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Research Article
Analysis of Hotspot Pattern Distribution at Sabah, Malaysia for Forest Fire Management

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Abstract
Forest fire is a major threat to tropical forest ecosystem and can be detected as hotspots using satellite technology. Its pattern and distribution can be used to identify areas where there are occurrence of forest fire. This study aims to assess and investigate the hotspots pattern in Sabah during 2006-2010. This study was conducted in Sabah, located in the northern part of Borneo Island. Hotspots data were obtained from Fire Information for Resources Management System (FRIMS). Hotspots data for 5 years (2006-2010) in longitude 114°E, 3.58°N and latitude 119°E, 7.22°N) were analysed using ArcMap 10.1 software. Descriptive statistics analysis was done using Microsoft Excel. Results showed that total number of hotspots observed annually were 382 in 2006, 572 in 2007, 294 in 2008, 554 in 2009 and 1082 in 2010. On monthly basis, the highest numbers of hotspots detected were in March, 2010 with 445 hotspots while January, 2009 was the lowest with no hotspot detected. Distribution by region showed the Interior region recorded the highest number of hotspots in 2010 with 594 hotspots, followed by Sandakan (697), West Coast South (475), North West Coast (327) and Tawau (226), respectively. In conclusion, the hotspots detected varied according to year, months and regions. Understanding hotspots patterns enables the allocation of resources for forest fire planning and management.

Key words: Forest fires, tropical forest, northern borneo, haze

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The occurrences of forest fire have always been a major threat to forest ecosystem. There are many negative effects of forest fire, which include global warming and human health (Harrison *et al*., 2009; Sahani *et al*., 2014), loss or reduction of biodiversity, vegetation (Syaufina and Ainuddin, 2011), soil (Certini, 2005), hydrology (Nuruddin *et al*., 2006) and transboundary haze (Sastry, 2000; Heil and Goldammer, 2001). High incidences of forest fire in Southeast Asia occurred during the strong El Nino which were in 1986-1987, 1994 and 1997-1998 (Tacconi *et al*., 2007).

In Malaysia, the occurrence of forest fires in the natural protected forests are generally low, but more frequent in peat swamp forests, secondary forest, plantations and forests logged area (Abdullah *et al*., 2002). Prolonged drought during to the El Nino phenomenon in 1997 and 1998 had caused forest fires nearly in all states where 65531 ha of peat forests were burned (Ahmad-Zainal, 2001). Most of the forest fire occurrences were caused by human activities during prolonged dry and hot weather.

Sabah is one of the states in Malaysia that were severely affected compared to the other states in Malaysia. The worst forest fires in Sabah reported in 1983-1985, where more than 1 million hectares of forest were burned, caused by the severe drought (IFFN., 2001). Furthermore, most of forest fires incidents were due to the agricultural activities where some farmers uses fire to prepare their land for planting. These burning activities were poorly managed thus lead to the spreading of fire to the nearby forest reserve (Goldammer, 1988)

Forest fires can be detected by satellites using hotspots (Razali *et al*., 2010; Sitanggang *et al*., 2013a, b). However, few studies on the trend of fire occurrence have been conducted in Sabah, therefore the objective of this study was to assess and investigate hotspots pattern for a period of five years (2006-2010) in Sabah. Hotspot pattern can be used to predict forest fire occurrences (Sitanggang *et al*., 2014) and this can provide useful information for forest fire management.

MATERIALS AND METHODS

The study area was Sabah (72,000 km^2), located in the northern part of Borneo (longitude and latitude; 114°E, 3.58°N and 119°E, 7.22°N). It is the second largest state in Malaysia after Sarawak. Most of Borneo topography is mountainous and covered by tropical rain forest. It has a humid climate and has a round of high temperature and heavy seasonal rainfall, especially during the North-East monsoon from October to March. In 2010, the daily average monthly temperature in Sabah was between 23 and 35°C and monthly total rainfall were between 1-1738 (mm). The daily average relative humidity recorded for the study area ranged from 68-92% from 2006-2010 (Forestry Department of Sabah, 2010).

Hotspots represent the coordinated central pixel fires detected with a high temperature and vary with ambient temperature by satellite sensor (Wright *et al*., 2004). Based on the spatial resolution (pixel size) of MODIS satellite images a fire pixel or hotspot point has a defined area of 1 km^2 and it indicated that there was a fire within this area or could be located around 500 m from the center coordinates (Siegert and Hoffmann, 2000). The hotspot data were obtained from the Agency Remote Sensing Malaysia (ARSM) and moderate resolution imaging spectroradiometer (MODIS). The MODIS hotspot data were requested and extracted in shapefile type through FIRMS (Fire Information for Resources Management System). The study was carried out using hotspots data from 5 years period (2006-2010) for the state of Sabah (longitude and latitude; 114°E, 3.58°N and 119°E, 7.22°N). Hotspot data was in the form of points and scattered all over the state. Each point has its own information such as station, date, acquisition time (time of the overpass of the satellite), latitude and longitude (center of point location), brightness (brightness temperature measured in Kelvin), satellite (terra or aqua), confidence (quality flag of the individual hotspot) and Fire Radiation Power (FRP). Fire Radiation Power (FRP) is a measure of the rate of radiant heat output from a fire. The FRP is contained in the moderate resolution imaging spectroradiometer (MODIS) daily active fire product and resulted as emissions of trace gases and particulate matter during wildfire or in fire activity levels, vegetation composition, latitudinal variation and fire spread behavior (Barrett and Kasischke, 2013).

In this study, hotspots frequency analysis (by year, month and division) were conducted and displayed using ArcMap 10.1 software and the descriptive statistics of the hotspot was analyzed using Microsoft Excel 2007. According to Fuller (1991), rainfall considered as a factor that can influence the increase in number of hotspots which indirectly increases the risk of fire occurrence.

RESULTS

The total number of hotspots in Sabah by year and month from 2006-2010 are shown in Table 1. Throughout the study

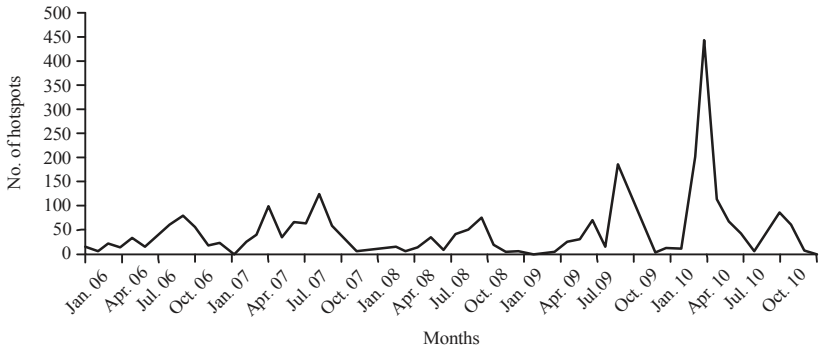

Fig. 1: Monthly pattern of hotspot number for period of 5 years (2006-2010)

Table 1: Frequency of hotspot in Sabah during the study period (2006-2010)

	Year					
Months	2006	2007	2008	2009	2010	Total
January	14	2	13	-	11	40
February	7	28	15	2	199	251
March	21	41	6	5	445	518
April	14	102	15	26	113	270
May	34	33	36	32	67	202
June	16	68	9	72	43	208
July	37	64	42	14	5	162
August	64	127	52	190	42	475
September	80	58	77	126	87	428
October	56	32	19	71	62	240
November	17	7	5	4	7	40
December	22	10	5	12	1	50
Total	382	572	294	554	1082	2884

period, 2884 hotspots were detected throughout the entire state. Year 2010 had the highest total number of hotspot with 1082 hotspots recorded while the lowest numbers of hotspots were recorded with only 294 in 2008. An increased pattern in number of hotspots has been shown from year to year. The same situation occurs from 2006-2007 which showed an increasing of number of hotspots from 382-572 while from 2007-2008, decrease from 572-294 hotspots. However, from 2008 onwards the number of hotspots increased again until year 2010. The total number of hotspot observed in 2009 and 2010 were 554 and 1082, respectively.

The frequency of the hotspot by month showed that the highest monthly total was 445 in March, 2010 while the lowest was in January, 2009 with no hotspots recorded. Figure 1 shows the cumulative hotspot graphs by month during the study period. Based on the annual statistics, the number of hotspot varied considerably from month to month. During the past five years, the first quarter of the years showed slight increase in number of hotspots from January until March. However, in the midst of the year shows the decreased in number of hotspots especially in June and July. The number of hotspot was observed to increase again from July to September. By the end of the year (November to December), it showed a decline in the number of hotspots for all years.

Table 2: Total hotspot in Sabah division for period time from 2006 until 2010

	Year					
Division	2006	2007	2008	2009	2010	Total
Interior	141	156	101	167	594	1159
West Coast South	47	132	61	100	135	475
West Coast North	50	44	38	121	74	327
Sandakan	95	172	70	134	226	697
Tawau	49	68	24	32	53	226

Table 2 shows the total number of hotspot in Sabah division between 2006 and 2010. Sabah divided into 5 divisions; Interior, South West Coast, North West Coast, Sandakan and Tawau. The total number of hotspot for the Interior was 1159 or 40% of total number of hotspot recorded from 2006 until 2010. This is followed by Sandakan, West Coast South and North West Coast with 697 hotspots (24%), 475 hotspots (17%) and 327 hotspots (11%) recorded, respectively. Meanwhile, Tawau shows the lowest number of hotspots with only 226 hotspots (8%) detected for 5 years period. During the period of five years, Interior region recorded the highest number of hotspots in 2010 with 594 hotspots. Tawau recorded the lowest number of hotspots throughout the year where only 24 hotspots detected in 2008.

DISCUSSION

The highest number of hotspots recorded during the study period were 1082 hotspots in 2010. In year 2008-2010, number of hotspot increases and this may be due to the rapid development, plantation and agriculture activities in the state. Schrier-Uijl *et al.* (2013) reported that, 1,340,317 ha of oil palm plantation were established in 2009 in Sabah. Due to the large land use conversion, burning increases leading to increase in number of hotspots detected. The most frequently used

method in forest plantations and agriculture activities is by using clear felling methods and burning method. This method was used to convert natural forest into plantation area as it was faster and cheaper compared to machinery. When the process is not properly controlled, it can cause forest fires to easily occur. Over 50 cases of forest fire incidence for the state in 2010 with damaged of 2,017.07 ha of forest reserve area and 399.6 ha of state lands (Forestry Department of Sabah, 2010). Meanwhile in 2008, the lowest numbers of hotspot have been recorded with only 294 hotspots. However, approximately 25 ha of industrial tree plantation area have been severely damaged by forest fire in 2008 (Forestry Department of Sabah, 2008).

State of Sabah is located in equatorial latitudes. Within these latitudes the climate is greatly influenced by the southwest monsoon season occurs from May to August while the northeast monsoon season from November to February. During monthly basis, the hotspot detected was highly influenced by the total rainfall received for the state. According to Walsh (1996), the monthly rainfall average is very important as general indication of any dry season in tropical environments. The changes of weather elements such as rainfall play an important role to the variation in the number of hotspots (Ainuddin and Ampun, 2008; Sitanggang *et al*., 2012). Additionally, high ambient temperature conditions greatly influence the number of hotspots detected. In March, 2010 recorded a very high number of hotspots compared to the other years. This was affected by the sudden changes of the rainy season in Malaysia. Where the rainy season for the state starts during the North-East monsoon from October/November and ends in late February/March (Ganz, 2002). Months with less rainfall (June until September) tends to have higher number of hotspots detected compared to the other months. While, months with high total rainfall (October until February) show lower number of hotspots detected.

During the period of five years, Interior division showed the highest number of hotspot detected compared to the other division. Meanwhile, Tawau recorded the lowest number of hotspots throughout the year where only 24 hotspots were detected in 2008. According to Forestry Department of Sabah (2009) the division of Interior, West Coast South (Kota Kinabalu) and West Coast North (Kudat), were more vulnerable to forest fire in year 2009. This may be due to the rapid development, plantation, agriculture activities and dry conditions during the year. McMorrow and Talip (2001) stated that, Interior and West Coast South parts had dense number of townships and main roads but less natural forest coverage. The opening of large areas for agriculture, logging and construction also will result in an increase of the secondary forest plant species, such as *Imperata cylindrica* (lalang), *Macaranga pruinosa* (mahang), *Melastomata malabathricum* (senduduk) and *Dicranopteris linearis* (resam). These plant species are more flammable and will increase the risk of forest fires occurrences. In addition, Abdullah *et al*. (2002) stated that, the activities such as agriculture, logging and construction can also be contributing factors that affected the increases number of hotspots.

CONCLUSION

Based on the finding of this study, it is found that the trend number of hotspot from 2008-2010 increases with year 2010 having highest number of hotspots. When comparing months, March had the highest in number of hotspots. Highest number of hotspots was distributed in the Interior region while smallest number were observed in Tawau region. The significance of understanding the hotspot pattern enables the management to foresee the risk of having forest fire with regards to climatic condition. In addition, fire control activities can be done more effectively and efficiently with the availability of a wider study to find this hotspots pattern it can be generated and served as a guideline for forest fire management especially for state of Sabah.

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REFERENCES

Abdullah, M.J., M.R. Ibrahim and A.R.A. Rahim, 2002. The incidence of forest fire in peninsular Malaysia: History, root causes, prevention and control. Proceedings of the Workshop on Prevention and Control of Fire in Peatland, March 19-21, 2002, Kuala Lumpur, Malaysia.

Ahmad-Zainal, M.I., 2001. Forest fire in Malaysia: Its management and impact on biodiversity. Asean Biodivers., 1: 31-35.

Ainuddin, N.A. and J. Ampun, 2008. Temporal analysis of the keetch-byram drought index in malaysia: Implications for forest fire management. J. Applied Sci., 8: 3991-3994.

Barrett, K. and E.S. Kasischke, 2013. Controls on variations in MODIS fire radiative power in Alaskan boreal forests: Implications for fire severity conditions. Remote Sensing Environ., 130: 171-181.

Certini, G., 2005. Effects of fire on properties of forest soils: A review. Oecologia, 143: 1-10.

Forestry Department of Sabah, 2008. Annual report 2008: Forest protection. Sabah Forestry Department, Malaysia, pp: 157-163. http://www.forest.sabah.gov.my/download/2008/19_Protection.pdf

Forestry Department of Sabah, 2009. Annual report 2009: Forest protection. Sabah Forestry Department, Malaysia, pp: 185-191. http://www.forest.sabah.gov.my/ar2009/chap%2019.pdf

Forestry Department of Sabah, 2010. Annual report 2010: Forest protection. Sabah Forestry Department, Malaysia, pp: 191-200. http://www.forest.sabah.gov.my/pdf/ar2010/Chap19.pdf

Fuller, M., 1991. Forest Fires: An Introduction to Wildland Fire Behavior, Management, Firefighting and Prevention. John Wiley and Sons, Inc., New York, pp: 238.

Ganz, D., 2002. Framing fires: A country-bycountry analysis of forest and land fires in the ASEAN nations. Project FireFight South East Asia, Jakarta, Indonesia.

Goldammer, J.G., 1988. Rural landscape use and wildfires in the tropics. Agrofor. Syst., 6: 235-252.

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

Heil, A. and J. Goldammer, 2001. Smoke-haze pollution: A review of the 1997 episode in Southeast Asia. Regional Environ. Change, 2: 24-37.

IFFN., 2001. Forest fire situation in Malaysia. International Forest Fire New, No. 26, January 2001, pp: 66-74. http://www.fire.uni-freiburg.de/iffn/country/my/my_2.htm

McMorrow, J. and M.A. Talip, 2001. Decline of forest area in Sabah, Malaysia: Relationship to state policies, land code and land capability. J. Global Environ. Change, 11: 217-230.

Nuruddin, A.A., H.M. Leng and F. Basaruddin, 2006. Peat moisture and water level relationship in a tropical peat swamp forest. J. Applied Sci., 6: 2517-2519.

Razali , S.M., A.A. Nuruddin, I.A. Malek and N.A. Patah, 2010. Forest fire hazard rating assessment in peat swamp forest using landsat thematic mapper image. J. Applied Remote Sens., Vol. 4. 10.1117/1.3430040

Sahani , M., N.A. Zainon, W.R.W. Mahiyuddin, M.T. Latif and R. Hod *et al*., 2014. A case-crossover analysis of forest fire haze events and mortality in Malaysia. Atmospheric Environ., 96: 257-265.

Sastry, N., 2000. Forest fires, air pollution and mortality in Southeast Asia. Demography, 39: 1-23.

Schrier-Uijl, A.P., M. Silvius, F. Parish, K.H. Lim, S. Rosediana and G. Anshari, 2013. Environmental and social impacts of oil palm cultivation on tropical peat-a scientific review. Roundtable Sustainable Palm Oil, 2: 131-168.

Siegert, F. and A.A. Hoffmann, 2000. The 1998 forest fires in East Kalimantan (Indonesia): A quantitative evaluation using high resolution, multitemporal ERS-2 SAR images and NOAA-AVHRR hotspot data. Remote Sens. Environ., 72: 64-77.

Sitanggang, I.S., R. Yaakob, N. Mustapha and A.N. Ainuddin, 2012. Application of classification algorithms in data mining for hotspots occurrence prediction in Riau province Indonesia. J. Theor. Applied Inform. Technol., 43: 214-221.

Sitanggang, I.S., R. Yaakob, N. Mustapha and A.N. Ainuddin, 2013a. Classification model for hotspot occurrences using spatial decision tree algorithm. J. Comput. Sci., 9: 244-251.

Sitanggang, I.S., R. Yaakob, N. Mustapha and A.N. Ainuddin, 2013b. Predictive models for hotspots occurrence using decision tree algorithms and logistic regression. J. Applied Sci., 13: 252-261.

Sitanggang, I.S., R. Yaakob, N. Mustapha and A.N. Ainuddin, 2014. A decision tree based on spatial relationships for predicting hotspots in Peatlands. Telkomnika, 1p2: 511-518.

Syaufina, L. and A.N. Ainuddin, 2011. Impacts of fire on Southeast Asia tropical forests biodiversity: A review. Asian J. Plant Sci., 10: 238-244.

Tacconi, L., F. Jotzo and R.Q. Grafton, 2007. Local causes, regional co-operation and global financing for environmental problems: The case of southeast Asian haze pollution. Int. Environ. Agreements: Politics Law Econ., 8: 1-16.

Walsh, R.P.D., 1996. Drought frequency changes in Sabah and adjacent parts of northern Borneo since the late nineteenth century and possible implications for tropical rain forest dynamics. J. Trop. Ecol., 12: 385-407.

Wright, D.B., T. Yotsumata and N. El-Sheimy, 2004. Real time identification and location of forest fire hotspots from geo-referenced thermal images. Int. Soc. Photogramm. Remote Sens., 1: 1-6.