Putra et al. 2019 J. Geomate

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International Journal of GEOMATE, Feb., 2019 Vol.16, Issue 54, pp.146 - 151
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.54.8243
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

UNDERSTANDING OF FIRE DISTRIBUTION IN THE SOUTH SUMATRA PEAT AREA DURING THE LAST TWO DECADES

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*Corresponding Author, Received: 15 Oct. 2018, Revised: 30 Nov. 2018, Accepted: 25 Dec. 2018

ABSTRACT: Peat fire is an annual catastrophic event in Indonesia, particularly in South Sumatra region during the dry season. Several previous studies have suggested that anthropogenic forces (land cover) contribute to peat fires. Analysis of the hotspots distribution on land cover types is needed to address peat fires in the futures. This study is aimed to evaluate the distribution of hotspots on the land cover type of the South Sumatra peat area during the last two decades (1997-2016). Remote sensing technique with visual image interpretation method using multitemporal satellite images is used to identify the variations of land cover in the study area. The results showed that the peat area of South Sumatra in 2013 dominated by ferns/ shrub (58%) and only about 10% covered by peat swamp forest (PSF). The largest hotspot distribution during the observation periods was spread in land cover types of Ferns/ shrub (34.808 hotspots) and Industrial Plantation (7.223 hotspots). Note that the densest hotspot located in the industrial plantation with an average of 37 hotspots/ 100 km^2 / year. Meanwhile, only a small percentage of the hotspots located in PSF and occurred consistently over the last five years of observation periods. Based on results, the South Sumatra peatland is very vulnerable to burn during the dry season in the future. The government as policy maker must protect the existence of PSF and keep the ferns/ shrub from the fires and subsequent land cover changes (Industrial plantation or small holder area).

Keywords: Peatland, Peat Fire, Hotspots, Land Cover

1. INTRODUCTION

Peat fire is an annual catastrophic event in Indonesia, particularly in South Sumatra region during the dry season. The severe peat fires in the last two decades occurred in 1997 and 2015, where the event coincided with extreme dry season due to the strong El Niño and positive IOD [1]. In 2015, fires burned more than 0.6 million hectares of peatland in the Sumatra, Kalimantan and Papua regions during July-October. This event resulted in haze disasters in the regions of Indonesia, Singapore, and parts of Malaysia [2,3].

Haze disaster due to peat fires causes serious problems for humans and the environment. Human health is the main problem when a haze disaster occurs. There were 19 cases of death and half a million cases of respiratory disease in Indonesia during the 2015 fire event [3,4]. Moreover, peat fire events emit carbon into the atmosphere which contributes to global warming. Over September-October 2015 the rate of carbon emitted was 11.3 Tg of CO_2 /day, this is the worst carbon emissions since 1997 caused by fires event [5]. In that event, South Sumatra peatland became the region with the worst impact of fire compared to other regions based on the data of the Indonesian Ministry of Environment, 2016.

Several previous studies have suggested that anthropogenic force (land use) contribute to peat fires [6–8]. Fire is widely used in the land clearing and preparation of agriculture and plantations on a small and large scale [9,10]. land preparation by fires is considered to improve the efficiency of productions costs. But in practice, land preparation by fires on peatlands is difficult to control because peat material is flammable and the thickness varies [11]. In addition, the peatland utilization for agriculture changes the natural hydrological system, which causes the condition of peatlands to be drier and susceptible to fire during the dry season [12].

During the past two decades in current management practices, Indonesia's peatlands have been seriously degraded due to fire, deforestation and anthropogenic drainage [11,13]. This study will identify land cover of South Sumatra peat areas and evaluate the distribution of hotspots on the land cover type of the South Sumatra peat area during the last two decades (1997-2016). It's important to understand the characteristics of the hotspot distribution on different types of land cover so that future fires events can be predicted and addressed properly.

2. DATA AND METHODS

2.1 Study Area

The study area is South Sumatra's peatlands with an area of 1.48 million ha which has varying levels of depth and peat maturity [14]. Most of South Sumatra's peatlands are spread in the northern part of South Sumatra area (Fig.1). The condition of peatlands in the study area has been degraded from the PSF land cover type to unmanaged type (ferns/ shrub) and managed land cover type (agriculture or plantation) [15–17].

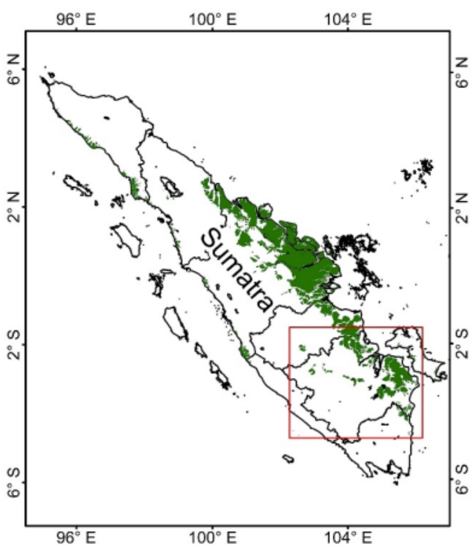

Fig. 1 Study area (red line present South Sumatra region and green shading indicate a peatland area)

2.2 Satellite Data

To identify the land cover types of South Sumatra peat areas, this study uses Landsat 7 and 8 satellite imagery were recorded in April-August 2013. This satellite image has a spatial resolution of 30 meters with an area coverage of 185 x 185 km. While the validation of classified data using high-resolution satellite images of Spot 5 and 6 was recorded in 2013 (data derived from The Indonesian National Institute of Aeronautics and Space / LAPAN Indonesia). This high-resolution image data has a spatial resolution of 5 meters with a coverage area of 60 x 60 km.

2.3 Classification of Land Cover

The land cover classification in this study is based on literature review [18] and regulations of the Indonesian Ministry of Environment and Forests of 2015 on land cover monitoring guidelines. The classification scheme classifies land cover into 8 types of land cover (Built-up area, Cleared area, Ferns/ Shrub, Industrial plantation, Primary Peat Swamp Forest/ PSF, Secondary PSF, Small holder area, and Water). The classification method is a visual image interpretation method, where classification is carried out in stages to produce 8 types of land cover in the study area.

2.4 Hotspot Data

The data of the hotspot distribution used in this study sourced by Along Track Scanning Radiometer World Fire Atlas (ATSR-WFA Algorithm 2) for observation during 1997-2002. The ATSR-WFA Algorithm 2 data has a spatial resolution of 1 km and the hotspot is identified when the surface temperature reaches ≥ 308 Kelvin [19]. While for observation during 2003-2016, this research uses Moderate Resolution Imaging Spectroradiometer (MODIS) and data of Visible Infrared Imaging Radiometer Suite (VIIRS) from Fire Information For Resource Management System (FIRMS) website. VIIRS data has a better resolution of 375 m compared to MODIS data which has a resolution of 1 km [20,21].

3. RESULTS AND DISCUSSION

Identification of land cover in the study area in 2013 shows that more than half (58%) of South Sumatra's peatlands were dominated by ferns/shrubs (Fig.3). Meanwhile, only 10% or approximately 1500 km^2 of the peatland were covered by Peat Swamp Forest (PSF) and most of them were under the management of protected forests in the northern part of South Sumatra (Fig.2). Furthermore, at least 21% of The South Sumatra peatland is occupied by the managed land cover (Industrial plantation and Small Holder area). The results show the variation of land cover that is relatively comparable with some previous research [15,22]. Furthermore, the land cover map was used as a spatial analysis material for hotspot distribution data in the study area over two decades of observation.

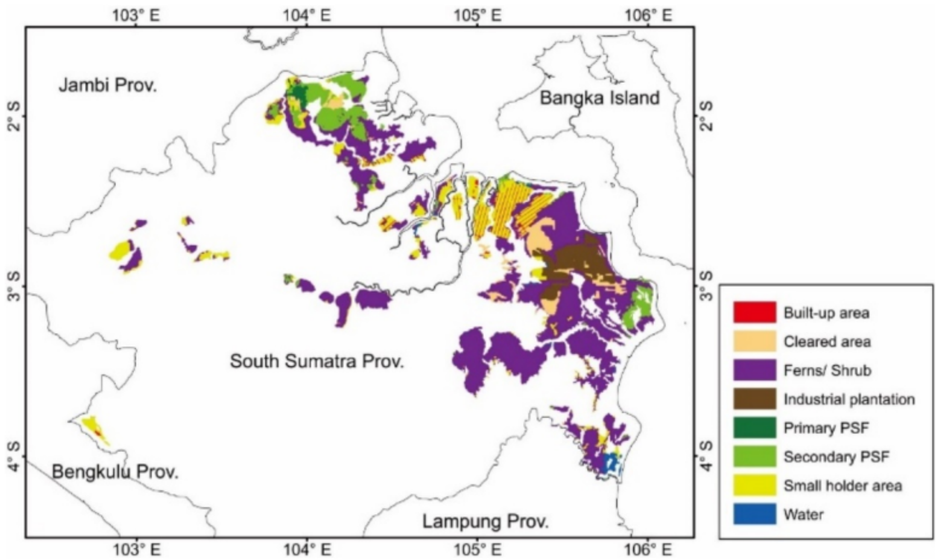

Fig. 2 Land cover classification map of South Sumatra peat area

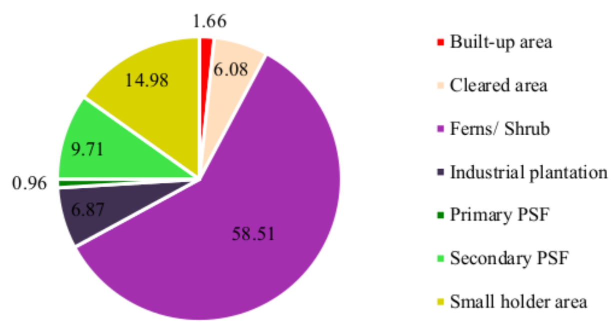

Fig. 3 Percentage of land cover on the South Sumatra peat area

In the last two decades, there have been three great peat fires events in South Sumatra (1997, 2006, and 2015). The events coincided with the phenomenon of El Niño – Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) which resulted in extreme deficit rainfall in Indonesia particularly in the South Sumatra region [1,23]. At least more than 37000 hotspots detected in the research area during those three events, with a density of 2 hotspots / km^2. While during 1998 and 2000-2001 Hotspot is almost undetectable in the South Sumatra peatland. Based on observations, 2015 is the largest fire event in the research area, where the hotspots are detected across the land cover types (Table 1).

The largest spread of hotspot during the last two decades was in land cover types of Ferns/ shrub (34.808 hotspots) and Industrial Plantation (7.223 hotspots). While the land cover types of built-up area and primary PSF were the land cover that has the least hotspot. The land cover type of industrial plantation has the highest density of hotspots in the last two decades. In 2015, the densest hotspot was in the primary PSF (5 hotspots / km^2), which is interesting because in previous years the hotspot was in the land cover type of industrial plantation.

Table 1. Distribution and density of hotspots on several variations of land cover, note that the density of hotspots is presented per 100 km (BUA: built-up area, CA: cleared area, F/S: ferns/ shrub, IP: industrial plantation, P-PSF: primary peat swamp forest, S-PSF: secondary peat swamp forest, and SHA: small holder area)

Year	BUA		CA		F/S		IP		P-PSF		S-PSF		SHA		Total Hotspot
	hs	dens	hs	dens	hs	dens	hs	dens	hs	dens	hs	dens	hs	dens	
1997	2	1	529	62	2707	33	874	90	8	6	94	7	327	15	4761
1998	0	0	0	0	1	0	0	0	0	0	0	0	7	0	8
1999	0	0	1	0	1	0	117	12	0	0	0	0	10	0	142
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	1	0	0	0	2	0	2	0	0	0	0	0	1	0	7
2002	0	0	93	11	53	1	149	15	0	0	0	0	12	1	334
2003	13	6	13	2	198	2	25	3	1	1	7	1	200	9	488
2004	20	9	206	24	1918	23	384	40	7	5	96	7	318	15	3094
2005	5	2	6	1	70	1	1	0	2	1	4	0	77	4	175
2006	33	14	1373	160	4930	60	1667	172	1	1	192	14	830	39	9519
2007	3	1	11	1	282	3	6	1	1	1	7	1	57	3	383
2008	3	1	20	2	239	3	34	4	0	0	5	0	58	3	379
2009	21	9	78	9	2144	26	47	5	3	2	109	8	194	9	2675
2010	0	0	14	2	32	0	0	0	0	0	3	0	17	1	69
2011	6	3	83	10	2528	31	154	16	12	9	387	28	166	8	3461
2012	13	6	105	12	2771	34	22	2	53	39	625	46	274	13	4030
2013	2	1	4	0	94	1	9	1	6	4	16	1	28	1	172
2014	7	3	547	64	4529	55	627	65	128	95	150	11	310	15	6624
2015	16	7	1865	218	12281	149	3098	320	709	526	2807	205	842	40	23112
2016	0	0	15	2	28	0	7	1	0	0	11	1	4	0	69
Total	**145**	**3**	**4963**	**29**	**34808**	**21**	**7223**	**37**	**931**	**35**	**4513**	**17**	**3732**	**9**	**59502**

The percentage of hotspot distribution in Fig. 4 Indicates hotspots consistently appear on the ferns/ shrub, small holder area, and industrial plantation during the last two decades. While forest cover (primary and secondary PSF) becomes the land cover type that has the least hotspot. But in the last five years (2011-2016) hotspots always appear on forest cover types.

The consistency of hotspots in ferns/shrubs is caused by the dry conditions on the peatlands and vegetation above which are highly vulnerable to burn during the dry season. In addition, the area of ferns/ shrubs that dominate more than half of the South Sumatra peat area is also the cause of hotspots that consistently appear on this type of land cover. As for the hotspots that appear on the type of managed peatland (small holder area, and industrial plantation) indicates that water management in managed peatlands has not proceeded properly during the dry season. In the last five years, hotspots have also consistently appeared in peat swamp forests, where most of the peat swamp forests are under the management of protected forests (conservation). The existence of hotspots in conservation areas can be assumed that illegal logging takes place in this land cover.

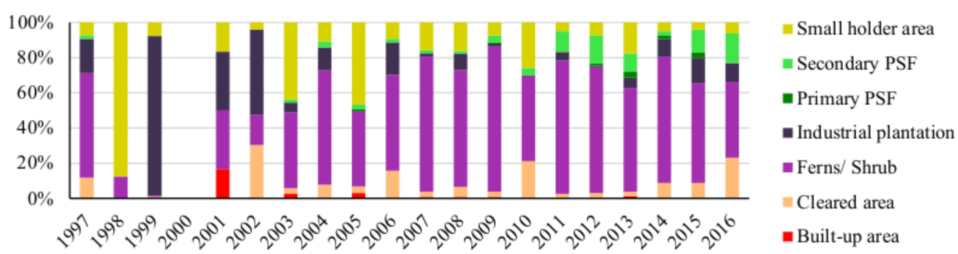

Fig. 4 Percentage of hotspots distribution on several variations of land cover for two decades of observation (1997-2016)

4. CONCLUSION

The land cover classification results indicate that the South Sumatra peatland was in the dangerous condition because the land cover was dominated by ferns/ shrub which is vulnerable to burn. Moreover, in another study [24] represents that the land cover of ferns/ shrub is the stage of intermediate change to the managed land type (Industrial Plantation or Smallholder Area). The largest hotspot distribution during the last two decades was in the land cover type of ferns/shrubs because the South Sumatra peatland was dominated by those land cover type. The highest hotspot density on the land cover type of industrial plantation indicates that the changed in the peat hydrological system result in dry condition and vulnerable peatlands to burn during the dry season.

The forest cover (primary and secondary PSF) is the land cover type that has the least hotspot distribution in the last two decades, although the hotspots appeared consistently in the last five years. The governments as policymakers should be able to protect the existence of peat swamp forests and keep the ferns/ shrub from the fires and subsequent land cover changes (Industrial plantation or small holder area). This is important to avoid the catastrophic haze disaster caused by peat fires in the future.

5. ACKNOWLEDGEMENTS

The first author was supported by the *Pendidikan Magister Menuju Doktor Untuk Sarjana Unggul* (PMDSU) scholarship program from the Ministry of Research, Technology and Higher Education of Indonesia.

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