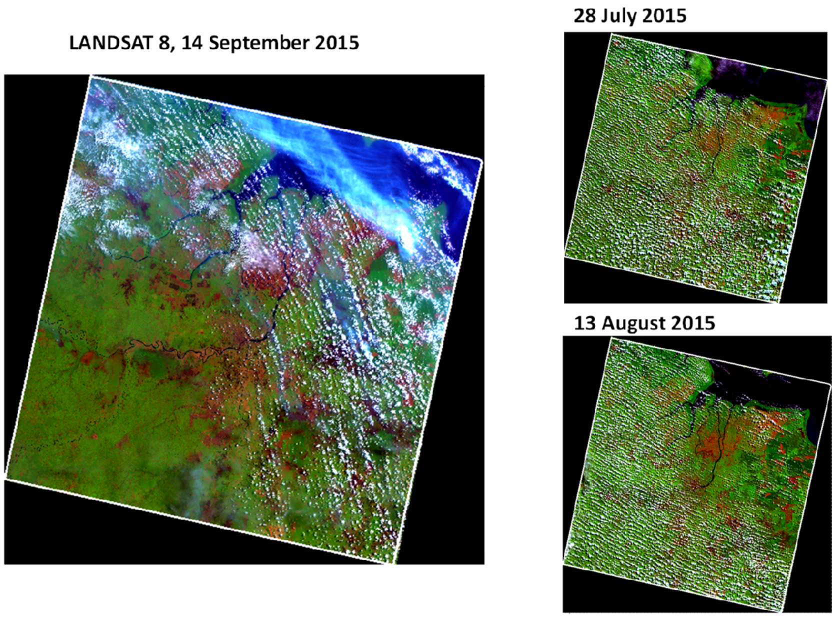


Figure 1. Landsat 8 data in the study area

Flowchart of this research is shown in Figure 2.Data correction was conducted in the pre-processing stage. Data corrections were consist of sun correction and atmospheric correction. In the sun correction, the values of the digital number of image pixel were converted into the reflectance value by considering conversion constanta and elevation angle that provided in metadata. The result of the sun correction is top of atmosphere reflectance (TOA Reflectance). The dark pixel subtraction method was used to do the atmospheric correctionto obtain surface reflectance. After finishing the data correction, the location and appearance of burned areas on the image was identify visualy by overlying the hotspot distribution data with the Landsat 8 image, so the appearance of burned area can be known accurately.

Sampling was done in the burned area, bare area, vegetation, water body and cloud. Based on the collected samples, spectral pattern of each object was made, compared and analysed to getsome band combinations or index that could be used to distinguish the pixel of spesific object with pixel of other object, and also to determine the threshold valuesof band combinations or index to separate the pixels into each class. The band combination or index and threshold values obtained from the previous step was applied into the Landsat data before the fire to classify image pixels into three classes, those are soil (consisting of bare area and burned area), non soil (vegetation, water so on) and cloud/haze. The band combination or index and threshold values wasalso applied into the Landsat data after the fireto classify image pixels into three classes, those are burned area, unburned area and cloud/haze.

Furthermore, the multi-temporal analysis was conducted to process the classification result (before and after the fires) using the rules as in Table 1.Based on the multi-temporal analysis, the final burned area aredivided into 4 classes, those are burned area, probably burned, unburned area, and no information. Verification of the burned area result were done two methods: 1) by overlay hotspot distribution on the burned area result, and 2) doing the visual comparison with RGB 653 compositeLandsat 8 image.

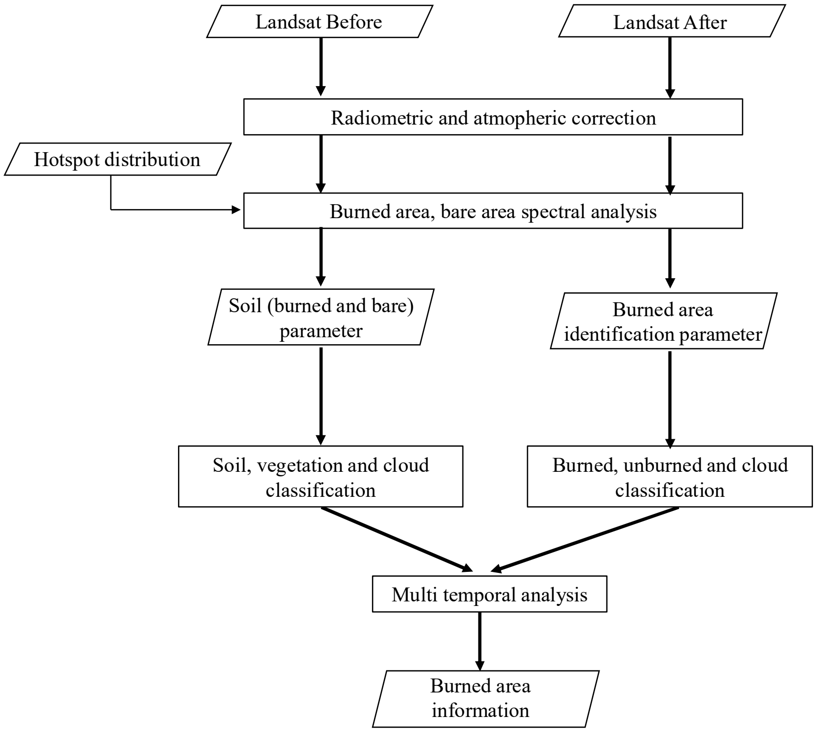


Figure 2. Flowchart of this research

Table 1. The rules of multi-temporal analysis

Landsat Before	Landsat After	Result
Vegetation	Burned area	Burned area
Cloud	Burned area	Probably burned area
Non Soil	Cloud	No information
Cloud	Cloud	No information
Soil	Burn area	Unburned area
Soil	Unburned area	
Soil	Cloud	
Non Soil	Unburned area	
Cloud	Unburned area	

3. Result And Discussion

Figure 3 shows the overlay between RGB 653compositeof Landsat 8 imagerecorded on September 14th 2015 with the distribution of hotspots (black dot) extracted from MODIS Terra data during the period August 1stto September 13rd 2015. Hotspot was extracted using the thermal band of Landsat satellite, and provides information thattemperature ona pixel is higher than temperature on its surrounding pixels. Hotspot can be used to predict the occurance of forest and land fires in spesificarea. In Figure 3, almost all hotspots gathered in areas with dark brown color on Landsat image, which indicates that the areas were burned areas. Based on this observation result, the burned area was indentified and characterized as dark brown color on theRGB 653composite of Landsat 8 image, irregular shape area, and sighting of smoke when they are still burning.

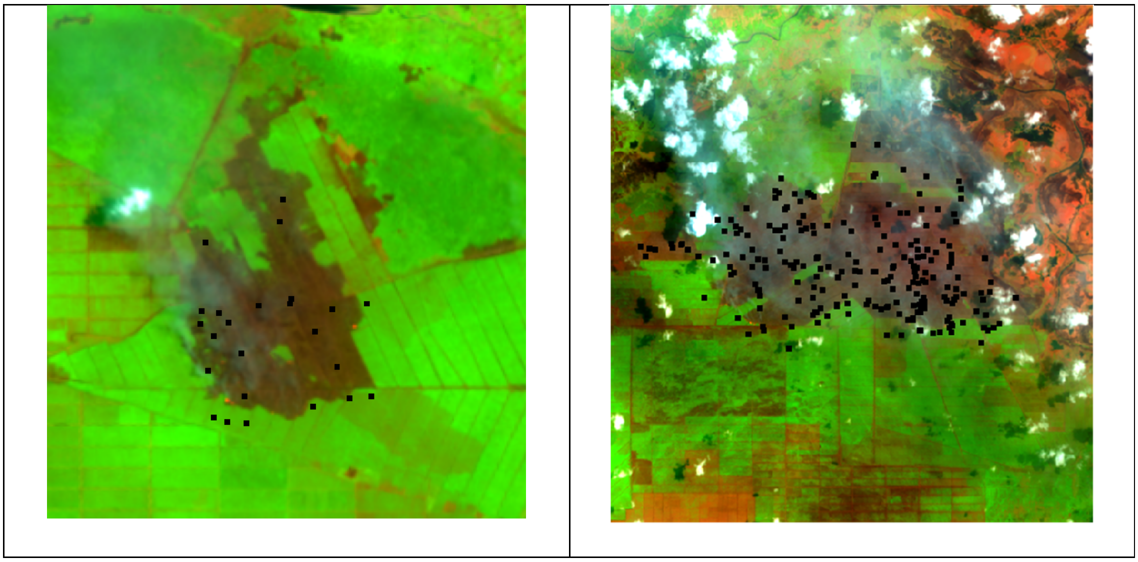


Figure 3. Overlay between RGB 653compositeof Landsat 8 imagerecorded on September 14th 2015 with the distribution of hotspots (black dot) extracted from MODIS Terra data

After the knowing the characteristic of burned area and also the characteristic of other land cover objects, then the samples were collected for some land cover objects in the image: cloud, vegetation, bare area, burned area and water body. All spectral patterns of land cover object were plotted, and then compared to determine combination bands or index that can be used to distinguish burned area from other land cover objects. Figure 4 shows a comparison of the spectral patterns of land cover objects (cloud, vegetation, bare area, burned area and water body). Spectral value of cloud is very high comparing to another land cover objects, so cloud can be separated easily using ocean blue band and cirrus band (band 1 and band 9) of Landsat. NIR band (band 5) can be used to separate the burned area with bare areaand vegetation, but it is still difficult to separate between burned area and water body. The separation between burned area and water bodies can be performed using the SWIR band (band 6). Based on the result, the combination of ocean blue band and cirrus band was used to classify cloud, then NIR and SWIR band was used to classify burned area and unburned area (other land cover objects). The classification was done in two stages, as follow:

If ocean blue band > A and cirrus band > B Then cloud pixel (Stage 1)

If NIR band < C and SWIR band> D and SWIR band< E then burned area pixel (Stage 2)

Other pixels are unburned area pixel

Where, A is athreshold value of cloud in the ocean blue band, B is a threshold value of cloud in cirrus band, and C, D, E are threshold values of burned areas in NIR band and SWIR band respectively.

The algorithm was applied into Landsat data after forest and land fires event (recording date September 14th 2015) to classify the data into three classes, those are burned area, unburned area and cloud.

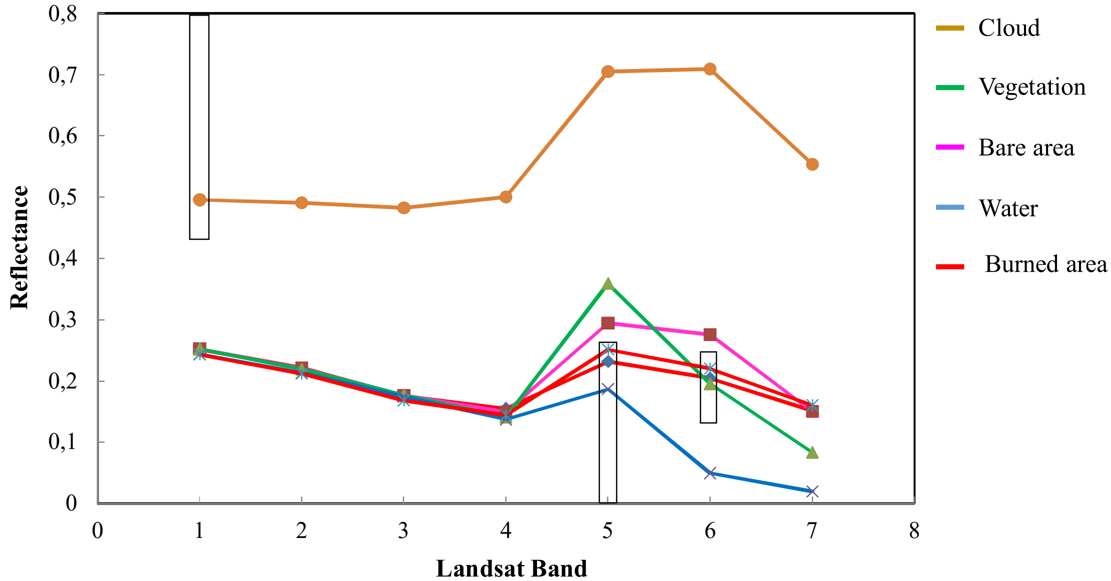


Figure 4. Comparison of the spectral patterns of land cover objects: cloud, vegetation, bare area, burned area and water

Figure 5 shows a comparison of spectral valuesof land cover object using several indices that are commonly used, those are Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI) and SWIR/NIR band ratio. The SWIR/NIR was used based on the results in Figure 3, that the separation of land cover objects can be done using NIR and SWIR band. The results in Figure 5 showed that NDVI index is difficult to distinguish between the soil (bare area and burned area), water body and cloud. Separation of soil from other land cover objects can be performed using NBR index and SWIR/NIR, although spectral value of cloud is still gathering with spectral value of soil. This is not a big problem because ocean blue and cirrus band can be used to separate cloud and soil accurately. It is also found thatSWIR/NIR has bigger gap difference of spectral value between soil and vegetationcomparing to gap difference of NBR index, so the combination of ocean blueband, cirrus band and the SWIR/NIR ratio can be used to separate the soil, clouds and non soil (other land cover objects). Based on this result, the combination of ocean blue band and cirrus bandwas used to clasify cloud, and SWIR/NIR ratio was used to clasify soil and non (other land cover objects). The classification was done in two stages, as follow:

If ocean blue band > A and cirrus band > B then Cloud pixel (Stage 1)

If SWIR/ NIR > F Then Soil pixel (Stage 2)

Other pixels are non soil pixel

Where, A is athreshold value of cloud in the ocean blue band, B is a threshold value of cloud in cirrus band, and F is threshold values of soil in SWIR/NIR.

The algorithm was applied into Landsat data beforeforest and land fires event (July 28th and August 13th 2015) to classify the data into three classes, those are soil, non soil and cloud. Due to high cloud cover on Landsat 8 before the forest and land fire, then the two data recording date (August 13, 2016 and July 28 2015) were used for classification, then the classification results are combined into one classification result.

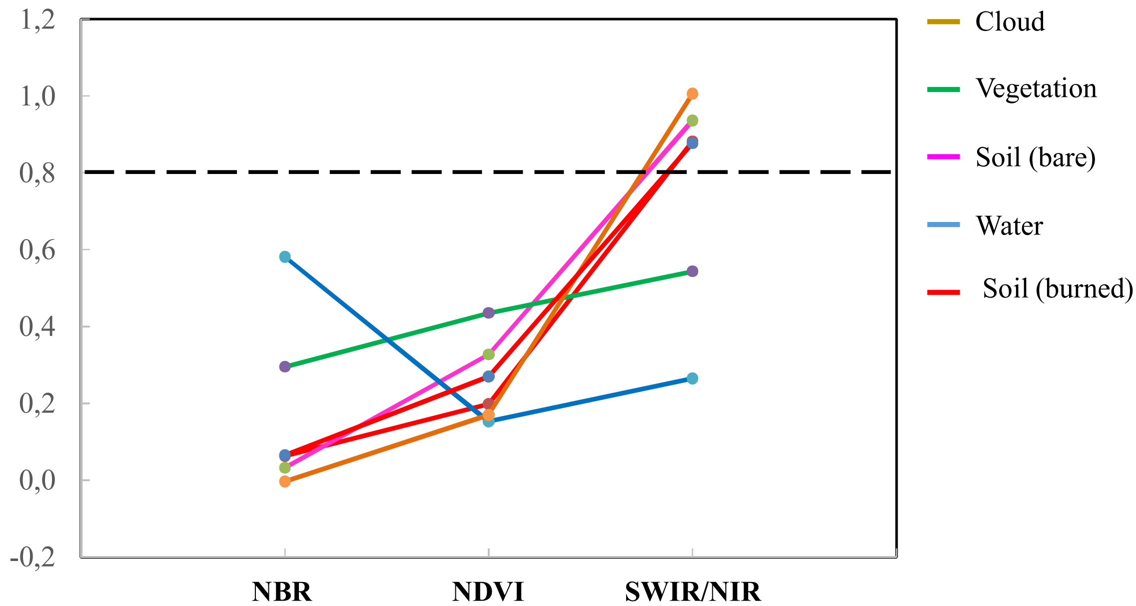
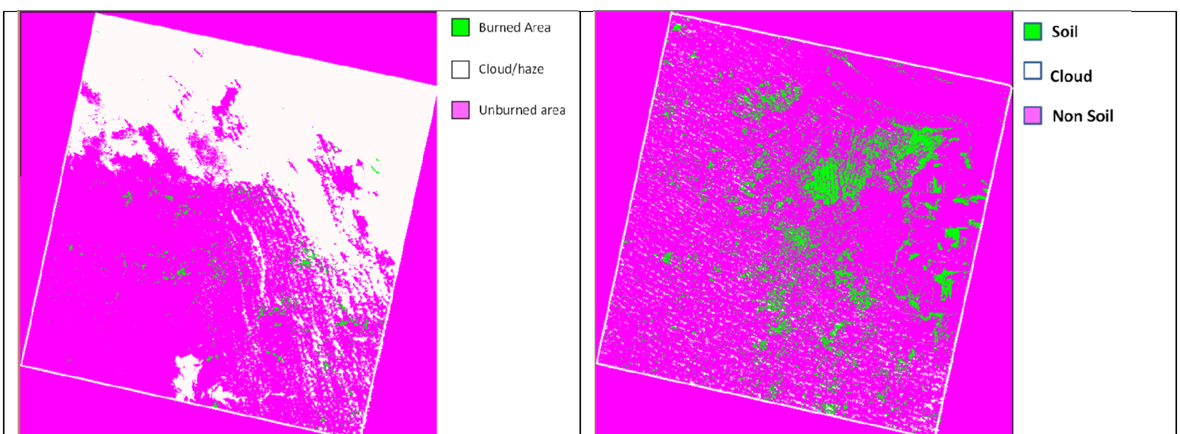


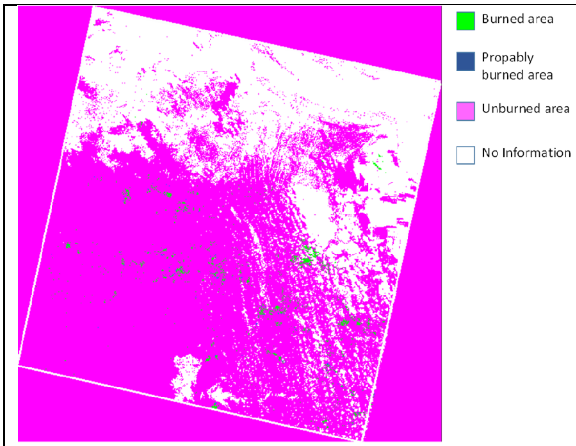
Figure 5. Comparison of spectral valuesof land cover object using NBR, NDVI and SWIR/NIR index

The classification result of the area burned, unburned area and the cloud of Landsat data after the forest and land fire event (September 14th 2015) is shown in Figure 6a, where the burned area is shown in green color, the unburned area with pink color and the cloud with white color. The classification result of soil, non soil and cloud before the forest and land fire event (August 13th and July 28th 2015) is shown in Figure 6b where the soil is shown in green color, non soil with pink color and the cloud with white color. The analysis process was then performed using multi-temporal analysis rules refering to Table 1. Multi-temporal analysis producedspatial information of burned area distribution in the study area that consists of four classes, those are:Burned area (green color), probably burned area (blue color), unburned area (pink color) and no information (white color) as shown in Figure 6c. Burned area and probably burned areas classes are more clearly shown in Figure 6d.

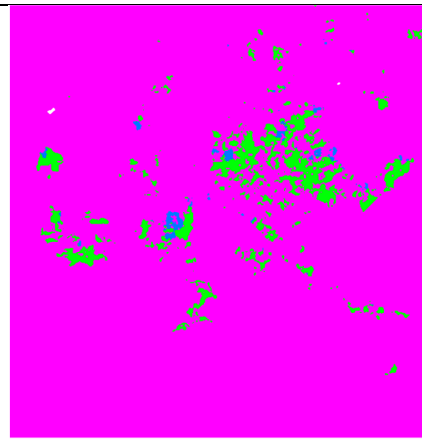


(a) Classification result of of Landsat data after the forest and land fire event (September 14th 2015)

(b) Classification result of of Landsat data before the forest and land fire event (August 13th and July 28th 2015)



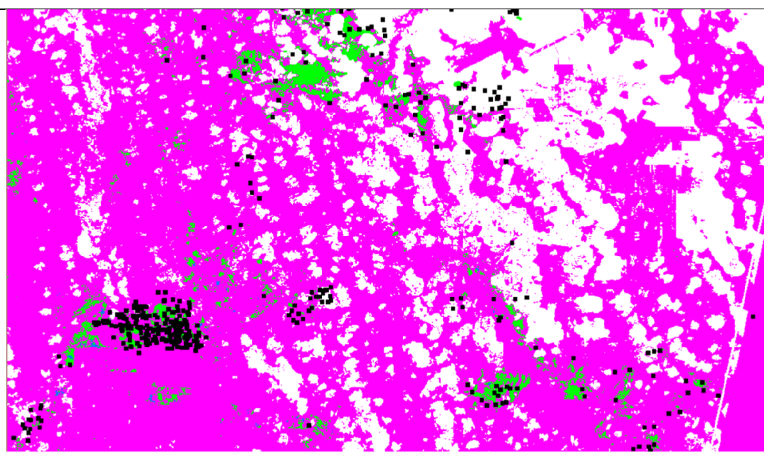
(c) Multi-temporal analysis of burned area



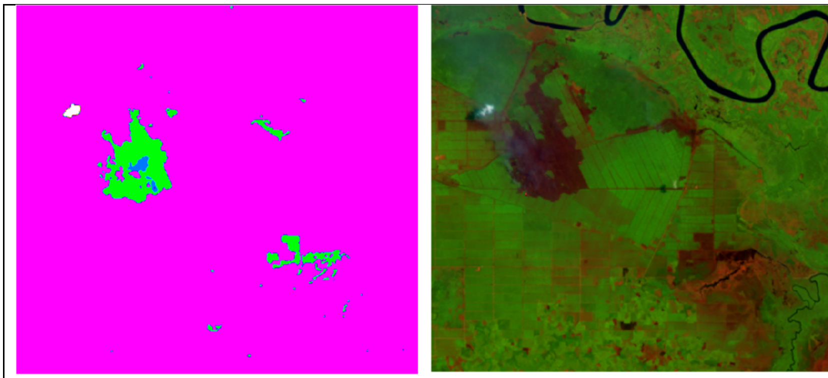
(d) Zooming of burned area and probably burned areas classes

Figure 6. Classification result before and after fire event and multi-temporal analysis result

Verification of the burned area mapping was done by comparing the final result of burned area with hotspots distribution during the period August 1st to September 13rd 2015 (Figure 7a) and by doing the visual comparisonbetween the final result of burned area with the RGB 653 composite Landsat image for the burned area appearance (Figure 7b). The verification results show that the hotspot points were concentrated in the areas that are classified as burned area, especially on medium and large area of the burned area. While few small area of burned area on Landsat data were not contained hotspot points, it was considered because:1) The hotspot point extracted from MODIS Terra has limitations in spatial resolution (1 km spatial resolution, it means that the area of 1 pixel of MODIS Terra is similar with the area of 9 pixel of Landsat 8), and 2) The high cloud cover or smoke fires above the study area caused hotspot point on the area can not be extracted from MODIS Terra data. The verification results are visually shown that the final result of burned areas are very similar to the visually identified burned area shape in the RGB 653 composite Landsat image. These results show that the developed burned area method in this research has quite excellent accuracy for identifying and mapping burned area using Landsat 8.



(a) Comparing the final result of burned area with hotspots distribution



(b) visual comparison between the final result of burned area with the RGB 653 composite Landsat image for the burned area appearance

Figure 7. Verification of the burned area mapping

4. Conclusions

Burned area mapping method was developed to identify and map burned area occured between two Landsat 8 data recorded in different dates. Spectral pattern analysis and multi-temporal analysis were conducted to classify the burned area. The results was verified using hotspot distribution and visual comparison. Some points are concluded as bellow:

1. Based on the spectral analysis result of land cover objects, cloud can be separated using band combination of ocean blue and cirrus band, burned area using combination of NIR and SWIR band, while bare area using SWIR/NIR band ratio.
2. The multi-temporal analysis generates spatial information of burned area distribution that consisting of four classes: burned area, probably burned area, unburned area and no information
3. The final burned area has high correlation with the hotspot distribution and visual appearance of burned area on the Landsat image, so it has quite excellent accuracy for identifying and mapping burned area using Landsat 8.

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