http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 7 No 1 2022

RESEARCH ARTICLE

Rapid Land Cover Change in The South Sumatera Peat Area Associated With 2015 Peat Fires

Raden Putra[1,2*], Tastaptyani K Nufutomo[1], Yuni Lisafitri[1], Novi K Sari[1], Alfian Zurfi[1], Deni O Lestari[2,3], Muhammad U Nuha[2,4]

[1]Department of Environmental Engineering, Faculty of Regional and Infrastructure Technology, Institut Teknologi Sumatera, Lampung 35365, Indonesia
[2]Research and Innovation Center for Disaster Mitigation and Early Detection of Wildfires, Institut Teknologi Sumatera, Lampung 35365, Indonesia
[3]Department of Atmospheric and Planetary Science, Faculty of Science, Institut Teknologi Sumatera, Lampung 35365, Indonesia
[4]Department of Geomatics Engineering, Faculty of Regional and Infrastructure Technology, Institut Teknologi Sumatera, Lampung 35365, Indonesia

* Corresponding author : raden.putra@tl.itera.ac.id
Tel: +62 721 8030188
Received: Feb 10, 2021; Accepted: Mar 30, 2022.
DOI: 10.25299/jgeet.2022.7.1.6395

Abstract

The peat fire events in Indonesia, particularly the South Sumatra area, changed the appearance of surface vegetation. The fires usually occur during the dry season from July to October. This study aims to evaluate land cover changes due to 2015's peat fire in the South Sumatra peatlands. Remote sensing techniques using a Normalized Difference Vegetation Index (NDVI) method were used to identify the change of vegetation density in the study area. The results showed that 69% of the total South Sumatra peatland was burned due to the 2015 peat fire event. The level of vegetation density was considerably decreased by fire events. The degradation in the burned area was dominated by land cover class of ferns/shrub. The Peat fires during the observation period have a negative impact on the peat ecosystem, so improvements are needed in peatland management practices. Improvements need to be made in fire prevention and management practices, as well as restoration of burnt land.

Keywords: Abstract Peat Fire, NDVI, Burned Area, Degradation

1. Introduction

Peatland is a unique ecosystem that provides multiple benefits of significant carbon sequestration, water catchments, and rich biodiversity (Agus et al., 2013; Page et al., 1999). Human activities such as deforestation, land conversion, and man-made fires are the primary pressures to peat degradation. In the current management practices, peatland is under a serious threat of land degradation in Southeast Asia, particularly in Indonesia. (Hooijer et al., 2006; Jaenicke et al., 2010; Miettinen et al., 2012b).

The South Sumatera peatlands have been degraded in the past two decades due to deforestation, illegal logging, and man-made fires (Miettinen et al., 2016; Thorburn and Kull, 2015). The Peat fire event commonly occurs during the dry season from June to November (Miriam E Marlier et al., 2015; Miriam E. Marlier et al., 2015a, 2015b). During the fire events, an incomplete combustion release carbon to the atmosphere and critically contribute to global warming. Moreover, peat material and surface vegetation burning generate haze disaster, which is deteriorated wildlife, human health, economy, and climate. The previous studies have reported that up to 300 people died in Indonesia, Malaysia, and Singapore caused by the severe haze pollution during September-October in 2015 (Harrison et al., 2009; Koplitz et al., 2016; Miriam E. Marlier et al., 2015b).

On the other hand, the fires also reduce the biodiversity and the appearance of surface vegetation along the burnt area (Page and Hooijer, 2016; Sloan et al., 2017). The objective of this study is to evaluate the land cover change due to the 2015 peat fires on the South Sumatera peatlands. Remote sensing techniques using the Normalized Difference Vegetation Index (NDVI) method were used in determining vegetation density in the study area. The NDVI identification was afterward analyzed spatially by overlaying with land use maps in order to evaluate the change of each land-use class.

2. Data and Method

2.1 Study Area

South Sumatra region has about 9% (1.48 million Ha) of the Indonesian peatlands (Wahyunto et al., 2004). Based on the data provided by the Indonesian National Board for Disaster Management (BNPB) in 2016, South Sumatra is the region that experienced the worst peat fires in Indonesia during the 2015 dry season. The South Sumatra peat area is located near the eastern coast of Sumatera bounded by 101° 35' 0" E - 105° 55' 0" E and 01° 10' 0" S - 04° 50' 0" S (See Figure 1).

2.2 Hotspot Data

Hotspot data were used to identify the South Sumatera peat fires during August - November 2015. The hotspot data were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on the TERRA and AQUA satellites with a resolution of 1 km. Those data were available online at the Fire Information for Resource Management System (FIRMS) website (*https://firms.modaps.eosdis.nasa.gov*). Hotspot data were analyzed by spatial buffer methods following the MODIS spatial resolution. The results show the burned area, which use to observe the change of vegetation density in the study area.

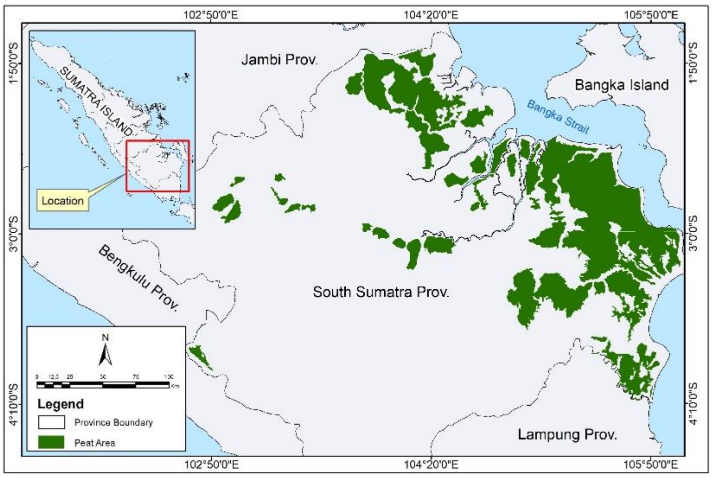

Fig. 1. Location of the study area, also shown are the distributions of peat area

2.3 Satellite Images

The vegetation density analysis in study area identified by Landsat 7 and 8 satellite images. These images had a spatial resolution of 30 meters with a coverage area of 185 x 185 km. The vegetation density determination observed pre- and post- 2015 peat fires event through Landsat data recorded in 2013 and 2016. The research area covered 4 sheets of the Landsat imagery, namely 123-062, 124-061, 125-061, 125-062, and 124-062 (path-row). The data were provided by the United States Geological Survey (USGS), Earth Explorer, and were available online at *http://earthexplorer.usgs.go*. The images had been registered and geo-corrected from the source. The atmospheric correction has been undertaken by the pre-processing Landsat tools in the QGIS software version 2.18.2. The calibration Landsat tool acquired the radiometric correction.

2.4 NDVI and Spatial Analysis

Normalized Difference Vegetation Index (NDVI) is a method of analyzing satellite imagery and commonly used to identify the surface vegetation density and land cover changes. The NDVI values were calculated by comparing the Red and NIR bands of the Landsat sensor system (Equation 1).

$$NDVI = ((NIR - Red)) / ((NIR + Red)) \quad (1)$$

The NDVI values range from −1 to +1. The higher the NDVI value, the more dense the vegetation, and the lower the NDVI value, the sparser the vegetation. (Bharathkumar and Mohammed-Aslam, 2015; Meneses-Tovar, 2011). This study divided the NDVI value into six vegetation density classes, each with its own vegetation density weight (See Table 1).

Table 1. Classification of NDVI value

NDVI Value	NDVI Class	NDVI Weight
< 0.0	Non-Vegetation	1
0.0 – 0.2	Very Low Vegetation	2
0.2 – 0.4	Low Vegetation	3
0.4 – 0.6	Moderate Vegetation	4
0.6 – 0.8	High Vegetation	5
0.8 – 1.0	Very High Vegetation	6

The difference in the weights of the 2016 and 2013 NDVIs is used to evaluate changes in vegetation density (equation 2). The Positive change values indicate that surface vegetation is growing, while negative values suggest that it is degrading. The classification of changes in vegetation density resulted in 11 classes, as shown in Table 2. Furthermore, changes in vegetation density were analyzed towards land cover data in 2013 (data collected from Putra et al., 2019) using the spatial overlay method to determine the characteristics of changes in each land cover class.

$$\text{Changed Value} = NDVI_{weight}\ 2016 - NDVI_{weight}\ 2013 \quad (2)$$

Table 2. Classification of the changing area

Changed Values	Classes
-5	Very High Degradation
-4	High Degradation
-3	Moderate Degradation
-2	Low Degradation
-1	Very Low Degradation
0	Unchanged
1	Very Low Veg. Increase
2	Low Veg. Increase
3	Moderate Veg. Increase
4	High Veg. Increase
5	Very High Veg. Increase

3. Results and Discussion

During the 2015 dry season (June-November), there were 21,173 hotspots detect over the peatlands of South Sumatra (See Figure 2). According to the buffer analysis, the extent of the burnt area at the observation area in 2015 was estimated to be 7,132 km^2, or approximately 69 percent of the entire area of peatland in South Sumatra. On the other hand, the spatial analysis presents fires spread evenly in the research area. Next, the identification of vegetation density before and after the 2015 fire period was carried out in the buffer area which is considered as a burnt area.

In 2013, the vegetation density index shows the state of the research area which is dominated by very high and high vegetation density classes. As shown in Figure 3, the eastern half of South Sumatra's peatlands have very high vegetation density characteristics, while the rest ranges between moderate and low vegetation density. While the NDVI analysis in 2016 shows a different condition, most of the observations area was dominated by high and moderate vegetation density classes. Significant changes took place in the eastern part of the observation area, where most of the area was classified as medium and low vegetation density classes. Noted, due to the availability of data and information, the southeastern part of the observation area was identified as a non-vegetation class in 2013 and 2016.

The comparison of the area of vegetation density in 2013 and 2016 in each class is presented in Figure 4. The decrease in area occurred in the very high and high density classes, while the increase in area occurred in the moderate and low density classes. these findings indicate that the fires event in 2015 caused the surface vegetation in the study area to be degraded.

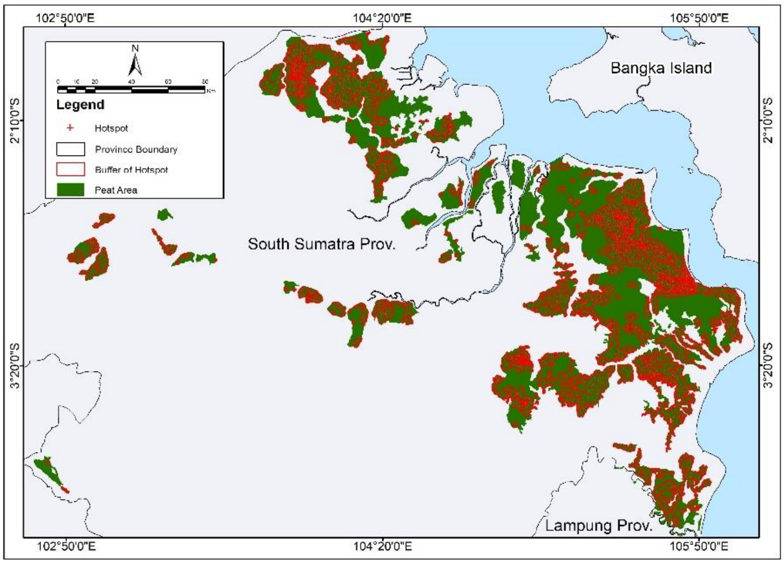

Fig. 2. The hotspots distribution and burned areas on South Sumatra peatlands in 2015.

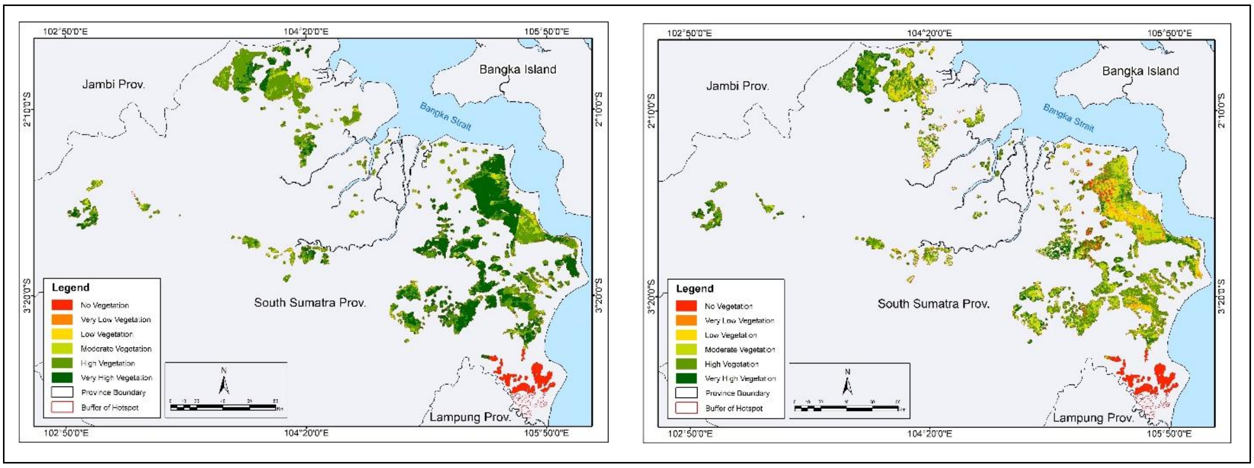

Fig 3. Vegetation density levels before and after 2015 fire event (left: 2013, right: 2016)

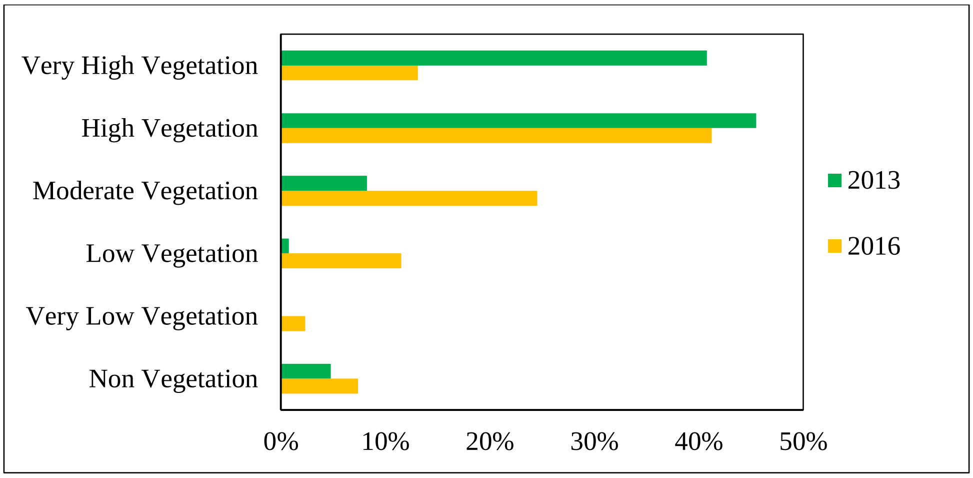

Fig. 4. Comparison of vegetation density areas between 2013 and 2016

The land cover change in the research area is the result of the 2013 and 2016 ndvi map overlays (figure 3). During the observation period, there were two types of land cover changes, namely a decrease (degradation) and an increase in the density of surface vegetation (vegetation increase). Based on table 3, land cover change is dominated by degradation, where 53% of the study area experienced a decrease in vegetation density classes with varying degrees. While the rest did not experience a change in vegetation density (about 34%) and another 11% experienced an increase in vegetation density. The changes that occur are closely related to the 2015 peat fire period, where the burned area (figure 2) experienced a decrease in vegetation density class or was degraded. On the other hand, the increase in vegetation density in a small part of the study area was forced by vegetation growth during the observation period.

Table 3. Percentage of land cover change in MK-PHR area

Changed Class	Hectare	%
Very high degradation	11,301.90	1.70
High degradation	9,817.19	1.48
Moderate degradation	48,282.49	7.26
Low Degradation	106,843.32	16.05
Very low degradation	181,928.17	27.34
Unchanged	230,297.37	34.61
Very Low Veg. Increase	69,164.22	10.39
Low Veg. Increase	7,583.04	1.14
Moderate Veg. Increase	264.53	0.04
High Veg. Increase	9.73	0.00
Total	665491.98	100.00

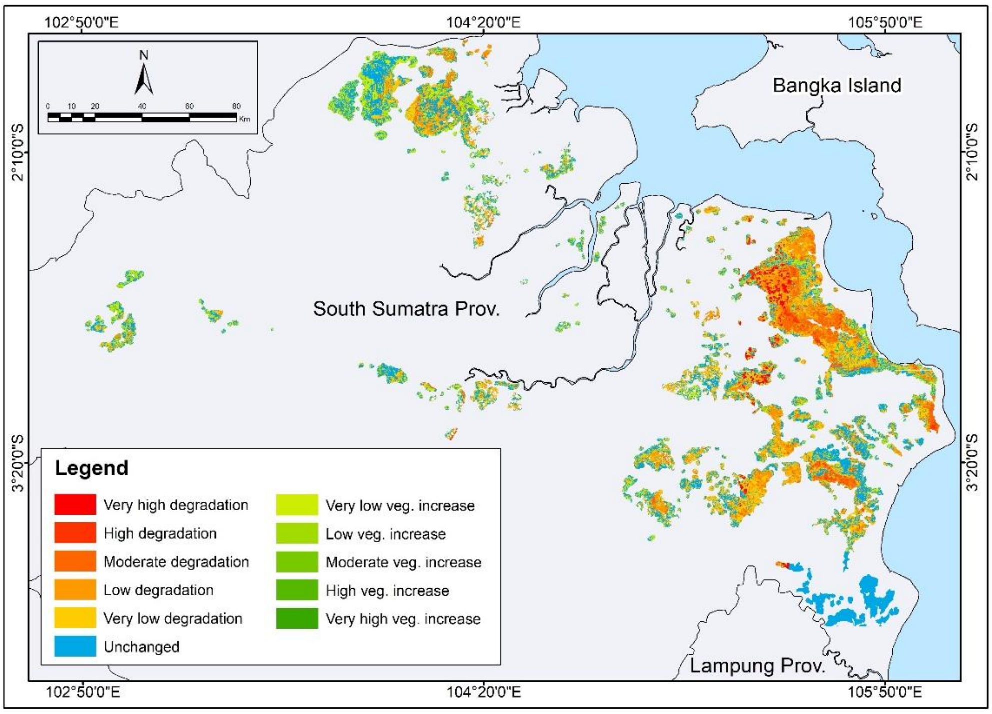

Fig. 5. The levels of changes in vegetation density due to the 2015 fire event

More than half (64%) of burned and degraded peatlands had been identified as a fern/ shrub land cover class. The land cover type of industrial plantation and secondary PSF (peat swamp forest) was estimated to 24% degradation of the total burned and degraded peatlands (See Table 4). Surprisingly, the industrial plantation was burned and degraded since this type of land cover was considerably managed land. In addition, fire and degradation in secondary PSF class indicated that fire was used for land preparation, as mentioned in several previous studies (Miettinen et al., 2012a).

Those negative impacts, as above-mentioned was an alarming rate to many crises. Some policy reformation is needed to alleviate the management failures of peat fires. Future improvements and actions should be conducted, such as forest policy reform, improved land use planning, improved governance, addressing market failures, and other changes (Pagiola, 2000). To prevent and make sustainable forest management, many stakeholders, who play important roles, should make the system works and better to avoid future possible peat fire events.

Table 4. Distribution of land degradation based on the land-use class due to 2015 fire event

Land Cover Class	Degradation (Ha)					Total	
	Very high	High	Moderate	Low	Very low	Ha	%
Ferns/ Shrub	8,255.28	5,583.67	25,958.26	67,483.20	123,211.62	230,492.03	64.55
Small holder area	495.23	775.21	670.98	2,135.47	7,393.53	11,470.41	3.21
Secondary PSF	50.32	250.87	4,670.26	12,793.79	20,892.85	38,658.09	10.83
Industrial plantation	519.63	2,477.06	14,901.68	14,906.26	15,037.94	4,7842.57	13.40
Cleared area	1,888.75	442.21	1,984.27	8,360.62	11,884.05	24,559.90	6.88
Built-up area	28.60	106.93	31.99	48.06	330.51	546.09	0.15
Primary PSF	0.84	0.56	26.98	908.74	2,584.03	3,521.16	0.99

4. Conclusions

The severe peat fires event in 2015 had burned more than half area (69%) of South Sumatra peatlands. The change of vegetation density indicated not only degraded vegetation but also vegetation regeneration based on observed pre- and post-fire event. The majority of vegetation density change in the 2015 was caused by land degradation, in which the classes of vegetation density turned into a lower class. The total of land degradation area remained of 53% of the total burned area with varying levels of degradation. All land cover classes in the burned area were degraded due to fires with varying percentages. The results point out that peatland fires had a negative impact and became a serious issue on peat ecosystems in the research area. South Sumatra's peatlands are still potentially at high risk of peat degradation since the land cover is dominated by ferns/ shrub. The prevention and proper forest management are needed to avoid future degradation of peat ecosystems.

5. acknowledgments

This study is fully funded by the “Guru Besar Under 45 (GBU45)” research scheme from Institut Teknologi Sumatera (ITERA).

References

Agus, F., Henson, I., Sahardjo, B.H., Harris, N., van Noordwijk, M., Killeen, T., 2013. Review of emission factors for assessment of CO2 emission from land use change to oil palm in Southeast Asia 7–28.

Bharathkumar, L., Mohammed-Aslam, M.A., 2015. Crop Pattern Mapping of Tumkur Taluk Using NDVI Technique: A Remote Sensing and GIS Approach. Aquat. Procedia 4, 1397–1404. https://doi.org/10.1016/j.aqpro.2015.02.181

Harrison, M.E., Page, S.E., Limin, S.H., 2009. The global impact of Indonesian forest fires. Biologist 56, 156–163.

Hooijer, Aljosja, Silvius, Marcel, Wösten, Henk, Page, Susan, Hooijer, A, Silvius, M, Wösten, H, Page, S, 2006. PEAT-CO2, Assessment of CO2 emissions from drained peatlands in SE Asia. Delft Hydraul. Rep. Q3943 36.

Jaenicke, J., W??sten, H., Budiman, A., Siegert, F., 2010. Planning hydrological restoration of peatlands in Indonesia to mitigate carbon dioxide emissions. Mitig. Adapt. Strateg. Glob. Chang. 15, 223–239. https://doi.org/10.1007/s11027-010-9214-5

Koplitz, S.N., Mickley, L.J., Marlier, M.E., Buonocore, J.J., Kim, P.S., Liu, T., Sulprizio, M.P., DeFries, R.S., Jacob, D.J., Schwartz, J., Pongsiri, M., Myers, S.S., 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. Environ. Res. Lett. 11. https://doi.org/10.1088/1748-9326/11/9/094023

Marlier, Miriam E., Defries, R., Pennington, D., Nelson, E., Ordway, E.M., Lewis, J., Koplitz, S.N., Mickley, L.J., 2015a. Future fire emissions associated with projected land use change in Sumatra. Glob. Chang. Biol. 21, 345–362. https://doi.org/10.1111/gcb.12691

Marlier, Miriam E, DeFries, R.S., Kim, P.S., Gaveau, D.L.A., Koplitz, S.N., Jacob, D.J., Mickley, L.J., Margono, B.A., Myers, S.S., 2015. Regional air quality impacts of future fire emissions in Sumatra and Kalimantan. Environ. Res. Lett. 10, 054010. https://doi.org/10.1088/1748-9326/10/5/054010

Marlier, Miriam E., DeFries, R.S., Kim, P.S., Koplitz, S.N., Jacob, D.J., Mickley, L.J., Myers, S.S., 2015b. Fire emissions and regional air quality impacts from fires in oil palm, timber, and logging concessions in Indonesia. Environ. Res. Lett. 10. https://doi.org/10.1088/1748-9326/10/8/085005

Meneses-Tovar, C.L., 2011. NDVI as indicator of degradation. Unasylva 62, 39–46.

Miettinen, J., Hooijer, A., Wang, J., Shi, C., Liew, S.C., 2012a. Peatland degradation and conversion sequences and interrelations in Sumatra. Reg. Environ. Chang. 12, 729–737. https://doi.org/10.1007/s10113-012-0290-9

Miettinen, J., Shi, C., Liew, S.C., 2016. Land cover distribution in the peatlands of Peninsular Malaysia, Sumatra and Borneo in 2015 with changes since 1990. Glob. Ecol. Conserv. 6, 67–78. https://doi.org/10.1016/j.gecco.2016.02.004

Miettinen, J., Shi, C., Liew, S.C., 2012b. Two decades of destruction in Southeast Asia’s peat swamp forests. Front. Ecol. Environ. 10, 124–128. https://doi.org/10.1890/100236

Page, S.E., Hooijer, A., 2016. In the line of fire: the peatlands of Southeast Asia. Philos. Trans. R. Soc. B Biol. Sci. 371, 20150176. https://doi.org/10.1098/rstb.2015.0176

Page, S.E., Rieley, J.O., Shotyk, W., Weiss, D., 1999. Interdependence of peat and vegetation in a tropical peat swamp forest. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 354, 1885–1897. https://doi.org/10.1098/rstb.1999.0529

Pagiola, S., 2000. Land Use Change in Indonesia. Environment Departement, World Bank

Putra, R., Sutriyono, E., Kadir, S., Iskandar, I., 2019. Understanding of fire distribution in the south. Int. J. GEOMATE 16, 146–151.

Sloan, S., Locatelli, B., Wooster, M.J., Gaveau, D.L.A., 2017. Fire activity in Borneo driven by industrial land conversion and drought during El Niño periods, 1982–2010. Glob. Environ. Chang. 47, 95–109. https://doi.org/10.1016/j.gloenvcha.2017.10.001

Thorburn, C.C., Kull, C.A., 2015. Peatlands and plantations in Sumatra, Indonesia: Complex realities for resource governance, rural development and climate change mitigation. Asia Pac. Viewp. 56, 153–168. https://doi.org/10.1111/apv.12045

Wahyunto, Ritung, S., Suparto, H. Subagjo, 2004. Map of Peatland Distribution Area and Carbon Content in Kalimantan.