

Identification of Land Cover Changes in The MK-PHR Conservation Area Associated With Fire Events

Raden Putra^{1,2*}, Tastaptyani Kurnia Nufutomo¹, Yuni Lisafitri¹, Novi Kartika Sari¹, Alfian Zurfi¹, Yanies Meiyanti³

¹Environmental Engineering Study Program, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia

²Research and Innovation Center for Disaster Mitigation and Early Detection of Forest Fires, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia

³Badan Perencanaan Pembangunan Daerah, Penelitian dan Pengembangan Provinsi Kalimantan Tengah 73111, Indonesia

*Corresponding author e-mail: raden.putra@tl.itera.ac.id

Abstract

Peat fire is one of the most environmental issues in Indonesia, particularly in the region of South Sumatra. The fires usually occur during the dry season from Juni to November. This study is designed to evaluate the impact of peat fires on changes in land cover in the Merang Kepahyang Peat Hydrological Region (MK-PHR) for the period of 2002 to 2015. The changes identified by the Normalized Difference Vegetation Index (NDVI) method using Landsat satellite imagery. The results of the study show that extreme peat fire associated with climate anomalies events occurred in 2006, 2012, and 2015. The largest peat fires during the observation period occurred in 2015 coincided with extreme climate anomalies generating negative changes in land cover in the most of MK-PHR areas. The changes occurred in almost half (49%) of the MK-PHR area, where it moved from the dense to moderate vegetation class. The spatial and temporal land cover changes will be discussed in more detail.

Keywords

anomalous climate event, land cover changes, NDVI, peat fire

Received: 13 January 2021, Accepted: 28 February 2021

<https://doi.org/10.26554/ijems.2021.5.1.1-4>

1. Introduction

The largest tropical peat ecosystem in Southeast Asia is located in Indonesia and covers 4 million hectares area, which distributed in Kalimantan, Sumatra, and Papua island (Wahyunto, 2004). In their management practices, Indonesian peat ecosystems are divided into small management units called peat hydrological regions. The condition of Indonesia's peatlands is currently degraded due to human activities such as illegal logging, land clearing, and fires. Based on the research (Putra et al., 2019), South Sumatra peat fires had occurred consistently since 2002 when the dry season lasted for the entire June to November period. Peat fires cause haze disasters and negatively impact humans and the environment. Koplitz et al. (2016) noted that 100-300 people died in Indonesia, Malaysia, and Singapore as a result of bad air quality that was due to haze. Moreover, the 2015 peat fire emitted CO₂ into the atmosphere with an average emission rate of 11.3 Tg/day from September to October, which contributed to global warming (Huijnen et al., 2016). The Merang Kepahyang Peat Hydrological Region (MK-PHR) is one of the peat conservation areas

in South Sumatra Province, Indonesia. Most of the MK-PHR areas are peat swamp forests with high biodiversity values. In 2015, the areas in MK-PHR were ignited and most of the surface vegetation burned during the dry season caused by the El Niño phenomenon. Furthermore, the dry peat material and lack of access to burnt areas make the process of extinguishing the fires difficult. Peat fires are also triggered by climate phenomena that affect rainfall in the regions. The Indonesia region has two phenomena that generate extreme dry season, namely El Niño and positive Indian Ocean Dipole (pIOD) (Lestari et al., 2018). This study identifies the dynamic relationships between climate anomalies indexes, precipitation, and hotspots, followed by an evaluation of the impact of peat fires on changes in land cover in the study area. This study aimed to analyze the land cover change rate in the MK-PHR area that is associated with peat fire that occurred during the observation period (2002 to 2015). The changes in land cover were identified through the Normalized Difference Vegetation Index (NDVI) method using Landsat satellite imagery data. The NDVI method was applied to Landsat satellite imagery recorded

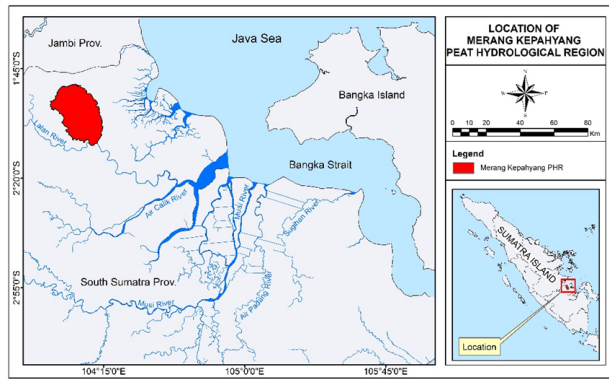


Figure 1. Location of the study

before and after the fire events. NDVI values are calculated by comparing the red and near-infrared reflectance (NIR) bands of the Landsat sensor system (Bharathkumar and Mohammed-Aslam, 2015; Meneses-Tovar, 2011)

2. Experimental Section

2.1 Study area

The MK-PHR is located between longitudes of 103° 51' 0" E and 104° 0' 0" E and latitudes of 01° 45' 0" S and 02° 03' 0" S. Administratively, this area is included in the territory of the Muara Merang and Muara Medak village, in the Musi Banyuasin District, in South Sumatra Province. MK-PHR is a project of peat restoration and conservation under the management of the South Sumatra Forest Department. Figure 1 shows the location of the MK-PHR.

2.2 Methods

Indonesia's climate is influenced by the El Niño / Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) phenomena. The strength of both phenomena is identified by calculating the climate anomaly index (Niño 3.4 index for ENSO and Dipole Mode Index (DMI) for IOD) (Aldrian and Susanto, 2003 ; Saji and Yamagata, 2003). This study develops the Niño 3.4 and DMI during the observation period (2002 to 2015) from the Intergovernmental Oceanographic Commission (IOC) website (<http://ioc-goosoopc.org>). In addition, monthly precipitation in this study is sourced from the Tropical Rainfall Measurement Mission (TRMM) 3B43 product with 0,25 x 0,25 degrees of resolution (<https://mirador.gsfc.nasa.gov>). The comparison of Niño 3.4, DMI, and precipitation with hotspot distribution data indicates the years when there were drought seasons. Hotspot distribution data is obtained from the Fire Information for Resource Management System (FIRMS) website (<https://firms.modaps.eosdis.nasa.gov>). Landsat satellite imagery is used to identify changes in land cover, before and after the peat fire events. This study uses Landsat satellite imagery recorded in 2006, 2007, 2011, 2013, 2015, and 2016. The data is provided by the United

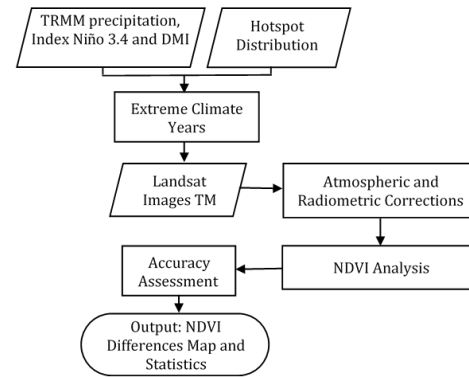


Figure 2. The flow of methodology chart

States Geological Survey (USGS) website, Earth Explorer (<http://earthexplorer.usgs.gov>). The images have been registered and geo-corrected from the source. The atmospheric correction has been done by preprocessing Landsat tools in the Quantum Geographic system (QGIS) software version 2.18.2, while calibration Landsat tools did the radiometric correction. Land cover identification in this study operates with the NDVI method. The NDVI value is calculated by comparing the red and NIR bands of the sensor system (Eq. 1). NDVI has a range from -1 to +1, in which the higher value indicates the higher vegetation density in that area. The NDVI maps in this study will be validated with field survey data from the South Sumatra Forest Department. Figure 2 shows all the processes in this study.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (1)$$

3. Results and Discussion

The comparison between the Niño 3.4 index, DMI, and precipitation with total hotspots (Figure 3) indicate that the peat fires in the MK-PHR occur when precipitation is low, and both climate anomaly indexes have a high rate (dry season). Based on this result, severe peat fires occurred in 2006, 2012, and 2015 so evaluation of land cover changes will be made in those years.

Recapitulation of land cover changes by the NDVI method is shown in Tables 1. The percentage of changed area is a ratio between the changed area in each class and the total changed area in the same period. The largest changed area in each period occurred in the dense vegetation class, and the changes were negative. From 2006 to 2007 and 2011 to 2013, the land cover moved one density class and from 2015 to 2016, it moved two density classes.

Based on the results (Figure 4 and Table 1), the total area of dense vegetation decreased after peat fires occurred in the studied area, while the total area of sparse vegetation increased. This means that the changes in land cover due

Table 1. Percentage of land cover change in the MK-PHR area (minus means land cover class decreased extensively)

NDVI Density Classes	Changed Area (%)		
	2006- 2007	2011- 2013	2015-2016
Sparse Vegetation	10.43	1.4	1.47
Moderate Vegetation	39.57	13.48	30.47
High Vegetation	-50	35.13	18.12
Dense Vegetation	0	-50	-49.93

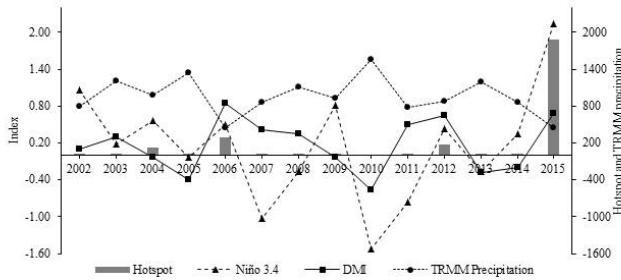


Figure 3. Indexes of large-scale circulation patterns in equatorial Asia. The Niño 3.4 index and DMI are averages from July to November of each year. Hotspot and TRMM precipitation (mm/month) are totals from July to November of each year.

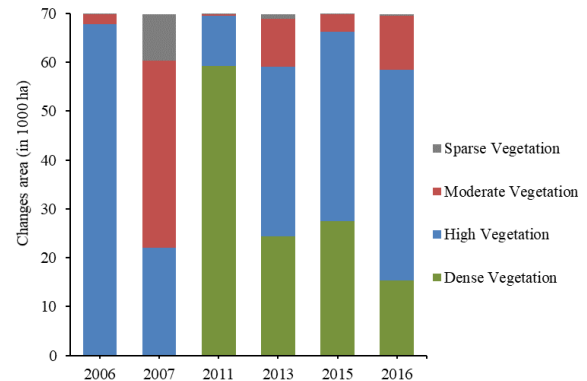


Figure 4. Progression of land cover changes in the MK-PHR caused by an extreme peat fire in 2006, 2012 and 2015

to peat fires were negative, in which the vegetation changed from dense to sparse class. In other conditions, when El Niño does not occur or La Niña occurs, the generative phase of vegetation causes the vegetation density value to increase and convert the sparse vegetation to dense. In the 2007 to 2011 period, TRMM precipitation and both of the anomaly indexes (Figure 1) indicate that El Niño did not occur and La Niña occurred in 2010. This condition caused the largest vegetation density class in 2007 (moderate class) to changed to dense vegetation in 2011. Spatial hotspot distribution and the NDVI map are shown in Figure 4. The results were validated using field survey data from the South Sumatra Forest Department. When a strong El Niño occurred in 2015, hotspots distribute in most areas of the MK-PHR, and the change of vegetation density occurred in most areas of the MK-PHR. Based on the spatial analysis, the change of vegetation density not only occurred in the hotspot burnt areas but also occurred in areas where hotspots undetected (unburnt areas). Changes in vegetation density levels in unburnt areas were caused by the accuracy of hotspot data used in this study.

4. Conclusion

The severe peat fires in the MK-PHR were associated with anomalous climate events occurred in 2006, 2012, and 2015.

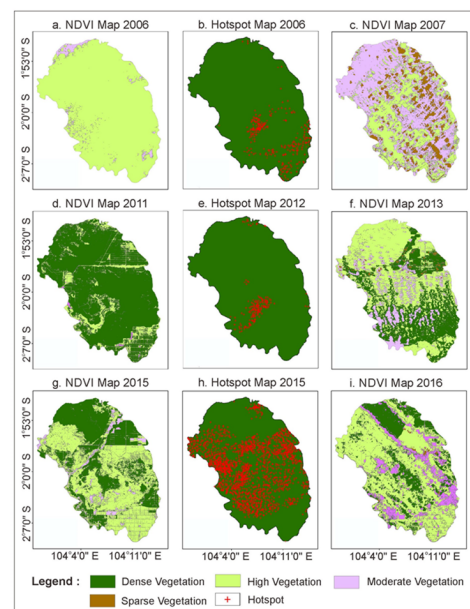


Figure 5. NDVI Density Map and Hotspot Distribution Map (NDVI maps 2006, 2011 and 2015 are classifications of vegetation density before peat fire; NDVI maps 2007, 2013, and 2016 are classifications of vegetation density after peat fire)

In particular, the 2015 peat fires were associated with the largest anomalous climatic index, had the most extensive hotspot distribution, and led to rapid land cover changes observed in most areas of the MK-PHR. The total average of land cover loss was about 49% of the total MK-PHR area. The results of this study indicate that peat fires are still occurring in the MK-PHR conservation areas and hurt ecosystems there.

Acknowledgement

The authors would like to thank Institut Teknologi Sumatera (ITERA) for funding this research through the “Guru Besar Under 45 (GBU45)” grant number B/409/IT9.C1/PT.01.03/2020.

REFERENCES

- Aldrian, E. and R. D. Susanto (2003). Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *International Journal of Climatology*, **23**(12); 1435–1452
- Bharathkumar, L. and M. Mohammed-Aslam (2015). Crop Pattern Mapping of Tumkur Taluk Using NDVI Technique: A Remote Sensing and GIS Approach. *Aquatic Procedia*, **4**; 1397–1404
- Huijnen, V., M. J. Wooster, J. W. Kaiser, D. L. A. Gaveau, J. Flemming, M. Parrington, A. Inness, D. Murdiyarso, B. Main, and M. van Weele (2016). Fire carbon emissions over maritime southeast Asia in 2015 largest since 1997. *Scientific Reports*, **6**(1)
- Koplitz, S. N., L. J. Mickley, M. E. Marlier, J. J. Buonocore, P. S. Kim, T. Liu, M. P. Sulprizio, R. S. DeFries, D. J. Jacob, J. Schwartz, M. Pongsiri, and S. S. Myers (2016). Public health impacts of the severe haze in Equatorial Asia in September–October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure. *Environmental Research Letters*, **11**(9); 094023
- Lestari, D. O., E. Sutriyono, I. Iskandar, et al. (2018). Respective Influences of Indian Ocean Dipole and El Niño–Southern Oscillation on Indonesian Precipitation. *Journal of Mathematical & Fundamental Sciences*, **50**(3)
- Meneses-Tovar, C. (2011). NDVI as indicator of degradation. *Unasylva*, **62**(238); 39–46
- Putra, R., E. Sutriyono, S. Kadir, and I. Iskandar (2019). Understanding Fire Distribution in The South Sumatra Peat Area during the Last Two Decades. *International Journal of GEOMATE*, **16**(54); 146–151
- Saji, N. and T. Yamagata (2003). Possible impacts of Indian Ocean Dipole mode events on global climate. *Climate Research*, **25**; 151–169
- Wahyunto, S. S. H. S., Ritung (2004). Map of Peatland Distribution Area and Carbon Content in Kalimantan