Forest Fire Occurrence in Berbak Sembilang National Park Jambi Province on 2000-2018 and its relationship with fuel load

A M Mora¹*, B H Saharjo¹ and L B Prasetyo²
¹ Department of Silviculture, Faculty of Forestry, IPB University (Bogor Agricultural University), Bogor, Indonesia
² Department of Forest Resources and Conservation & Ecotourism, Faculty of Forestry, IPB University (Bogor Agricultural University), Indonesia

*Corresponding author e-mail: andita_mimo@apps.ipb.ac.id

Abstract. There are many researches on forest and land fires has been carried out, however, forest and land fires in Indonesia still occur every year. It has been a historical record that in 1982-1983 forest and land fires in West Kalimantan which burned an area of 3.6 million hectares seemed not to be a lesson in monitoring fire, especially in forest areas. Berbak Sembilang National Park (TNBS) consists of ecosystems of peat swamps and freshwater swamps which are very vulnerable to fire especially during long drought and severe dry season. Fires in 2015 brought a major impact to people in Sumatra Island. This research analyzed hotspot occurrences on different land cover and land use in TNBS. Hotspot were analyzed by using Getis-Ord-Gi*. The result showed that repeated fires continue to occur in the TNBS area every year either during El-Nino or La-Nina period, resulting on ecological change in TNBS.

1. Introduction
Fire in tropical forests of continental Southeast Asia is dependent on three conditions that must occur simultaneously, e.g (a) dry microclimatic conditions, (b) available fuels and (c) an ignition source. In Southeast Asia have long been poorly studied about peat swamp forests and our current knowledge of their composition, dynamics, and ecology.

Berbak Sembilang National Park (TNBS) consists of two ecosystem types of freshwater swamp forest and peat swamp forest. Freshwater swamp forest at TNBS characterized by the existence of large Pulai Alstonia pneumatopore including Antidesma montanum, Baccara bracteata, and abundance of palms. There was noted of 261 flowering species found in TNBS, of which 67% of them are tree and shrub, 17% liana and herbs and epiphytes 8% [1]. TNBS covers 12% of peat land area in Jambi Province, 79% hotspot were situated in Berbak National Park. Knowledge on the remote sensing system is obviously essential for monitoring real time fire data such as one that derived from MODIS sensor [2]. Sentinel-2 is designed to provide multispectral data to maintain continuity of Land Use and Land Cover Change (LULCC) relates with a forest fire.

In this study, we evaluated the history of fire in TNBS and fuel loading after forest fire occurrence. Overlying hotspot, fuel load and land cover has been useful approach to deliniating fire events in spatial terms.
2. Method

2.1. Location
TNBS located in Jambi and Sumatera Selatan Provinces with an area of approximately 200,000 hectares. TNBS forms part of the vast alluvial coastal plain of eastern Sumatra, that is assumed to have formed about 5,000 years BP. Evidence indicates that sea levels have dropped about two meters during the past 5,000 years, with sediments – mainly supplied by the Batanghari River – accumulating along the accreting coastline. On the highly weathered sediments, peat has formed, with an average age of about 4,500 years, and in some areas with a depth of more than 20 meters [3]. Berbak is very flat, and at no point is the elevation more than about 15 meters.

2.2. Forest and land fire history
Hotspot data from 2000 – 2018 were downloaded from MODIS active fire data. The hotspot data were selected based on 80% confidence level. Hotspot distribution was analyzed by using Getis-Ord-Gi* statistic, a spatial analysis tool in ArcGIS software (Formula 1, 2, and 3).

\[
G_i^* = \frac{\sum_{j=1}^{n} w_{ij} X_j - \sum_{j=1}^{n} w_{ij} \bar{X}}{\sqrt{\frac{\sum_{j=1}^{n} w_{ij}^2 (\sum_{j=1}^{n} w_{ij})^2}}}
\]

\[
\bar{X} = \frac{\sum_{j=1}^{n} X_j}{n}
\]

\[
\bar{S} = \sqrt{\frac{\sum_{j=1}^{n} X_j^2}{n} - (\bar{X})^2}
\]

Where:
- \( x_j \) is attribute value for feature \( j \)
- \( w_{ij} \) is the spatial weight between feature \( i \) and \( j \)
- \( n \) is equal to the total number of feature.

Since the input data was point feature (hotspot data), the tools will cluster the hotspot points based on the number of hotspot occurrence points per grid (fishnet) that derived during processing. Based on tools determine statistically the significant spatial clusters with high values automatically (called hotspots) on low values (called as cold spots) and not significance area. Further, the hotspot and cold spot area was classified into 90%, 95% and 99% probability occurrence.

2.3. Relationship of fire to land use and land cover
The land cover identified from 2000-2018 based on visual classification of Sentinel 2. Classification technique used on key identification an object such as on color, tone, size, shape, texture, pattern, site and association. Land use and land cover after fire occurrence determined based on Sentinel data a year before fire occurrence (hotspot acquisition), meanwhile land use and land cover after occurrence determined based on Landsat taken 3 years after fire occurrence. This period of fire is determined to identify the land-use type clearly.

2.4. Fuel loading and fire history
Surface fuel assessments were done post-burned areas accompanied by peat burnt using the quadratic method (square plot – has been modified from [4] and methods developed during the KFCP project [5]. Heavy fuels (> 7.5 cm) are measured in square transects of 120 m long (30 m each). The diameter of each type of fuel (dry or dead branches, roots, branches etc.) transversely above this triangular transect is required at the intersection point. Medium fuel (2.5-7.5 cm) is measured in a square transect with a length of 40 m (10 m each side). Fine fuel using a 1 m × 1 m plot built on each side of 120 m
square transect. All fuels must be stored to a large plastic bag, then weighed and dried oven to meet a constant weight.

| No | Fuel type     | Fuel size |
|----|---------------|-----------|
| 1  | Fine fuel     | <2,5 cm   |
| 2  | Medium fuel   | 2,5-7,5 cm|
| 3  | Heavy fuel    | > 7,5 cm  |

Table 1. Fuel type and size

Figure 1. Layout for the fuel assessment using quadratic method

3. Result and discussion

3.1. Distribution of hotspot

There were 32,501 hotspot occurrences in TNBS. Among them 12,084 hotspot were selected, in which is having probability 80% of confidence level. Hotspot occurred either during drought condition of El Niño in the year of 2004, 2006, 2009 and 2015 or wet condition of La Niña in the year of 2011 and 2012 (Fig 2 and 3). There was no relationship between climate anomalies with the number of hotspot after 2012. * Gispatial statistic showed that most of hotspot occurrences in an area surrounded TNBS categorized as hotspots area with confidence level more than 90%.

Repeated and high frequency of fire events will eventually alter the ecosystem in the direction of the grass swamp ecosystem or swamp forest. During 2000 to 2018, land cover before fire occurrences in every year mostly the same, in which dominated by mixed fields and agricultural fields, followed by primary swamp forest, secondary swamp forest, primary mangrove forest, secondary mangrove forest and burnt area.
3.2. Relationship of fire to land and land cover

Most of hotspot occurrences in TNBS found in the burned area classified as secondary swamp forest” (Fig 5). Larges fires in TNBS occured an all of land cover there in 1997/1998 [6] when the area had more fuel load. Less fire is found during the periode of 2000-2018 as recurrant fires in the area consumed the biomass, providing less fuel load to be consumed in 2000-2018 fire episodes.
Table 2. Percentage of hotspot in TNBS based on Land Cover, hotspot percentage on 2000-2018

| Land Cover         | Hotspot percentage | Total |
|--------------------|--------------------|-------|
|                    | 2002 | 2003 | 2004 | 2006 | 2009 | 2011 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 |       |
| Primary swamp forest| 0.00 | 0.02 | 0.01 | 0.01 | 0.04 | 0.03 | 0.16 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.45  |
| Secondary swamp forest| 0.00 | 0.04 | 0.07 | 0.05 | 0.06 | 0.10 | 0.37 | 0.00 | 0.41 | 0.00 | 0.00 | 0.10 | 1.24  |
| Primary mangrove   | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00  |
| Secondary mangrove | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00  |

Table 3. Percentage of hotspot around TNBS based on Land use on 2000-2018

| Land Cover  | Hotspot percentage | Total |
|-------------|--------------------|-------|
|             | 2002 | 2003 | 2004 | 2006 | 2009 | 2011 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 |       |
| Fields      | 0.00 | 1.42 | 5.12 | 2.74 | 4.38 | 7.64 | 8.76 | 0.00 | 8.9  | 0.00 | 0.00 | 2.39 | 41.35 |
| Mixed field | 0.00 | 5.43 | 7.89 | 4.32 | 8.97 | 9.8  | 1.89 | 0.00 | 6.98 | 0.00 | 0.00 | 6.5  | 51.78 |
| Plantation  | 0.00 | 2.34 | 9.85 | 4.32 | 3.21 | 1.47 | 1.56 | 0.00 | 1.39 | 0.00 | 0.00 | 1.92 | 26.06 |

3.3. Fuel loading and hotspot

Fuel load is important for tropical ecosystems. In these research fuel load measured in two of land cover (primary swap forest, and secondary swap forest). Figure 5 shows that heavy fuel biomass (diameter >7.5 cm) is found dominated in every land cover than medium and fine fuel. Heavy fuel with diameter > 7.5 cm is primarily comprised of cellulose (41-53%), hemicellulose (15-25%), and lignin (16-33%). While medium and heavy fuel is dominated by cellulose and hemicellulose with smaller lignin components. Therefore, as woody materials decay, the relative proportion of lignin in the remaining biomass increase, potentially becoming as high as 65% [7][8]. The substances in heavy fuels like chemical compounds and volatile oils having a very high energy contents and resulting to its ease to burn.

![Figure 5. Fuel load in Land Cover in TNBS](image-url)
4. Conclusion
For both inside and outside TNBS landscapes, the protection area and restoration of fire-damage area should be done in TNBS to avoid rapid forest degradation and future loss of carbon stored in these peat swamp forest. Heavy fuel load is found higher in TNBS, and therefore enhance probability higher fire risk in TNBS.

Acknowledgments
The research is funded by the Ministry of Research, Technology & Higher Education of Indonesia, under Research Grant PMDSU. The authors would like to convey gratitude for continuous support.

References

[1] Giesen W 2004 Part of the project on “Promoting the river basin and ecosystem approach for sustainable management of SE Asian lowland peat swamp forests: Case study Air Hitam Laut river basin, Jambi Province, Indonesia.” Water for Food and Ecosystems Programme.
[2] Active Fire Data | Earthdata. [Online]. Available: https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data. [Accessed in Februari 05 2019].
[3] Scholtz U 1983 – The Natural Regions of Sumatra and their agricultural production pattern. A Regional Analysis. Ministry of Agriculture [Bogor: Gaya Teknik Press]
[4] Schophuys, Van Wagner C E 1982 Practical Aspects of the Line Intersect Method. Information Report PI-X-12. (Ontario: Petawawa Canadian National Forestry Institute).
[5] Graham L, Manjin S, Juni T E, Waldram M, Massal F, Ichsan N, Fatkhurohman, Applegate G 2014 KFCP Heavy Fuel Load Assessment Line. (Central Kalimantan: Kalimantan Forests and Climate Partnership)
[6] Mudiyarso D, Widodo M and Suyamto D 2002 Science in China, Series C. 45, 71.
[7] Pyne S J 1996 Introduction to Wildland Fire (New York: John Willey & Sons).
[8] Cochrane M A 2009 Tropical Fire Ecology. (Chichester:Praxis Publishing).