VEGETATION FIRES IN THE PEATLANDS OF SUMATRA IN 2019

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ABSTRACT: Tropical rain forests in their original undisturbed state do not burn easily. But human intervention such as logging, peatland draining and conversion of natural ecosystems into plantation and small holder agriculture area has made natural ecosystems in the humid tropical insular Southeast Asia vulnerable to fires. During the past decades, vegetation fires in tropical regions have attracted attentions and become an important global environmental issue. The peatlands of Sumatra, especially in the provinces of Riau, Jambi and South Sumatra, have been the main fire areas. In this study we used Moderate Resolution Imaging Spectroradiometer (MODIS) active fire hotspots, peatland distribution maps and a peatland land cover map to investigate the temporal and spatial distributions and characteristics of fire activity in this region in 2019. We also compared the characteristics of fire distribution in 2019 with the previous 10 years from 2009 to 2018. Our results shown that nearly two third (63.5%) of the fires were located in peatlands that covered 27.25% of the three provinces. The peatland fire density was 4.6 times that of the mineral soils. The hotspots in 2019 were mainly contributed by industrial plantations and small holder areas as in the previous years. However, there was evidence of increasing fire activities in the less managed land cover classes of ferns/low shrub and previously cleared land areas. They were found to have the highest hotspots density suggesting increased land conversion activities in these areas. The total number of hotspots (26627) detected in 2019 was only slightly higher than the average over the previous 10 years. However, the fire season in 2019 lasted until November, unlike the previous 10 years. The longer fire season was due to the dryer and hotter month of November in 2019.

1. INTRODUCTION

Tropical rain forests in their original undisturbed state do not burn easily. But human intervention such as logging, peatland draining and conversion of natural ecosystems into plantation and small holder agriculture area has made natural ecosystems in the humid tropical insular Southeast Asia vulnerable to fires (Miettinen et al. 2012). Vegetation fires result in transboundary haze pollution and carbon emissions contributing to global climate change (Bowen et al. 2000, Page et al 2002, Cochrane 2003, Muridiyarso & Adiningsih 2007). Spatial and temporal distributions and characteristics of vegetation fires have been analysed to provide references for policy making and land use management (Miettinen et al. 2010, Shi et al. 2010). The peatlands of Sumatra, especially in the provinces of Riau, Jambi and South Sumatra, have been the main fire areas in tropical Southeast Asia. In this study we used MODIS active fire hotspots, peatland distribution maps and a peatland land cover map to investigate the temporal and spatial distributions and characteristics of fire activity in this region in 2019. We also compared the characteristics of fire distribution in 2019 with the previous 10 years from 2009 to 2018 as well as hotspots distribution over different land cover/land use types.

As in our previous studies, the current study shows that most of the fires were in peatlands. However, the 2019 fires seem to exhibit different spatial temporal patterns compared to previous years. In 2019, the highest hotspots density occurred in the ferns/low shrub and cleared areas land cover classes instead of in plantations. The total hotspots number was only slightly higher than the annual average over the previous 10 years period, but the fire season in 2019 lasted until November, longer than the previous 10 years.

2. MATERIALS AND METHODS

2.1 Study areas

The study area including 3 provinces of Indonesia: Riau, Jambi and South Sumatra in Sumatra Island (Figure 1). The total study area is 225, 954 km^2. The study area has a humid tropical climate. The weather is hot and humid all year round, with a relatively drier period from June to October. The temporal distribution of fires generally follows the climate and weather pattern, reaching its peak during the dryer month (Miettinen J. 2007).

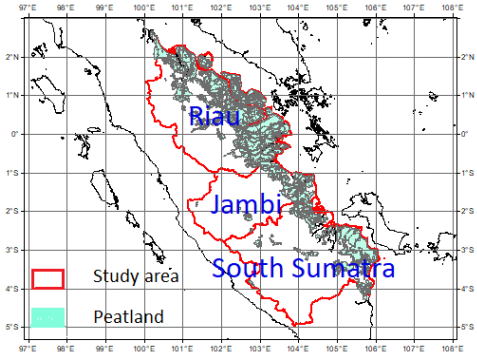

Figure 1. Study areas

The most important feature of the study area is the widely distributed peatland. Previously published atlases by Wetlands International (Wahyunto R. & Subagjo H., 2003) provided the information on the extent and locations of peat areas in the scale of 1:700 000. The study area has about 61,572 km^2 of peatland that covers 27.2% of the total area, mainly in the east coast of the study area. About 40% of peatlands are in Riau, 38% in South Sumatra and 22% in Jambi (Table 1).

Table 1. Peatland distribution in the study area

	Peatland		Mineral soil		Total area
	Area (km^2)	% of province	Area (km^2)	% of province	Area (km^2)
Riau	40114.4	44.5	50074.3	55.5	90188.8
Jambi	7121.0	14.5	42023.3	85.5	49144.3
South Sumatra	14336.2	16.6	72285.0	83.4	86621.1
Total	61571.6	27.2	164382.6	72.8	225954.2

2.2 Hotspots data

Hotspots detected by the MODIS sensors were used in this study (Giglio et al, 2016; Davies et al., 2009). The MODIS sensors on-board the Terra and Aqua satellites acquire data over Sumatra four

times daily. This enables a good detection of general hotspot distribution in this region. All hotspots acquired in year 2019 were analysed to investigate the fire characteristics in the study area. Hotspots from January 2009 to December 2018 were used for historical analysis and comparing with year 2019. Hotspots data were downloaded from NASA's Fire Information for Resource Management System (FIRMS; Davies et al., 2009).

2.3 Peatland land cover map

A land cover/land use map (Miettinen et al. 2016) with 11 classes within peatlands of the study area is for this study (Table 2).

Table 2. Peatland land cover classes of study area

	Riau		Jambi		South Sumatra		Total study area	
Landcover type	Area(Ha)	(%)	Area(Ha)	(%)	Area(Ha)	(%)	Area(Ha)	(%)
Water	3.2	0.1	0.08	0.0	12.03	0.8	15.31	0.2
Seasonal water	20.31	0.5	3.55	0.5	12.21	0.8	36.07	0.6
Pristine PSF	294.98	7.3	71.86	10.7	11.03	0.8	377.87	6.1
Degraded PFS	686.26	16.9	100.43	15.0	76.88	5.3	863.57	13.9
Tall shrub/ secondary forest	86.55	2.1	27.23	4.1	315.01	21.6	428.79	6.9
Ferns/ low shrub	131.83	3.2	42.92	6.4	117.22	8.0	291.97	4.7
Smallholder area	1501.98	37.0	241.04	35.9	271.74	18.7	2014.76	32.5
Industrial plantation	1209.53	29.8	178.09	26.5	618.16	42.4	2005.78	32.4
Urban	3.03	0.1	0.69	0.1	0.04	0.0	3.76	0.1
Clearance	102.27	2.5	5.67	0.8	20.52	1.4	128.46	2.1
Mangrove	22.48	0.6	0.02	0.0	1.95	0.1	24.45	0.4
Total	4062.42	100.0	671.58	100.0	1456.79	100.0	6190.79	100.0

The peatland of Riau and Jambi is dominated by small holders and industrial plantations. Peat swamp forests (pristine and degraded) still covered about one quarter of land area in Riau and Jambi. In South Sumatra peatland, the dominant land cover is industrial plantation (42.4%) followed by tall shrub/secondary forest and small holders, with only 6.1% covered with swamp forest.

2.4 Data analysis

Hotspots data are overlaid on the peatland map and peatland land cover map for analysis of their spatial and temporal distributions. Statistics of hotspots acquired during the preceding 10 year from 2009 to 2018 were calculated for comparison with the 2019 hotspots characteristics.

3. RESULTS

3.1 Spatial hotspots distribution

In total, 26627 MODIS hotspots were registered in the study area in 2019. Among those, 10893 were detected in South Sumatra, 8816 in Riau and 6918 in Jambi (Table 3). The hotspots density is highest in Jambi (14.1/km^2) and lowest in Riau (9.8/km^2). Nearly two third of the fires were

located in peatlands which covered only 27.25% of the study area. The hotspots density was 4.6 times higher in peatlands than in mineral soils. In Jambi, it is 13.2 times more than in mineral soils. Jambi has the highest hotspots density (36.5/km^2) in its peatlands which is much higher than that of Riau (17.1/km^2).

Table 3. Hotspots statistics in peat, mineral soils and total study area

	Peat			Mineral soil			Total study area		
	Number	(%)*	Density**	Number	(%)	Density	Number	(%)	Density
Riau	6876	25.8	17.1	1940	7.3	3.9	8816	33.1	9.8
Jambi	4786	18.0	67.2	2132	8.0	5.1	6918	26.0	14.1
South Sumatra	5239	19.7	36.5	5654	21.2	7.8	10893	40.9	12.6
Total study area	16901	63.5	27.4	9726	36.5	5.9	26627	100.0	11.8

* (%) = percentage of total hotspots detected in 2019 in the study area.
** Density = number of hotspots per 100 square kilometer.

3.2 Temporal hotspots distribution

The 2019 monthly hotspots distribution is shown in Table 4 and Figure 2. Hotspots in Riau peaked in March and August/September. Jambi and South Sumatra had only one peak in September/October. For comparison, the 10-year average monthly hotspots distribution (2019 to 2018) is shown in Table 5. The total number of hotspots detected in 2019 (26627) was only slightly higher than the average over 10 years (22047 per year). However, the fire season in 2019 lasted until November, hotspots count in November 2019 was 1956, much higher than the 10 years average 514. Especially in South Sumatra, hotspots count in November 2019 was 4.5 times higher than the 10 years average (1735 vs. 387). However, the 2019 hotspot count in Jambi was not much different from the 10 years average (48 vs. 44).

Table 4. Hotspots distribution by month in 2019

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Riau	51	658	1342	154	220	140	619	2149	3028	217	171	67	8816
Jambi	6	6	9	10	44	17	153	720	4672	1221	49	11	6918
South Sumatra	10	7	18	21	75	44	114	744	4128	3952	1736	44	10893
Total study area	67	671	1369	185	339	201	886	3613	11828	5390	1956	122	26627

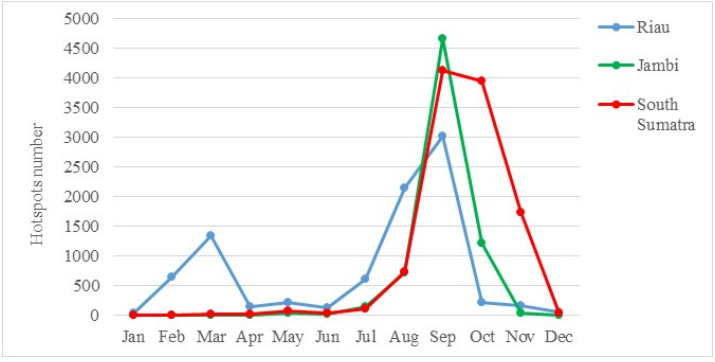

Figure 2. Monthly hotspots distribution in 2019

Table 5. Ten-year average monthly hotspots distribution (2009 – 2018)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (per year)
Riau	385	1470	1364	280	523	2077	1699	1716	682	416	83	45	10741
Jambi	53	52	102	42	97	250	353	643	794	318	44	17	2765
South Sumatra	23	22	38	47	105	219	463	1356	3601	2255	387	27	8541
Total study area	461	1544	1504	369	725	2546	2515	3715	5077	2989	514	89	22047

3.3 Hotspots distribution by land cover types

The hotspots distribution over different land cover types are shown in Table 6. As in previous years, most hotspots occurred in industrial plantations (19.4%), small holders (22.8%) which together accounted for 42.2% of the total hotspots. The next three land cover categories that contributed to the hotspots were degraded peat swamp forests (16.4%), tall shrubs/secondary forest (16.1%) and fern/low shrubs (15.6%). These three classes together accounted for 48.1% of the hotspots. The distribution of hotspots over land cover types are different in the three provinces as shown in Figure 3. In Jambi, the largest number of hotspots occurred in degraded peat swamp forests (36.1%) followed by ferns/low shrub (22.5%), whereas in Riau and South Sumatra, they were in small holder areas (46.2%) and Tall shrubs/secondary forests (40.3%) respectively. About the same proportions of hotspots (~20%) were found in industrial plantations in all three provinces.

Table 6. Hotspots statistics by land cover types in the peatland of study area

	Riau			Jambi			South Sumatra			Total study area		
Land Cover Type	N	%	Density	N	%	Density	N	%	Density	N	%	Density
Water	0	0	0	0	0.0	0.0	1	0.0	0.8	1	0.0	0.6
Seasonal water	12	0.2	5.9	57	1.2	160.5	93	1.8	76.2	162	1.0	44.9
Pristine PSF	33	0.5	1.1	325	6.8	41.3	4	0.1	9.3	362	2.1	9.6
Degraded PFS	480	7.0	7.0	1727	36.1	170.5	560	10.7	73.7	2767	16.4	32.0
Tall shrub/ secondary forest	297	4.3	34.3	320	6.7	117.5	2109	40.3	67.0	2726	16.1	63.6
Ferns/low shrub	807	11.7	61.2	1078	22.5	244.7	758	14.5	65.3	2643	15.6	90.5
Small holder area	3174	46.2	21.5	231	4.8	8.6	442	8.4	16.4	3847	22.8	19.1
Industrial plantation	1390	20.2	11.6	820	17.1	44.4	1075	20.5	17.5	3285	19.4	16.5
Urban	9	0.1	29.7	0	0.0	0.0	0	0.0	0.0	9	0.1	24.0
Clearance	670	9.7	65.5	228	4.8	351.6	197	3.8	100.0	1095	6.5	85.2
Mangrove	4	0.1	1.8	0	0.0	0.0	0	0.0	0.0	4	0.0	1.6
Total	6876	100.0	17.1	4786	100.0	66.9	5239	100.0	36.4	16901	100.0	27.4

* Density = number of hotspots per 100 square kilometer.

In terms of hotspots density, however, the highest density was found in the Ferns/low shrub (90.5/100km^2) and Clearance (85.2/100km^2) classes that occupy, respectively, only 4.7% and 2.1% of the study area. These two land cover classes were areas under conversion and fires were probably used for land clearing in preparation for conversion. Pristine peat swamp forest and mangrove have very low hotspots density of 9.6/100km^2 and 1.6/100km^2 respectively. The fire density in industrial plantations (16.5/km^2) and small holders (19.1/km^2) was not as high as in previous years (Shi et al. 2010, Miettinen et al. 2016).

In summary, our results suggest that vegetation fire characteristics in insular Southeast Asia vary significantly between peat and mineral soil areas and are strongly dependant on land cover types which are probably influenced by land management issues.

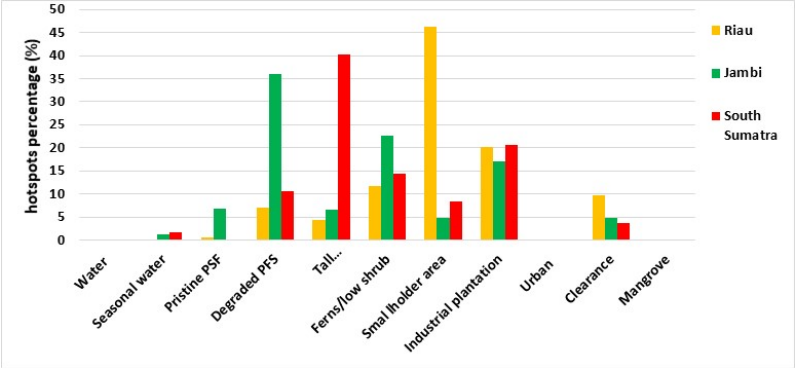

Figure 3. Hotspots percentage in the three provinces by land cover types

4. DISCUSSION AND CONCLUSION

In this study, we analysed the spatial distribution of MODIS hotspots in the year 2019 in three provinces of Sumatra, i.e. Riau, Jambi and South Sumatra. Among the total of 26627 detected hotspots, South Sumatra had the most hotspots (40.9%), followed by Riau (33.1%) and Jambi (26.0%). In terms of hotspots density, Jambi had the highest density (14.1/km^2) which is only slightly higher than the average of 11.8/km^2 in the whole study area.

The hotspots density in peatlands (27.4/km^2) was much higher than in mineral soils (5.9/km^2). Peatlands of Jambi has the highest density (67.2/km^2), about 2.5 times of the average and was much higher than the peatland in Riau and South Sumatra. This observation suggest that fires concentrated on peatland in year 2019 especially in Jambi peatland.

In relation to land cover classes, industrial plantations and small holder areas remained the main contributors to fires in the study area in 2019. The highest number of hotspots occurred in industrial plantations and small holder areas which together accounted for 42.2% of the hotspots. However, unlike in previous years, the less managed land cover classes of fern/low shrubs, tall shrubs/secondary forests and clearance together contributed to almost 50% of the total hotspots. The highest hotspots density was found in the classes of ferns/low shrub and clearance. These land classes were potential areas for land conversion. The increased fires activities in these areas indicated the use of fires in land preparation for future conversion. Meanwhile, pristine peat swamp forest and mangrove have very low hotspots density.

The distribution of fires over land cover classes are not the same in the three provinces. In Riau nearly half of the hotspots were distributed on small holder areas and 20.0% were on Industrial plantations. This distribution was not different from the previous years. However, in Jambi, the largest proportion of hotspots were detected in degraded peat swamp forests, followed by Ferns/low shrub class. These results suggested that Jambi peatlands were undergoing increasing land conversion activities and fire was used as a tool in land conversion.

The fire activity level in year 2019 was not different from the average of the previous 10 years. In Riau, fire activities peaked in August/September, and in March. Jambi and South Sumatra had

a single peak in September/October. However, the fire season in 2019 lasted until November, unlike the previous 10 years. In November 2019, the number of hotspots detected was almost 4 times the 10 years average. In South Sumatra, hotspots count in November 2019 was 4.5 times the 10 years average. The longer fire season was due to the dryer and hotter month of November in 2019.

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