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Burnscar Analysis Using Normalized Burning Ratio (NBR) Index During 2015 Forest Fire at Merang-Kepahyang Peat Forest, South Sumatra, Indonesia

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Abstract. Forest fire, classified as a natural hazard or human-induced hazard, has negative impacts on humans. These negative impacts are including economic loss, health problems, transportation disruption and land degradation or even biodiversity loss. During 2015, forest fire had occurred at the Merang-Kepahyang peat forest that has a total area of about 69.837,00 ha. In order to set a rehabilitation plan for recovering the impact of forest fire, information on the total burnscar area and severity level is required. In this study, the total burnscar area and severity level is evaluated using a calculation on the Normalized Burning Ratio (NBR) Index. The calculation is based on the Near Infra Red (NIR) and Short Wave Infra Red (SWIR) of the satellite imageries from LANDSAT. The images of pre-and post-fire are used to evaluate the severity level, which is defined as a difference in NBR Index of pre- and post-fire. It is found that about 42.906,00 ha of the total area of Merang-Kepahyang peat area have been fired in 2015. These burned area are classified into four categories, i.e., unburned, low, extreme and moderate extreme. By overlying the spatial map of burning level with other thematic maps, it is expected that strategy for rehabilitation plan can be well developed.

Keywords: *Forest Fire, Normalized Burning Ratio (NBR), Peat Land, Remote Sensing, Landsat 8*

INTRODUCTION

Forest fires are one of the main causes of tropical forest degradation in Indonesia. During 1997/1998 large fire, approximately 25 million hectares of forest area were burned around the world, including 2.124.000 hectares of peat swamp forest in Indonesia [1]. In recent years, forest fires have become a concern of the global community as an environmental and economic issue. In particular, the El Nino Southern Oscillation (ENSO) in the year 1982/1983, 1994 and 1997/1998 has resulted in a large fire in Indonesia [1]. Forest fires in the South Sumatra, especially in the area of peat swamp forest Merang-Kepahyang are one of the causes of land degradation in this region. This natural phenomenon evolved into a form of natural disasters that have an impact on aspects of people's life.

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Because it has a considerable impact, it takes a disaster mitigation and rehabilitation effort. An effort that is very helpful in supporting the mitigation is the provision of information on the spatial distribution areas that have a high potential burn and areas that have been burned. This information is very important in the process of rehabilitation of burnt area and also to support the mandate of PP No. 1 2016 about PeatLand Rehabilitation Agency. However, direct measurement of the large and remote burned area is difficult, expensive and time consuming. An alternative method that can be performed to obtain information of the burned area quickly, simultaneously and low coast but with a level of accuracy that can be justified, is by using satellite imagery [2].

Those indices are compared to the directly observed data or field data (Burn Composite Index – CBI). The results show that the Normalized Burn Ration (NBR) index generated using the NIR and SWIR spectral has a high correlation with the field data (CBI) compared to the other indices, especially in the forest vegetation. The use of spectral irradiance Near Infrared (NIR) and shortwave infrared (SWIR) was excellent for separating the burned and unburned area. The decline in the canopy of trees and water content after the fire can be responded well by increasing reflectance of the SWIR spectrum [3], [4].

This study investigates the burned areas at the Merang Kepahyang Peat Swamp Forest after severe forest fires in 2015. The Landsat 8 satellite imageries are used in this study and the method of Normalized Burning (NBR) Ratio is applied to evaluate the burned area. NBR has been adopted as part of the FireMon program and routinely used by the Burned Area Emergency Response (BAER) team for the assessment of post-fire by the American Land Management agencies [5]. This method is based on the reflectance of NIR (Band 4) and SWIR (Band 7) of the Landsat 8 image.

STUDY AREA

The study area is in the District of Bayung Lencir, Banyuasin Regency, South Sumatra. The study area is mainly peat swamp forest and it is located between the Merang River and the Kepahyang River (Figure 1). This area is located at an altitude of 2-10 m above sea level, with a slope below 3%, and has an area of approximately 69.837 ha. The area along the Merang River is dominated by the alluvial soil. The annual rainfall is 2,454 mm, in which the lowest monthly rainfall is 85 mm occurring in August and the highest one is 324 mm occurring November. Based on Oldeman climate classification, the Merang-Kepahyang has a B1 rainfall zone, which means that this area has adequate rainfall intensity.

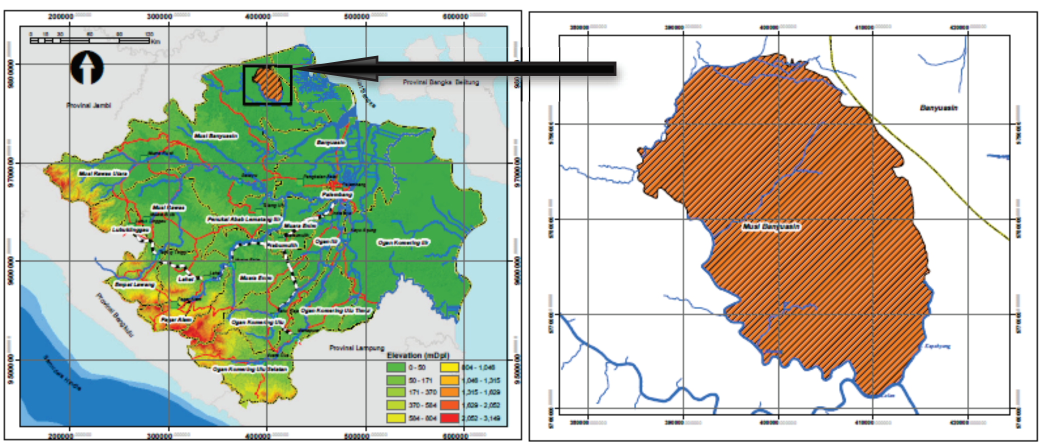

FIGURE 1. Map of Study Area.

MATERIAL

This study used satellite imageries obtained from the Landsat 8 Path/Row 125/061. In order to analyze forest fire occurring in 2015, hotspot information from the MODIS C6 Satellite for a period of September - December 2015 is used in this study. The prefire image used the Landsat 8 image recorded at January 2015 with 2% cloud cover, while the post fire image used image recorded in 2016 that has the cloud cover less than 5%. In addition, the validation of burnscar used the aerial photos with DJI Phantom 3 Drone by 31 observation points conducted in April 2016.

METHODS

The NBR method is considered to have a high accuracy when it is applied on the tropical highland forests having a diversity of forest cover [4], [6]. Thismethod compares the correlation of remote sensing data with the field data from four types of levels, namely unburned, low-burned, burned (moderate), and moderate extreme. In this study, the NBR method is applied on the peat lands.

First, the NBR indices for the prefire and postfire of the Band-4 (NIR) and Band-7 (SWIR) of the Landsat 8 are calculated. Then, the NBR difference (dNBR) between the prefire and postfire images are calculated. A threshold has been developed to get higher accuracy or optimum separation for the dNBR. The calculation of threshold values is done by calculating the average ($\ddot{x}$) and standard deviation (σ) of each index value derived from the Landsat 8. The threshold value is defined as $\ddot{x}$ - 1σ, σ and $\ddot{x}$ + 1σ. This calculation is conducted by comparing the extracted dNBR index with the field measurements of the burned area, and also by analyzing the kappa coefficient that represents the consistency accuracy of the classification.

DATA PROCESSING

The first step in the data processing is a geometric correction by using the ortho-retrificated images. The next step is a radiometric corrections, which usually considers several factors from atmospheric, such as sun angle, the light path, gas absorption, scattering by aerosols in the atmosphere. The radiometric correction is done by converting the digital number of band (NIR and SWIR) into the reflectance values by using:

$$\rho\lambda' = M\rho\, Q_{cal} + A\rho, \quad (1)$$

where $\rho\lambda'$ is the TOA planetary reflectance without correction of the solar angle. $M\rho$ is band-specific multiplicative rescaling factor from the metadata (Reflectance_Mult_Band_x, where x is the band number). $A\rho$ is the band-specific additive rescaling factor from the metadata (Reflectance_Add_Band_x, where x is the band number), and Q_{cal} is the quantized and calibrated standard product pixel values (DN).

The conversion of digital numberinto the reflectance value carried on the Band-4 (NIR) and Band-7 (SWIR) of the Landsat 8 is conducted for the prefire and postfire images. Then, the extracted NBR index is calculated by using:

$$NBR = (R_4 - R_7) / (R_4 + R_7), \quad (2)$$

where R_4 and R_7 are the reflectance of band 4 and band 7, respectively.

Figure 2 shows the composite image on the RGB format and the generated NBR indices for the pre- and post-fire images.

The next step is classification of the burned and unburned area by calculating the difference of the pre- and post-fire NBR indices (Key and Benson, 1999):

$$\boldsymbol{dNBR = NBR_{prefire} - NBR_{postfire}}. \quad (3)$$

Having obtained the dNBR, we extract the index values and perform statistical analysisto obtain the average value and standard deviation of the 31 sampling points obtainedby the drone survey. The result is shown in Figure 3.

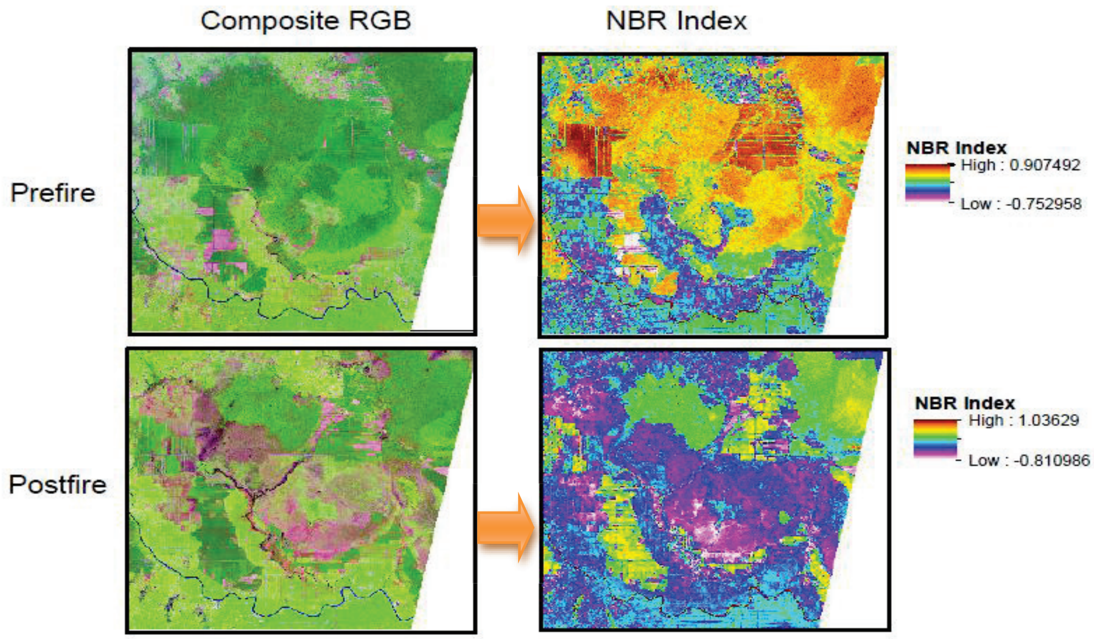

FIGURE 2. Map of composite RGB images (*left panel*) and NBR Index (*right panel*)

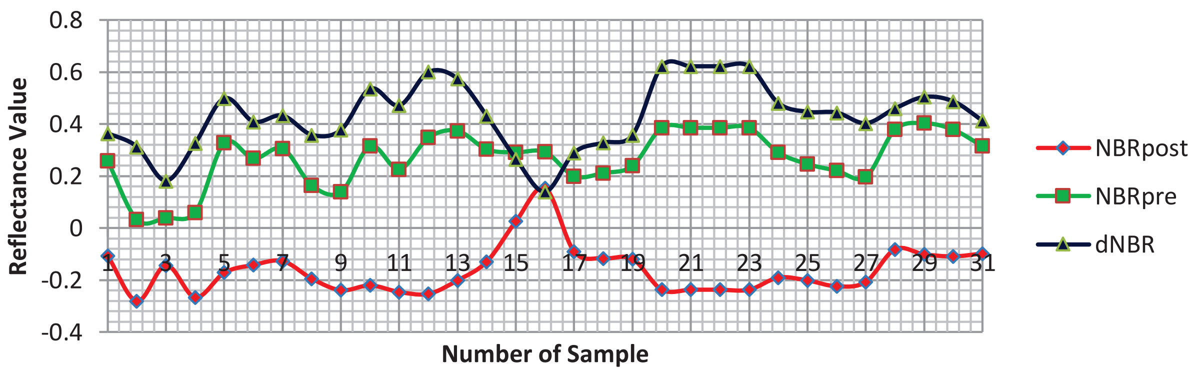

FIGURE 3. Reflectance curve for each sampling

In general, the NBR index before burning is higher than that after the fire, so that the difference (dNBR) index will be positive. It is shown that all dNBR indices have positive values, indicating that all sampling points are located on the burned area. Note that the dNBR threshold value is determined based on the field verification to minimize the errors in identifying the burned areas. Our calculation results in the threshold values of 0.29, 0.42 and 0.55. Figure 4 indicates the ground truth classification images, namely unburned, low, moderate and moderate extreme images.

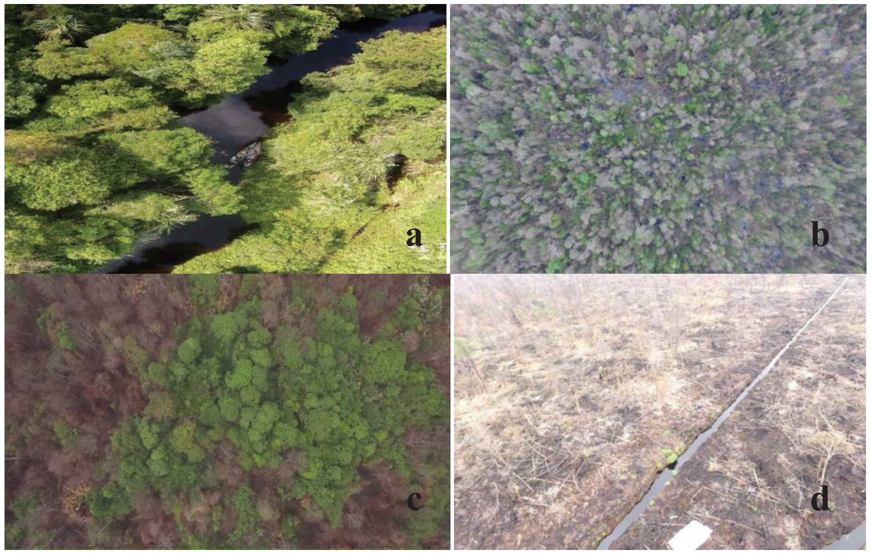

FIGURE 4. Ground truth classification images; (a) Unburned; (b) Low; (c) Moderate; (d) Moderate Extreme

From the calculation of dNBR index and the classification burned classes based on the generated threshold values and the comparison with the direct observational data, we conducted a statistical analysis to test the accuracy and to get the *Kappa coefficient*. The result is presented in Table 1.

TABLE 1. Confusion matrix and results from the statistical analysis

dNBR Index	**Field Assessment**				**Total**
	Unburned	***Low***	***Moderate***	***Moderate Extreme***	
Unburned	3	1	0	0	4
Low	0	7	2	1	10
Moderate	0	4	7	0	11
Moderate Extreme	0	0	1	5	6
Total	3	12	10	6	31
Producer Accuracy %	100.00	58.33	70.00	83.33	
User Accuracy %	75.00	70.00	63.64	83.33	
Omission Error %	0.00	41.67	30.00	16.67	
Commission Error %	25.00	30.00	36.36	16.67	
Overall Accuracy %	70.97				
KappaCoeff	0.592				

RESULTS AND DISCUSSION

From the image analysis the highest reflectance value on prefire image are average 0.197 with a standard deviation of 0.175 and the reflectance values postfire image are average of -0.056 with a standard deviation 0.143 (figure 2), in the sampling area the reflectance values (NBR) of the prefire are larger than those of the postfire as shown in Figure 3. Over the entire area, it is shown that the NBR of prefire is 0.9, while the NBR of postfire is about 0.2. A low value indicates that the area no longer has vegetation cover. In general, charcoal and ash has a low reflectance, typically 0.05 (400 nm) to 0.10 (2500 nm) [5]. The difference in reflectance values on prefire and postfire (dNBR) which shows changes in vegetation cover. Based on the threshold calculated using all field sampling points, we classifiedthe severity level into*unburned, low, moderate* and *moderate extreme classes* (Figure 4). In the peat swamp area, the *unburned class*is characterized by high vegetation cover. Mean while *low class* is the burned area that has rapid succession. The *moderate class* indicates burned area that still has standing burned-trees and experiences slow succession. Finally, *the moderate extreme class* shows the loss of standing trees and vegetation cover and has a deposit of charcoal and high ash.

The statistical analysis of the accuracy test of the NBR indices shows overall accuracy of about 70.97% with *Kappa* coefficient of 0.592. The *Kappa* coefficient indicates that the classification is able to avoid about 59.2% errors that will appear on the classification of the field.

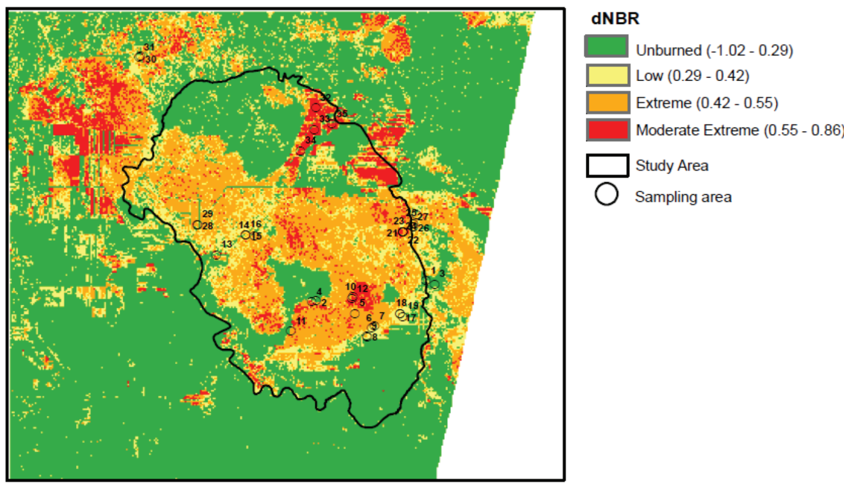

FIGURE 5. Classification map for each severitylevel.

The analysis over entire Merang-Kepahyang area shows that the burned area is about 42,906 hectares, in which about 12.209, 25.836,20, and 4.861,44 hectares are classified as *low class*, *moderate class*, and *moderate extreme class,* respectively. The remaining area, 26.930,60 hectares, is classified into *unburned class*. We may suggest that the severity level can be used asa reference data for the rehabilitation of forest and land.

CONCLUSIONS

This study has shown that the Landsat 8 satellite imagery which has a spatial resolution of 30 m×30 m can be used to map the burnscar by utilizing the Band-4 (NIR) and Band-7 (SWIR) reflectance. We noted that the dNBR is very sensitive to water levels in burned area, especially in the peat swamp area which has low water content during dry season [7]. We also found that the separation of *moderate extreme class* still has a weakness. It is difficult to classify an unburned open-land covering by mineral soil. Out analysis shows that the dNBR in the unburned open-land is above 0.55 as shown by the samples 32-35 in Figure 5.The *Kappa* coefficient is 0.592 because the sampling points at *moderate extreme class* is very limited. In addition, as explained earlier, it is difficult to classify the *moderate extreme class* from the unburned open-land. Finally, our study shows that the total burned area in the Merang-Kepahyang area during 2015 extreme forest fire is about 42,906 hectares, which about 61% of the total area (69.836,6 hectares).

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REFERENCES

1. Tacconi, L. 2003. *Kebakaran Hutan di Indonesia: Penyebab, Biaya dan Implikasi Kebijakan*. CIFOR Occasional Paper No. 38(i).
2. Cochrane, M. A., 2003. *Fire Science for Rainforests*, Nature*,* 421, 913-919.
3. Key, C.H., and N.C. Benson. 2002. *Measuring and remote sensing of burn severity, U.S*. Geological Survey wildland fire workshop.
4. Escuin, S., R. Navarro, P. Fernandndez. 2008. Fire severity assessment by using NBR (Normalized Burn Ratio) and NDVI (Normalized Difference Vegetation Index) derived from LANDSAT TM/ETM images. *International Journal Remote Sensing*.29:1053-1073.
5. Roy,D.P.,Frost.P.G.H.,Justice,C.O.,Landmann.T.,Roux.Le.,Gumbo.K.,Makungwa.S.,Dunham.K.,Toit.Du.,Mhwandagara.K.,Zacarias.A.,Tacheba.B.,Dube.O.P.,Pereira.J.M.C.,Mushove.P.,Morisette.J.T.,Vannan.S.K.S.,Davies.D. 2005. The South African Fire Network (SAFNet) regional burned-area product validation protocol.,*International Journal of Remote Sensing*. Vol. 26, No 19, 4265-4292.
6. Suwarsono. Rokhmatuloh., Waryono T., 2013. Pengembangan Model Identifikasi Daerah Bekas Kebakaran Hutan dan Lahan (Burned Area) Menggunakan Citra MODIS di Kalimantan .*Jurnal Penginderaan Jauh* Vol. 10 No. 2:93-112.
7. Roy, D. P., Boschetti, L. and Trigg, S. N. 2006. Remote sensing of fire severity: assessing the performance of the Normalized Burn Ratio. *IEEE Geoscience and Remote Sensing Letters*, 1, pp. 112-116