TECHNIQUE FOR IDENTIFYING BURNED VEGETATION AREA USING LANDSAT 8 DATA

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Abstract. During the last two decades, forest and land fire is a catastrophic event that happens almost every year in Indonesia. Therefore, it is necessary to develop a technic to monitor forest fires using satellite data to obtain the latest information of burned area in a large scale area. The objective of this research is to develop a method for burned area mapping that happened between two Landsat 8 data recording on August 13rd and September 14th 2015. Burned area was defined as a burned area of vegetation. The 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 from this research. Samples were taken at several land covers to determine the spectral pattern differences among burned area, bare area and other land covers, and then the analysis was performed to determine the suitable spectral bands or indices and threshold values that will be used in the model. Landsat recorded on August 13rd before the fire was extracted for soil, while Landsat recorded on September 14th after the fire was extracted for burned area. Multi-temporal analysis was done to get the burned area occurring during the certain period. The results showed that the clouds could be separated using combination of ocean blue and cirrus bands, the burned area was extracted using a combination of NIR and SWIR band, while soil was extracted using ratio SWIR / NIR. Burned area obtained in this study had high correlation with the hotspot density of MODIS with the accuracy was around 82,4 %.

Keywords: *burned area, Landsat 8, bare area, hotspot distribution*

1 INTRODUCTION

Forest and land fires are disasters in Indonesia that occur repeatedly each year with large-scale damage. The impacts caused by fires could be the loss of forest potential, such as: loss of forest standing trees, that can be used to meet various needs of human life, and the smoke or haze pollution from the fires could also affects human 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 Agency for Disaster Management (BNPB) representative said that based on information from MODIS Terra data until October 20th, 2015, the total of the 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 2015 were more severe compared to previous years. BNPB noted that peat fires happened most frequently in Kalimantan, and followed by Sumatra and Papua. Fortunately 75% of forest fires in Indonesia occurred in non-peatland forest (http://www.cnnindonesia.com/).

Forest and land fire monitoring and burned area mapping are very important to provide information system about current fire conditions and extensive damage caused by the fire. This information will be used by the stakeholders to take proper precautions (early warning), quick response, and rapid estimation about the damage 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 has 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 or even near real time.

Utilization of remote sensing data has been done to monitor hotspot, as an indication of the forest fire occurrence, by utilizing the thermal bands of 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 burned area mapping has also been carried out intensively using optical satellite data and synthetic Aperture Radar (SAR). Nakayama (2011) compared SAR data capabilities of ERS-1/2 data and JERS-1 data to map burned areas and verified the results with the optical satellite of Landsat data. Chavez et al. (2002) was more focused on using the C band data of ERS and obtained the result that the data was very potential for global scale mapping of burned area. The ERS-2 was also used by Ruecker and Siegert (2000) for burned area mapping in East Kalimantan, Indonesia with an accurate estimation of 90%. Another research was also done by Polychronaki et al. (2013) using ALOS PALSAR data for burned area mapping with an accuracy up to 82%. Based on the previous studies, SAR data are 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 data in various spatial resolution, such as using a 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 a low spatial resolution MODIS Terra data had been conducted in the Indonesian National Institute of Aeronautics and Space. Suwarsono et al. (2009) used specific change of Normalized difference 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 specific change of the NBR index before and after the fire to map burned area with an accuracy of about 63% (Suwarsono et. al, 2013). The research is still being conducted now to improve the mapping accuracy. LAPAN used the burned area mapping based on NBR methods to estimate the burned area occurred from July 1st to October 20th, 2015 over the whole Indonesia area and got the result that the burned area estimated by MODIS Terra data reached 2 million hectares.

Information of burned area from MODIS Terra data produced by LAPAN needs verification and validation to know the 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 high spatial resolution of satellite data can give the appearance of burned area more detail and accurate. Landsat 8 is the latest satellite of the Landsat satellite program with the medium spatial resolution and it can record wide area of earth surface. So Landsat 8 is very suitable to be used to identify and map burned area at national scale, and also can be used as reference data to verify the burned area information produced from MODIS Terra data. The objective of this research is to develop the method for identifying and mapping the burned area by using Landsat 8 data.

2 MATERIALS AND METHODOLOGY

The study area is located in South Sumatra Province, which experienced extensive forest and land fires in 2015. The satellite data in this research were Landsat 8 data with 30 meter spatial resolution (Figure 2-1). To identify and map burned area between two Landsat 8 data recording, we used multi-temporal Landsat 8 before the forest and land fire event (July 28th and August 13th 2015) and after the fire event (September 14th 2015). Landsat 8 data has 15 m spatial resolution for panchromatic band, and 30 m for multi spectral bands. This research also used hotspot distribution during the period of August 1st to September 13rd 2015 extracted from MODIS Terra data with 1 km spatial resolution. Hotspots were extracted using the thermal bands of MODIS Terra data. The hotspot provides information that temperature on a pixel is higher than the temperature on its surrounding pixels. Historical hotspot data can be used to predict the occurrence of forest and land fires in specific area. The hotspot distribution data were used to do visual identification of the burned area in the image, and also to be used to verify the burned area produced from Landsat 8 data.

Data correction was conducted in the pre-processing stage as shown in Figure 2-2. Data corrections consisted of sun correction and atmospheric correction. In the sun correction, the values of the digital number of image pixels were converted into the reflectance value by considering conversion parameters 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 correction to obtain surface reflectance. After finishing data correction, the location and appearance of burned areas on the image was identified visually by overlaying the hotspot distribution data with Landsat 8 image, so the burned areas can be identified accurately.

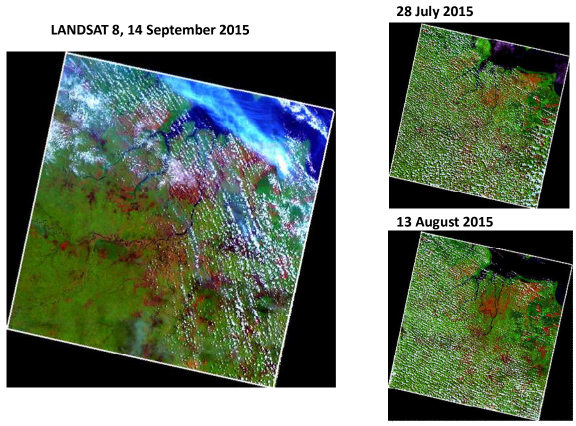


Figure 2-1: Landsat 8 Data in The Study Area

Pixel 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 analyzed to obtain several band combinations or indices that could be used to distinguish the pixels of specific objects from pixels of other objects, and also to determine the threshold values of band combinations or indices to separate the pixels into classes. The band combination or indices and threshold values obtained from previous steps were then applied to Landsat data of the date before the fire, to classify image pixels into three classes. The classes are soil (consisting of bare area and burned area), non soil (vegetation, water so on), and cloud/haze. The band combination or indices and threshold values were also applied to Landsat data of the date after the fire, to classify image pixels into three classes. The classes are burned area, unburned area, and cloud/haze. Therefore, in this study burned area was definitely the burned area of vegetation happened during the certain period (between two Landsat 8 data recording dates).

Furthermore, multi-temporal analysis was conducted to process the classification result, including before and after the fires, using the rules as in Table 2-1. Based on multi-temporal analysis, final burned area classification is divided into 4 classes. Those are burned area, probably burned, unburned area, and no information. Verification of burned area was done using three methods: 1) overlaying hotspot distribution with the burned area result, 2) visual comparison with RGB 653 composite Landsat 8 image, and 3) calculation of relative accuracy of burned area against the hotspot from MODIS Terra data with confidence level more than 90%.

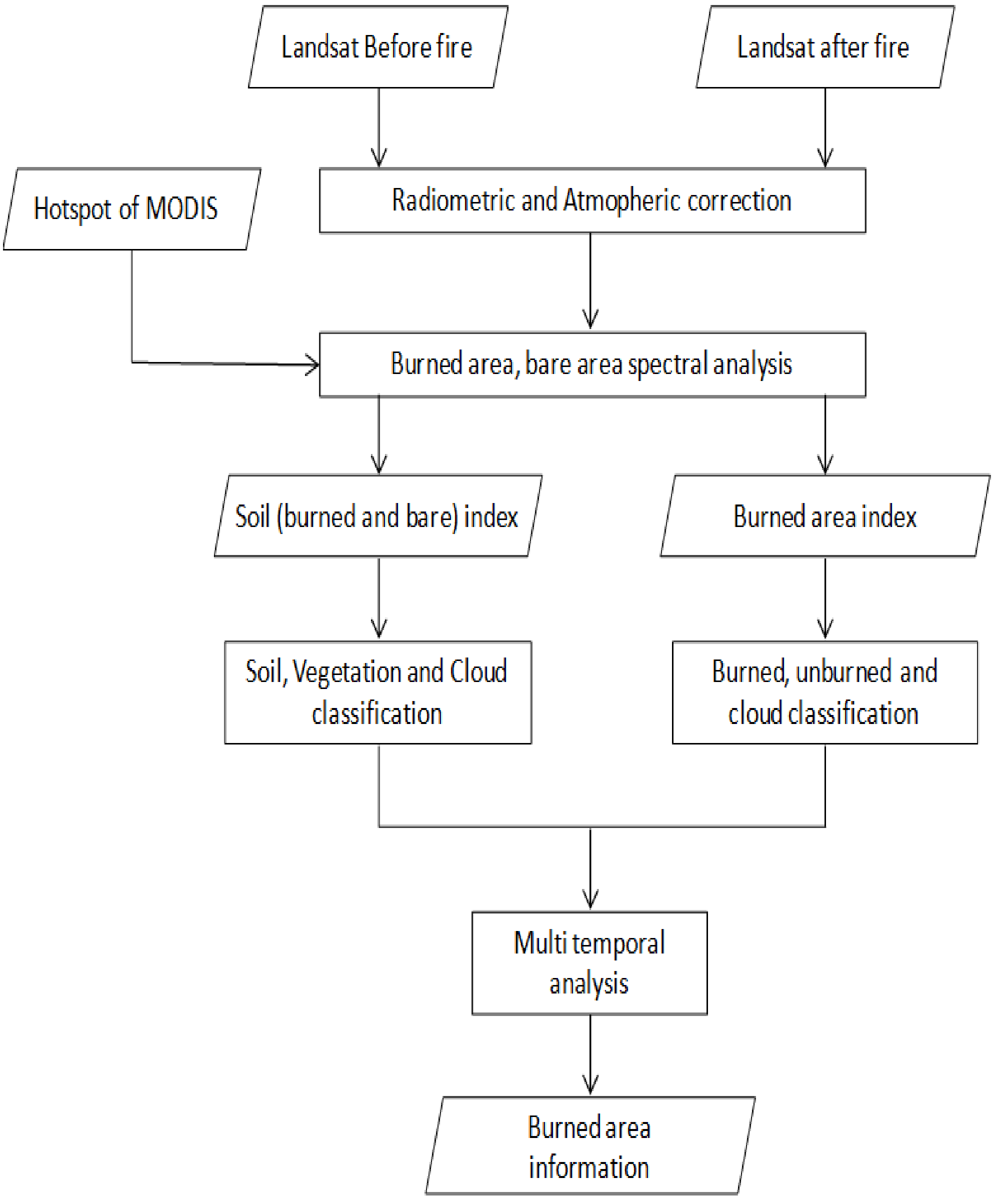


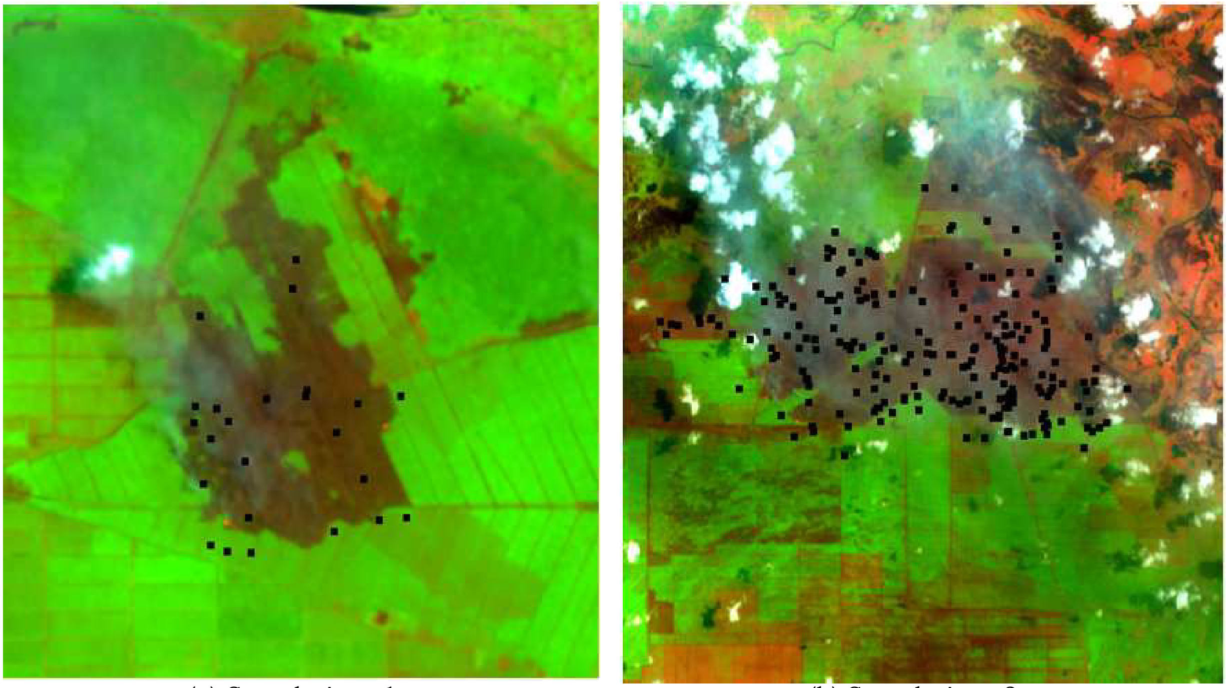
Figure 2-2: Flowchart of Research Method

Table 2-1: The Rules of Multi-Temporal Analysis of Burned Area

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

3 RESULTS AND DISCUSSION

The characteristic of burned areas in Landsat image was identified by overlaying hotspot of MODIS on RGB 653 composite of Landsat after the fire occurence, and then doing the visual observation in some sample locations. Figure 3-1 shows two examples of the suspected burned area of Landsat 8 imagery with hotspot distribution from MODIS (black dots) in (a) sample area 1 and (b) sample area 2. In both samples, 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 identified and characterized as dark brown color of the RGB 653 composite of Landsat 8 imagery, irregular shape area, and sighting of smoke when they are still burning.



(a) Sample Area 1 (b) Sample Area 2

Figure 3-1: Suspected Burned Area of Landsat 8 Imagery with Hotspot of MODIS (Black dots) in (a) Sample Area 1 and (b) Sample Area 2

After knowing the characteristic of burned areas and characteristics of other land cover objects, then the pixel samples were collected for several 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 indices that can be used to distinguish burned area from other land cover objects. Figure 3-2 shows a comparison of spectral values of land cover object (cloud, vegetation, bare area, burned area and water body) using several indices which are commonly used. Those are Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), and SWIR/NIR band ratio. SWIR (band 6) and NIR (band 5) was used as those bands are sensitive for detecting soil and vegetation objects. The results in Figure 3-2 shows that NDVI index is difficult to distinguish soil (bare area and burned area) from water body and cloud. Separation of soil from other land cover objects can be performed using NBR index and SWIR/NIR band ratio, although the spectral values of clouds are still mixed with the spectral values of soil areas. We solved this problem easily since ocean blue (band 1) and cirrus (band 9) can be used to separate cloud and soil accurately. It was also found that SWIR/NIR band ratio has bigger gap difference of spectral value between soil and vegetation compared with the gap difference of NBR index. Therefore the combination of the ocean blue band, cirrus band and the SWIR/NIR band ratio can be used to separate soil, clouds, and non soil (other land cover objects). Based on this result, the combination of ocean blue band and cirrus band was used to classify cloud, while SWIR/NIR ratio was used to classify soils and non (other land cover objects). The classification was done in two stages, as follows:

(i) If ocean blue band value > A and cirrus band value > B then estimated as cloud pixel (Stage 1)

(ii) If SWIR/NIR value > C then estimated as soil pixel (Stage 2)

Other pixels are estimated as non soil pixels

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

The algorithm was applied to Landsat data of the dates before forest and land fire events (July 28th and August 13th, 2015) to classify pixels into three classes, which are soil, non soil and cloud. Due to high cloud cover of Landsat 8 before forest and land fire, then the data of two recording dates (August 13th, 2016 and July 28th 2015) were used together for classification, then the classification results were combined into one classification result.

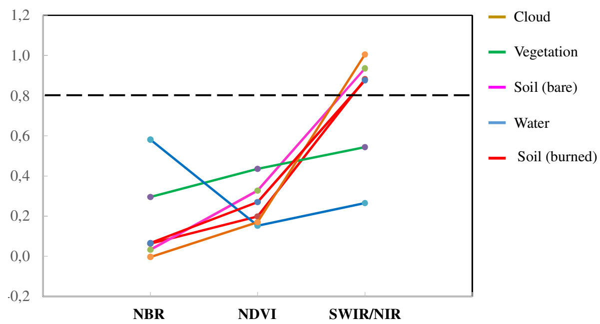


Figure 3-2: Comparison of Spectral Values of Land Cover Object using NBR, NDVI and SWIR/NIR Index

Figure 3-3 shows a comparison of the spectral patterns of land cover objects (cloud, vegetation, bare area, burned area and water body). The spectral values of clouds are very high compared with spectral values of other land cover objects, so clouds can be separated easily using

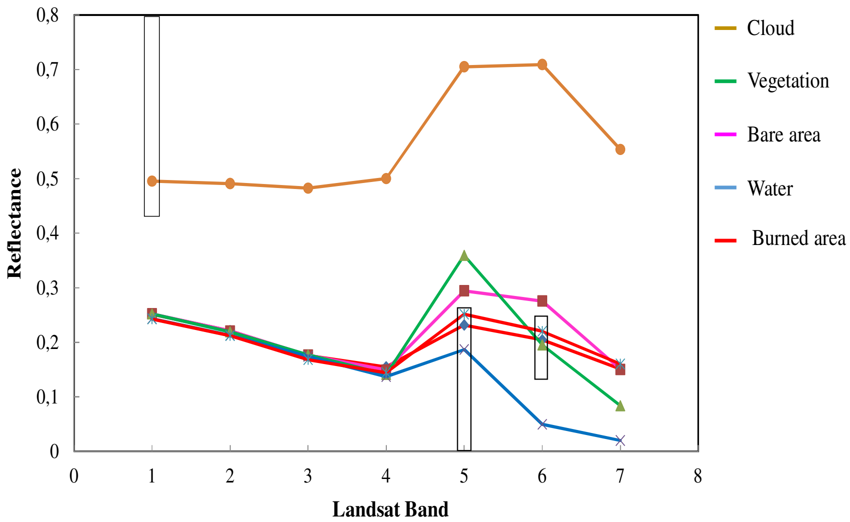


Figure 3-3: Comparison of the Spectral Patterns of Land Cover Objects: Cloud, Vegetation, Bare Area, Burned Area and Water

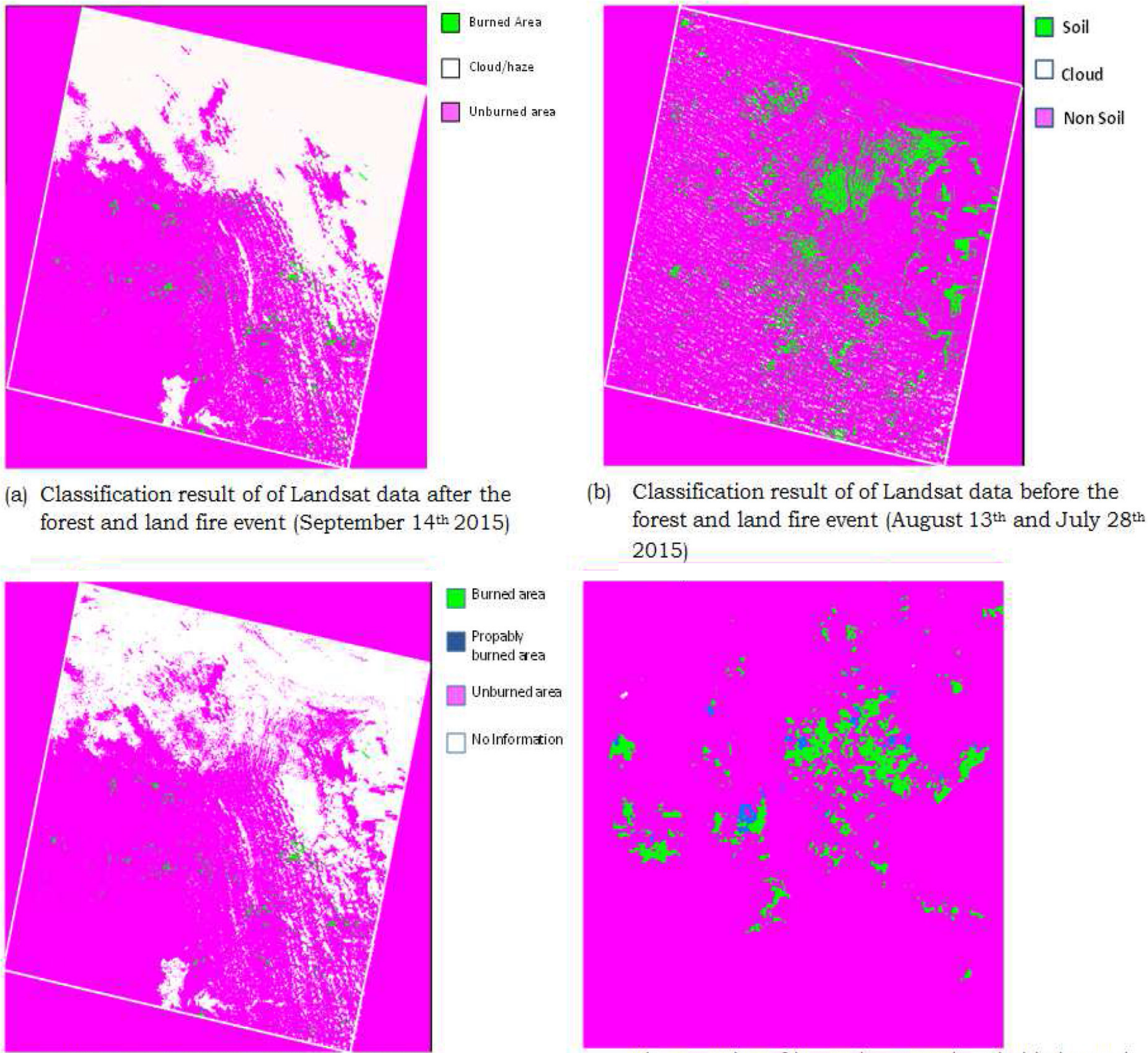
ocean blue band and cirrus band (band 1 and band 9) of Landsat. NIR band (band 5) can be used to separate the burned area with bare area and vegetation, but it is still difficult to separate between burned area and water bodies. The separation between burned area and water bodies can be performed using 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 steps, as follows:

(i) If an ocean blue band values > A and cirrus band values > B then estimated as cloud pixels (Step 1)

(ii) If NIR band values < D, and SWIR band values > E, and SWIR band values < F then estimated as burned area pixel (Step 2) Other pixels are estimated as unburned area pixels.

Where, A is threshold value of cloud in the ocean blue band, B is threshold value of cloud in cirrus band, while D, E, and F are threshold values of burned areas in NIR band and SWIR bands respectively. The algorithm was applied in Landsat data of the date after forest and land fire event (September 14th 2015) to classify the pixels into three classes. Those are burned area, unburned area, and clouds.

The classification results of burned areas, unburned areas, and clouds of Landsat data after the forest and land fire event (September 14th, 2015) is shown in Figure 3-4a. In that figure the burned area is shown in green color, the unburned area in pink color, and the cloud in white color. The classification result of soil area, non soil area, and clouds before the forest and land fire events (August 13th and July 28th 2015) is shown in Figure 3-4b, where the soil is shown in green color, non soil in pink color, and the cloud in white color. The analysis was then conducted using multi-temporal rules referring to Table 2-1. Multi-temporal analysis produced spatial information on 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 3-4c. Burned area and probably burned areas classes are more clearly shown in Figure 3-4d.



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

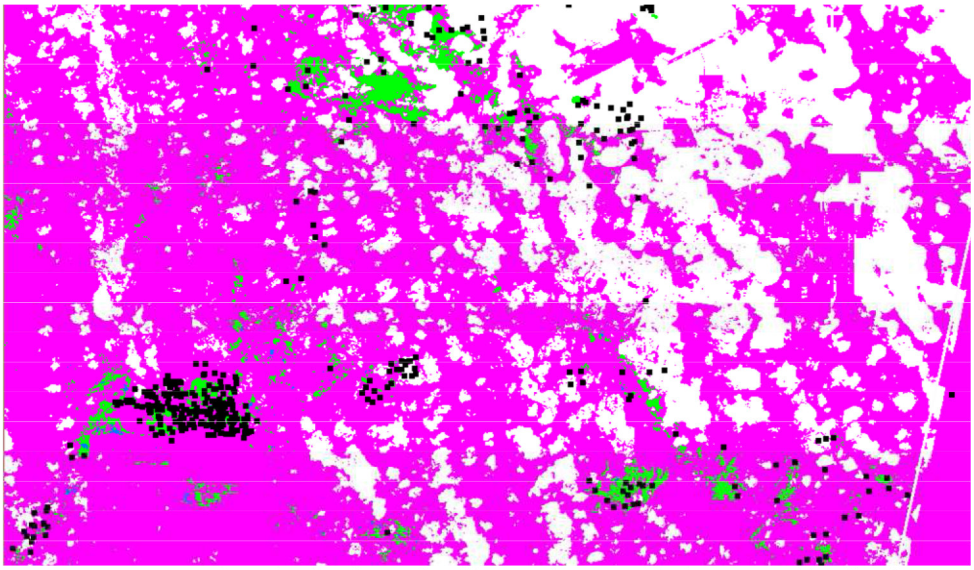
(b) Classification result of of Landsat data before the forest and land fire event (August 13th and July 28th 2015)

(c) Multi-temporal analysis of burned area

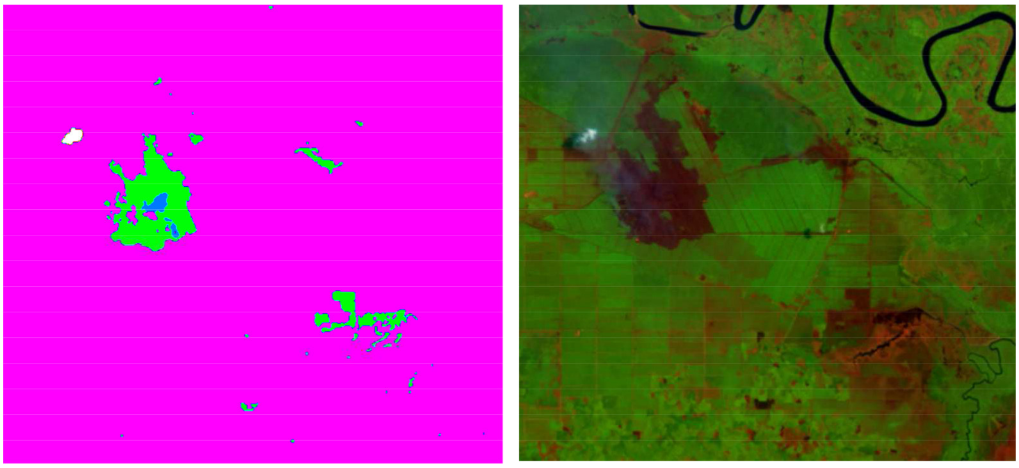
(d) Zooming of burned area and probably burned areas classes

Figure 3-4: 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 hotspot distribution during the period August 1st to September 13rd 2015 (Figure 3-5a) and by doing the visual comparison between the final result of burned area with the RGB 653 composite Landsat image for the burned area appearance (Figure 3-5b). The verification results showed that hotspots were concentrated in the areas classified as burned area, especially on medium and large burned areas. Only a few small areas of burned areas of Landsat imageries did not contain hotspots. It was considered because: 1) the hotspots extracted from MODIS Terra have limitations in spatial resolution (1 km spatial resolution, meaning that the area of 1 pixel of MODIS Terra is similar to the area of 9 pixels of Landsat 8), and 2) high cloud cover or smoke fires over the study area caused hotspot location on the area could not be extracted from MODIS Terra data. The verification results showed that the final result of burned area identification is visually very similar to the burned area shape identified in the RGB 653 composite Landsat image.



(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 3-5: Verification of the Burned Area Mapping

The accuracy of burned area mapping was also quantitatively evaluated using hotspot distribution of MODIS Terra with confidence level more than 90%. The evaluation was conducted in cloud clear area, and the total number of hotspot used was 85 hotspots. The hotspots were buffered to get the circular area with a 1 km diameter (it is same with one pixel size of MODIS Terra with 1 km spatial resolution). The hotspots were overlaid on the burned area, and then the number of hotspots that intersect with burned area was calculated. It was found that 70 hotspots were located in the burned area, which indicated the accuracy of this information was about 82,4% relative to the hotspot of MODIS. These results have also shown that burned area method developed in this research has good accuracy for identifying and mapping burned area using Landsat 8 data.

4 CONCLUSION

The burned area mapping method was developed to identify and map burned area occurrances from two Landsat 8 data of different acquisition dates. Spectral pattern analysis and multi-temporal analysis were conducted to classify the burned area. The results were verified using a hotspot distribution of MODIS

Terra data. Some points are concluded as bellow:

- Based on the spectral analysis result of land cover objects, the cloud can be separated using band combination of ocean blue and cirrus band, burned area using a combination of NIR and SWIR band, while bare area using SWIR/NIR band ratio.
- The multi-temporal analysis generates spatial information on burned area distribution that consists of four classes: burned area, probably burned area, unburned area and no information. The burned area in this study was defined as a burned area of vegetation which happened during a certain period (between two Landsat 8 data recording).
- The final burned area classification has high correlation with hotspot distribution of MODIS in which the accuracy was 82,4 % relative to the hotspots However, further evaluation on the accuracy has to be done using ground measurement to get more confident accuracy.

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