INTEGRATION OF GIS AND REMOTE SENSING FOR HOTSPOT DISTRIBUTION ANALYSIS IN BERBAK SEMBILANG NATIONAL PARK

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Abstract. This paper describes hotspot distribution during 2000-2018. The study was conducted in Jambi and Sumatra Selatan Provinces, located in Berbak Sembilang National Park (TNBS) at 1°08'-1°43' LS, 104°05' -104°26' BT and 1°08' -1°41' LS, 104°15'-104°15' BT. The study area was approximately 200,000 hectares, mostly covered by peat lands. The main objective of the paper is to determine the distribution of fire occurrence based on historical hotspot data during an 18 year period (2000-2018), with analysis of land cover and land use trajectories after the occurrence of fire in the park. The data used include hotspot data obtained using Getis-Ord-Gi*. The results show that the total number of hotspots observed in the 2000-2018 period in TNBS was 32,501, of which 12,084 had a probability at the 80% confidence level of fires occurring on peat land every year, either during *La Niña* period. Distribution by land use and land cover showed the highest distribution of hotspots in mixed field land use (51.78%), fields (41.35%), plantations (26.06% whereas in TNBS Land cover in primary swamp forest (0.45%), secondary swamp forest 1.74%. In conclusion, hotspot distribution was mostly in land use areas and the associated fires were utilised by farmers and companies (forest plantation) for land preparation around TNBS.`

Keywords: *Berbak Sembilang National Park, Getis-Ord-Gi*, hotspot, fire distribution, land use and land cover*

1 INTRODUCTION

The occurrence of forest fires in 1997/1998 was driven by an El Niño-Southern Oscillation (ENSO) event, and threatened the existence of tropical forests in Indonesia. In the last twenty years, forest and land fires have occurred in tropical rainforests, especially in Indonesia. The country, especially Jambi Province, experienced very intensive fire periods in 1982-1983, August 1990, June-October 1991 and August-October 1994, with the 1997 and 2015 fires the largest to have ever occurred in Indonesia and Southeast Asia. The drought caused by the El Niño Southern Oscillation (ENSO) in 1997-1998 led to fires in tropical forests around the world (Siegert & Hoffmann, 2002), Indonesia being no exception.

TNBS is a protected area in Indonesia's ramsar site and one of the country's biosphere reserves. Despite its protected status, TNBS is threatened from both outside and from within the region. One of the biggest threats to the area, besides illegal logging, is forest fires. Therefore, to prevent, control and monitor forest damage and forest fires in areas that have a high risk of fire,

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hotspots can be used as indicators of land and forest fires (Siegert & Hoffmann, 2000).

A variety of technologies for collecting, handling and analysing spatial data have emerged in the past three decades. If attention is limited to those that deal strictly with geographical data, rather than the more generally defined spatial data, then the list would have to include GPS, the *global positioning system* based on analysis of signals from a constellation of orbiting satellites; electronic surveying technology as typified by the modern 'total station'; remote sensing; and geographic information systems (GIS).

Earth data observation satellites can be used for wild fire monitoring and fire danger assessment. MODIS was designed to monitor the Earth's land areas; in essence, it is an instrument similar to AVHRR, but tailored to monitoring land resources (in contrast to the meteorological mission of AVHRR). MODIS data permit analysts to monitor biological and physical processes on the Earth's land surfaces and water bodies and to collect data describing cloud cover and atmospheric qualities. MODIS collects data describing range and forest fires, snow cover, chlorophyll concentrations, surface temperature, and other variables (Campbell et al., 2013).

Research on hotspot analysis has also been conducted in the provinces of Riau, South Sumatra and Jambi by Usman et al. (2015), Prasetyo et al. (2016), Firdaus (2017) and Sumarga (2017), and shows that hotspots are mostly found in peat and dry land. Nuruddin (2016) found that the upward trend had increased in 2010. This research used hotspot data of forest and land fires in 2000-2018 from Earth data from the National Aeronautics and Space Administration (NASA). Data from the period 2000-2018 was chosen for the study because many fires occurred at that time (Syaufina, 2008). The hotspots were selected on the basis of an 80% confidence level in their threshold value.

The objective of the research is to determine the distribution of fire occurrence based on historical hotspot data during the 18 year period (2000-2018), and consequently ascertain the probability of fire occurrence in a particular area. Hopefully, the research results can be used to improve policy development to mitigate forest and land fire occurrence and to determine priority areas.

2 MATERIALS AND METHODOLOGY

2.1 Study Site and Data

The study site was located in TNBS in Jambi and Sumatra Selatan Provinces, covering an area of approximately 200,000 hectares (Fig. 1). TNBS forms part of the vast alluvial coastal plain of eastern Sumatra, which is believed to have formed about 5,000 years BP. Evidence indicates that sea levels have dropped around two metres during the past 5,000 years, with sediment, mainly from the Batanghari River, accumulating along the accreting coastline. Peat has formed on the highly weathered sediment,with an average age of about 4,500 years, and in some areas to a depth of more than 20 metres (With & Euroconsult, 2004). Berbak Sembilang National Park is very flat, and at no point is the elevation more than 15 metres.

The study area can be reached in several ways. It takes a minimum four day round trip if visitors intend to visit the core zone of the National Park. An alternative way is via the South China Sea, towards the Air Hitam Laut River.

2.2 Hotspot Distribution

Hotspot distribution was analysed using Getis-Ord-Gi* statistics, a spatial analysis tool in ArcGIS software (Formulas 1, 2, and 3). Since the input data was point feature (hotspot data), the tool performs clustering of hotspot points based on the number of their occurrences derived automatically during processing.

The tool then determines statistically significant spatial clusters of high values (known as hotspots), low values (called coldspots) and non-significant areas. Furthermore, the hotspot and coldspot areas are classified into 90%, 95% and 99% probability occurrence areas (Prasetyo, 2016).

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}{}^2 - \left(\left(\sum_{j=1}^{n} w_{i,j}\right)^2\right)\right]}{n-1}}} \tag{2-1}$$

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \tag{2-2}$$

$$\bar{S} = \sqrt{\frac{\sum_{j=1}^{n} x_j{}^2}{n} - (\bar{X})^2} \tag{2-3}$$

in which x_j is the attribute value for feature j; $w_{i,j}$ is the spatial weight between features i and j ; and n is equal to the total number of features.

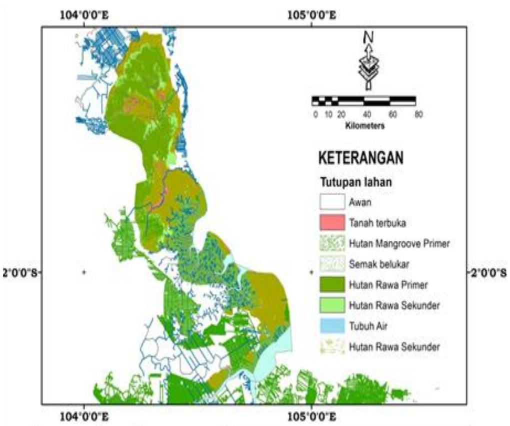

Figure 2-1:TNBS 1°08’-1°43’ LS, 104°05’ -104°26’ BT and 1°08’ -1°41’ LS, 104°15’-104°15’ BT location.

2.3 Historical forest, land fire and land cover trajectory data after fires

Hotspot data from the period 2000 to 2018 for Berbak National Park were downloaded from MODIS active fire data. The data were selected according to an 80% confidence level in their threshold value. GIS and remote sensing have emerged as distinct spatial data handling technologies, with their own methods of data representation and analysis. Combining them as tools to support the analysis of hotspot data.

Land cover identification was made based on the visual classification of Landsat Imageries (TM, ETM and OLI),

taken in 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014 and 2015. The classification technique relied on identification of key features, such as colour, tone, size, shape, texture, pattern, site and association. Land use and land cover after fire occurrence were determined based on Landsat data from approximately 4 years after the event.

3 RESULTS AND DISCUSSION

3.1 Hotspot distribution

Between 2000 and 2018 there were 32,501 hotspot occurrences at TNBS. Among these, 12,084 were chosen because they had a high level of confidence (80%). Hotspots occurred either during the El Niño drought conditions of 2004, 2006, 2009 and 2015, or the La Niña wet conditions of 2011 and 2012. Based on historical hotspot occurrence (Fig. 3), it seems that there is no relationship between climate anomalies and the number of hotspots after 2012; similar results were obtained by Prasetyo (2016). In 2011 and 2012, a great number of hotspots was detected, even though the period was one of La Niña wet conditions. Base on Gi* spatial statistics, the area around TNBS has an occurrence confidence level greater than 90% and is defined as hotspot area (Fig. 4).

During the 2000-2018 period, there were 32,501 hotspot occurrences in TNBS, of which 12,084 had a probability of fire occurring in peat land every year at the 80% confidence level, either during La Nina period. Because of the increased intensity and frequency of forest fires, protection from or restoration of fire damage is vital in the area. If nothing is done, the result will be rapid forest degradation and loss of the carbon stored in the peat swamp forests.

3.2 Historical forest, land and land cover trajectory of data after fires

Repeated and frequent fire events will eventually alter the ecosystem towards a grass swamp or swamp forest one. Between 2000 and 2018, land cover before hotspot occurrence in was mostly the same every year, dominated by mixed and agricultural fields, followed by TNBS primary swamp forest, secondary swamp forest, primary mangrove forest, secondary and mangrove forest.

A high frequency of hotspots occurred in TNBS in the burned area classified as "non-swamp vegetation" (Fig 3). The accumulated frequency of hotspots in TNBS land cover types is only 1.65%, while around the TNBS, hotspot frequency is almost 90%. Previous research (Mudiyarso, Widodo & Suyamto, 2002) recorded that high frequencies of hotspots occurred on Berbak National Park land cover during the period 1997/1998. This trend was supported by the fact that forest cover in 1997/1998 was greater (fuel load) than in the 2000-2018 period. Fuel is still widely available, and recurrent fires in primary forest cover make biomass and fuel in the 2000-2018 fires less than in 1997/1998.

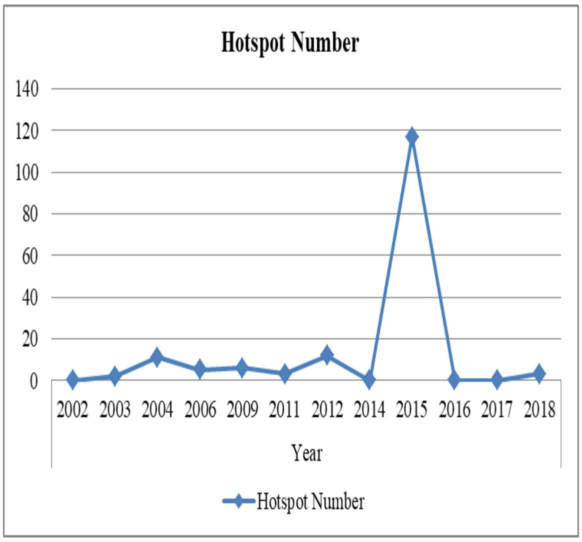

Figure 3-1: Number of hotspots during the period 2000-2018

Based on the distribution and trajectory of hotspots, many fires occur precisely outside the TNBS area (Figs 6 and 7). This is not surprising, as for several decades there have been many land clearing activities by settlers from outside the province of Jambi, providing access to the land clearings by burning. This is serious and must be a primary concern in mitigation efforts.

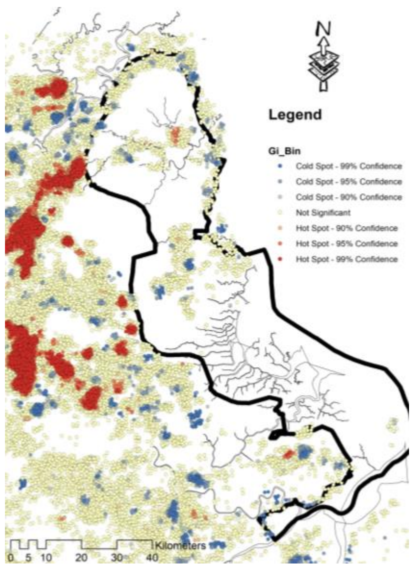

Figure 3-2: Hotspot occurrence distribution between 2000 and 2018

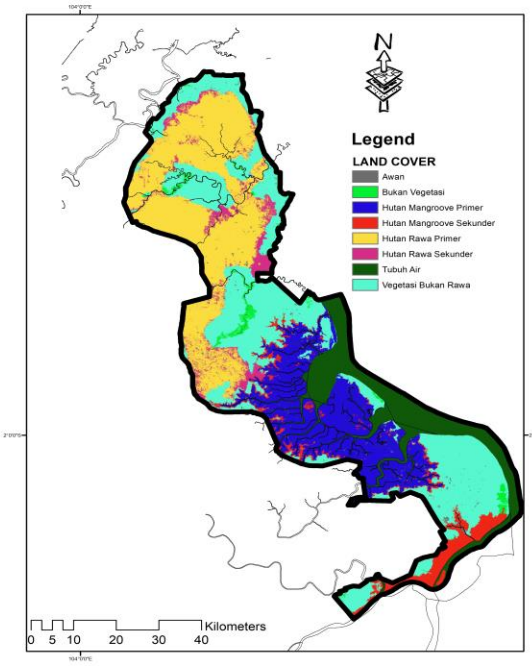

Figure 3-3: TNBS land cover

In Figure 3-4 (a), (b), (c) and (d), look burnt at the site of primary forests and expanding in 2008 and appears to occur succession back in 2018. But in relation to the period of 10 years from 2008 to 2018, there has been a succession in the forest area of primary gamput contained in the Simpang Gajah (Core Zone) of TNBS. This is an area that is very difficult to reach because of high accessibility. The area that was burnt several times was first affected in 1997/1998, when it still had Marga Satwa status, so it was very vulnerable to fire. In fact, according to the history of fires in tropical forests (Tate, 1932; Barber & Schweithelm, 2000; Goldammer & Seibert, 2001) and the soil charcoal profile (Uhl, Kauffman and Cummings, 1988; Hammond & ter Steege, 1998), it is shown that both tropical forest fires and wetter forests are unprecedented.

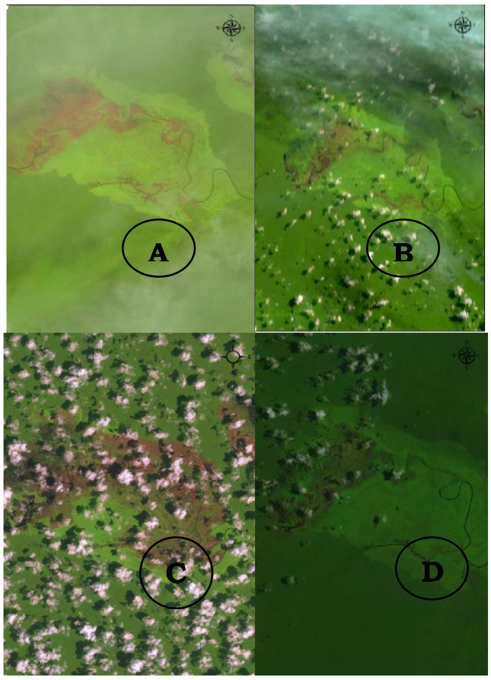

Figure 3-4: Trajectory from primary swamp forest to secondary swamp forest: Landsat false colour composite (a) 2000; (b) 2004; (c) 2008; and (d) 2018.

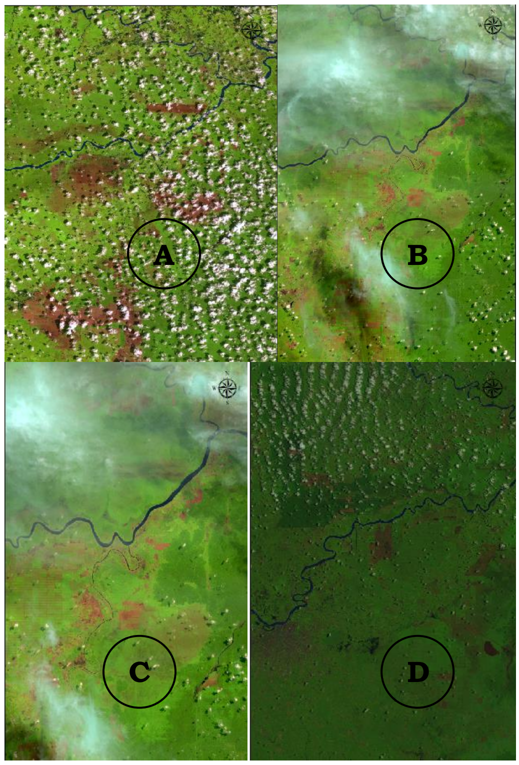

Figure 3-5: Trajectory from mixed fields to mixed field: Landsat false colour composite (a) 2000; (b) 2004; (c) 2008; and (d) 2018.

Figures 3-5 and 3-6 show mixed field and plantation development from 2000, 2004, 2008, 2015 and 2018 outside the TNBS area. At the hotspot distribution Fig 4, this location is that with the most hotspots compared to inside the TNBS area. It is interesting to note that in most of the land clearing in the TNBS buffer zone area fire is still used, which threatens the existence of the park. Based on Law no 32/2009 on the Protection and Management of the Environment (Perlindungan dan Pengelolaan Lingkungan Hidup), fire control burning is still allowed for land preparation under 2 Ha. However, in order to minimise operation costs, companies were using fire for land preparation (Varma, 2003).

Table 3-1: Hotspot percentage based on land use and land cover

Land Use/Land Cover	Hotspot percentage
Fields	41.35
Mixed fields	51.78
Plantations	26.06
Primary swamp forest	0.45
Secondary swamp forest	1.74
Primary mangrove	0
Secondary mangrove	0

Hotspot Occurring based on Land Cover in Berbak Sembilang National Park. Secondary swamp forest is an area of peat swamp that continues to be burnt, resulting in repeated fires. For hotspot occurrence based on land use in Berbak Sembilang National Park, mixed fields, plantations and fields have the highest hotspot percentage compared to land cover. This indicates that farmers around the TNBS area have often been observed clearing land by fire each year, although the impact could be very dangerous for the region, the park and human health.

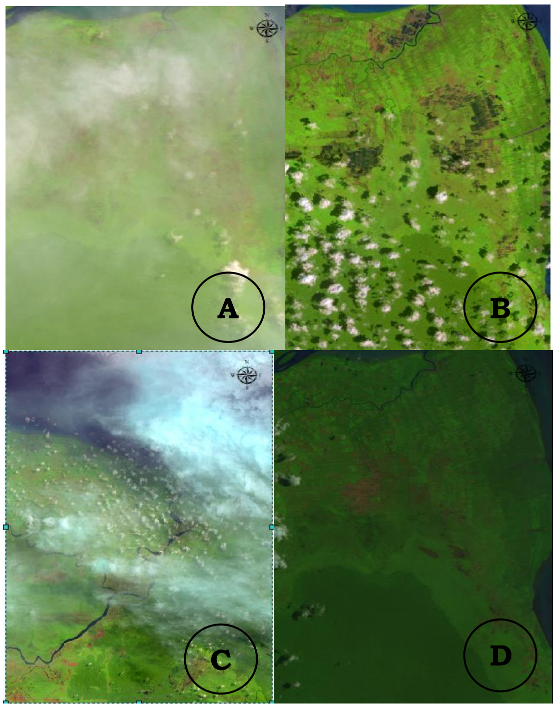

Figure 3-6: Trajectory from plantation to field: Landsat false colour composite (6-5-4) (a) in 2000; (b) 2004; (c) 2015; and (d) 2018.

Table 3-2: Percentage of hotspots in TNBS in the period 2000 – 2018 based on land cover and land use after fire occurrence

Land Cover	**Hotspot incidence**												**Total**
	2002	2003	2004	2006	2009	2011	2012	2014	2015	2016	2017	2018	
PSF	0	0,02	0,01	0,01	0,04	0,03	0,16	0	0,2	0	0	0	0,45
SSF	0	0,04	0,07	0,05	0,06	0,1	0,37	0	0,4	0	0	0,1	1,74
PM	0	0	0	0	0	0	0	0	0	0	0	0	0
SM	0	0	0,05	0	0	0	0	0	0	0	0	0	0,05

Land Use	**Hotspot incidence**												**Total**
	2002	2003	2004	2006	2009	2011	2012	2014	2015	2016	2017	2018	
F	0	142	512	247	438	764	876	0	890	0	0	239	41,35
MF	0	543	789	432	897	980	189	0	698	0	0	650	51,78
PL	0	234	985	432	321	147	156	0	139	0	0	192	26,06

PSF= Primary Swamp Forest; SSW= Secondary Swamp Forest; PM= Primary Mangrove; SM= Secondary Mangrove; F= Field; MF= Mixed Field; PL= Plantation Land.

The analysis of land cover after the incident (Table 3-2), interestingly to note that if we look at land use category, after fire was occurrence on average 51.78% in mixed field and 41.35% was occure into field area. The plantation areas (26.06%) were community and company land (Table 3-2). This situation proves that fire was not only used by the farmers, but also by companies.

4 CONCLUSION

Mapping of hotspot distribution has a long and largely effective history. At the most fundamental level, geographical data can be defined as a collection of facts about places. However, with the introduction of remote sensing as a commonly used and efficient means of mapping the distribution of hotspots in TNBS in the 2000-2018 period, the results of the remote sensing hotspot data show that there were 32,501 hotspot occurrences in TNBS, in which 12,084 occurrences. During the period of analysis, 51.78% mixed field of the post fire incidence and 41.35% field, meanwhile 93.13% were smallholder areas or community land areas. This finding proves that fire was used either by communities or by companies for land clearing activities.

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