Temporal Distribution and Causes of Forest and Land Fires in North Sumatera Province, Indonesia

A. S. Thoha [1], Onrizal [1] and P. Patana [1]
[1] *Faculty of Forestry, Universitas Sumatera Utara,, Jalan Tridarma Ujung No. 1 Medan, Indonesia*

Keywords: Forest and land fires, hotspot, spatial analysis, fire period.

Abstract: Determining the characteristic of fires and fire-prone areas will help in low-emission land-based development planning. This study aims to identify temporal patterns and causes of forest and land fires in North Sumatra. The temporal pattern was determined by spatial analysis and descriptive of rainfall and fire hotspot during 2001-2017. The causes of fire were determined by observation and in-depth interview on the location of the indication of fire based on hotspot density analysis result. Based on temporal distribution, the hotspot of fire increases every five years. Peak forest and land fires occurred in two periods each year namely February-March and June-August. The causes of forest and land fires in North Sumatra were not same across regions. The most common causes were fires due to land clearing activities for plantation areas, whether coffee plantations, rubber plantations or oil palm plantations. Other causes were grazing, negligence of the community, conflict companies and for customary reasons.

1 INTRODUCTION

Recurrent forest and land cultivation incidents and increasingly severe impacts should receive the attention of all parties. In Indonesia, forest and land fires occur repeatedly almost every year during the dry season with different frequency and level of risk. The impacts of forest and land fires will be worse when they occur on peatlands. Peatland fires in 1997/1998 that occurred El Nino in Indonesia, contributing 13-40% of emissions from global emissions. (Page 2002, Harrison, et al. 2009 and Langmann et al., 2009). According to data from the National Disaster Management Agency (BNPB) of forest and land fires in 2015 estimated to result in losses of 221 trillion rupiah (Kompas.com, 2016). In the long run, the impact of fires resulted in global warming, loss of biodiversity and desertification (Goldammer et al., 2006).

North Sumatera Province is one of the prone areas of forest and land fires in Indonesia. In North Sumatra, there are thousands of hectares of peatland and natural reed grasslands and critical lands that are prone to fire during the dry season. In 2013, the area of critical land in North Sumatra reached 1,069,467 hectares (KLHK, 2017). Extensive critical land is located in Lake Toba Water Dump Area (DTA) which reaches 248,000 hectares or 45% of the total DTA area (beritasatu.com, 2016). Critical land in the form shrubs and reed are generally not managed generally will be a source of fire (Thoha et al 2014, Prasetyo et al 2016).

Development of Early Warning Systems for Community-based Forest and Land Fire is urgently needed to find solutions from today's centralized and costly systems and encourage people to play a more active role in their own protection. According to UNISDR (2009), the community-based early warning system is a community-centered system consisting of four key elements; (i) knowledge of risk (ii) monitoring, analyzing and forecasting hazard threats, (iii) communication or dissemination of alert messages and warnings; and (iv) local capacity to respond to warnings received. According to de Leon (2009) Community Early Warning System is an operational structure that allows residents to take steps to minimize the impact of natural disasters.

Determining the characteristics of fire in the form of temporal pattern and the cause of fire is an important step in order to build early warning system. Determination of fire characteristics will assist in the planning of development of low-emission land-based areas. This study aims to identify the temporal distribution and causes of forest and land fires in North Sumatra.

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2 MATERIAL AND METHOD

2.1 Material

The materials in this research were hotspot map 2001-2017 from MODIS satellite (Moderate-resolution Imaging Spectroradiometer), map of district administration boundary and monthly rainfall. The tool in this research consisted of data collection tools and data analysis tools. Field data retrieval tools included GPS, camera and voice recorder. Data analysis tool was Spreadsheet software and GIS Software.

2.2 Method

2.2.1 Data Collection

Hotspot data from Terra / Aqua satellites with MODIS (Moderate-resolution Imaging Spectroradiometer) sensor of 2001-2017 were obtained from Fire Information for Resource Management System (FIRMS) which can be accessed free of charge at https://earthdata.nasa.gov/data/near-real-time data/firms/active-fire-data. Field rainfall data was obtained from Indonesian Agency for Meteorology, Climatology and Geophysics Region I Medan. To determine the location of the survey for observation and groundcheck obtained based on input from Manggala Agni Natural Resources Conservation Center of North Sumatra and spatial analysis results based on villages with high density hotspots. For the collection of fire characteristic data obtained from the observation and recording of community activities at the site of the fire through interviews with the community about the history of the fire, the cause of fire and the practice of the community to prepare the land by burning. Public knowledge of the causes of fires was obtained through indepth-interview. Interview sources were selected through snowballing method with the first resource person becomes the key person in determining the next response. (Bungin, 2010).

2.2.2 Temporal Analysis of Forest and Land Fires

Identification of forest and land fire characteristics was determined by determining the temporal pattern of fires conducted by field rainfall data analysis and number of annual hotspots and monthly hotspots. Hotspots with level above 50% were used to analyze fire analysis because they were categorized as hotspots that fall within the nominal and high category (Giglio et al., 2015) and vigilant and immediate action of fire prevention in the field (LAPAN 2016) was required. Thoha et al. (2014) found that Terra Aqua satellite hotspot (MODIS) with level above 50% illustrates a strong relationship with fire activity in the field.

2.2.3 Analysis of Causes of Forest and Land Fire and Local Community Knowledge

Descriptive and tabulation analysis was used to find the cause of forest and land fires in relation to community activities. Community activity data analyzed was obtained by observing and recording community activities at the site of the fire through interviews about the history of fires, the causes of fires and the practice of preparing the land by burning. The location of interview was determined from the village that has a hotspot and recommendation from the local government about prone villages to forest and land fires. The result of spatial analysis and recommendation from institution that play a role in forest and land fire control was 25 villages in six districts for field observation and interview.

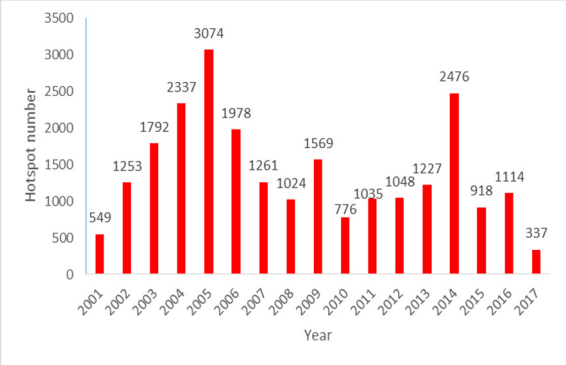
3 RESULT AND DISCUSSIONS

North Sumatra Province is one of the provinces whose territory occurs forest and land fire in the dry season. Based on fire historical data from hotspot MODIS with level confidence more than 50% (C> 50), the distribution of hotspots yearly and monthly in North Sumatra province can be seen in Figure 1 and Figure 2.

The hot spot observed from satellites in North Sumatra Province for 17 years (Figure 1) shows that there is a steady increase in hotspots every five years. In the first five years (2001-2005) the hotspot increased in 2004 and 2005. Furthermore, the hotspots increased to the highest number in 2009 and 2014. This pattern is not in accordance with climatic conditions in Indonesia in general where in the years of anomalies climate with below average rainfall or El Nino (2002 and 2015) the number of hotspots is not too high number. The highest hotspot in North Sumatra occurred in 2005 where in general the

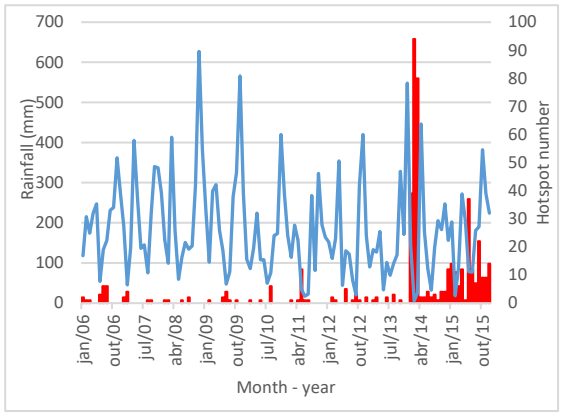
climatic conditions in Indonesia are not in El Nino condition at high level.

Figure 1. Distribution of hotspots percentage per year in North Sumatra Province



Analysis of hotspots on a monthly basis shows that for almost 17 years, the highest percentage of hotspots occurred in July at 24.92%. This means that fire activity in a year is potentially very large in July. The hotspots in North Sumatra Province have two periods of increasing both the number and percentage. The first period of hotspots increases from January to April while the second period is June-August. Thoha et al. (2014) in Central Kalimantan and Tata et al (2018) in Riau found a similar pattern that hotspots increase in June-August each year.

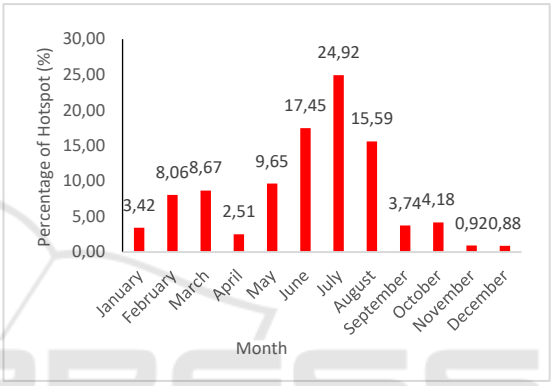
Figure 2. Percentage of hotspots per month in North Sumatra Province



From the analysis of hotspot distribution and interviews with fire control stakeholders, there are three groups of fire prone areas in North Sumatra. The first is the highland and hilly areas in Karo District, Toba Samosir and Simalungun. Second, peatland and lowland areas, where fire-prone areas are scattered in Labuhan Batu Utara, Labuhan Batu, Labuhan Batu Selatan and Asahan. Third, hilly lowlands and mineral soil areas, where fire-prone areas are found in Padang Lawas, Padang Lawas Utara and Mandailing Natal.

Based on the temporal analysis of rainfall and hotspots, it is found that there are differences in distribution patterns between the three groups of fire areas. Figure 3 shows the temporal distribution patterns of forest and land fires occurring in mountainous areas.

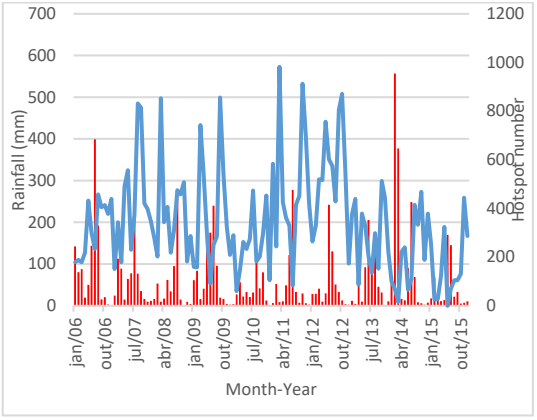
Figure 3. Temporal distribution of rainfall (blue line) and hotspots (red line) in mountainous areas of North Sumatra.



Temporal patterns of forest and land fires in upland areas in North Sumatra indicate that hotspots increase in number when rainfall decreases sharply (very low). Generally, hotspots that describe the activity of fire began to increase in June-August in 2006 - 2013 and February - March in 2014-2015. This indicates there are two periods of forest and land fires in the highlands of North Sumatra.

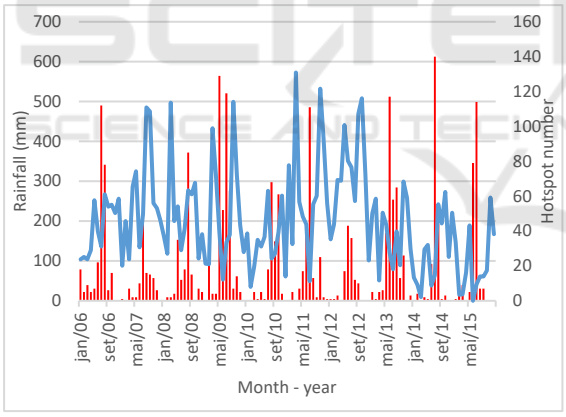
Figure 4 shows the temporal pattern of hotspots and rainfall of lowland and peatland areas in North Sumatra. The temporal pattern in this second area indicates that there are two periods of fire each year between February-April and June-August for the last 10 years. In very low rainfall conditions, hotspots will increase sharply.

Figure 4. Temporal distribution of rainfall (blue line) and hotspots (red line) in lowland and peatlands in North Sumatra Province



Temporal pattern of rainfall and hotspots relationship in lowland non-peat hilly areas is presented in Figure 5. Based on Figure 5, when rainfall decreases sharply, there is a very high increase of hotspots. In this region, temporal patterns of precipitation and hotspots indicate that there are two periods of fire activity (increased hotspots) namely on February-March and June-August.

Figure 5. Temporal distribution of rainfall and hotspots of precipitation and hotspots in non-peat hilly lowland areas in North Sumatra Province.



Rainfall is very influential on the water content of fuel, especially on peatlands. As rainfall increases, peatlands will store large amounts of water so that the water content of the fuel increases and is difficult to be burned. When the rainfall decreases, the water content of the peat decreases. Peat with low moisture is very susceptible to burning. Taufik et al (2011) explains that rainfall is very influential on the dynamics of groundwater and groundwater levels. The fluctuations of both are strongly influenced by the dynamics of rain falling and wetting the soil. In low rainfall seasons, water levels fall on critical thresholds that cause highly flammable peatlands (Wosten et al 2008).

An increase in the number of hotspots in June-August is related to community activities that adjust to the end of the dry season and the beginning of the rainy season. In June, most of the livelihoods of farmers have cleared and cleared land for cultivation. Burned and cleaned fuels are allowed to dry for one to two months. The following month is August at the end of the dry season according to their habit of burning biomass or waste from clearing the land. Community activity related to clearing of land in the dry season is also confirmed in the Someshwar et al (2010) study which mentions that fires in Central Kalimantan occurred during the dry season from May to September. Farmers and planters cleared land during that time, when the biomass was drier. Study by Thoha et al. (2014) in Borneo Tenagh also found that when rainfall decreases, hotspots increase sharply, especially in August-October. The temporal analysis of hotspots and rains is also in line with predictions from local knowledge in Central Kalimantan where in June-August most forest and land fires occur (Thoha et al., 2018)

Forest and land fires in North Sumatra province are closely related to community activities that adjust to the period or season of fire. Results of interviews with communities at various fire-prone sites or fire prone locations were found to be the cause of fires as presented in Table 1. According to Table 1, causes of forest and land fires in North Sumatra are not same across regions. The most common causes are fires due to bushfire activity and land clearing activities for dry agricultural land, coffee plantation and rubber plantations. Other causes are grazing (Padang Lawas Utara), neglect of the community, conflicts with companies and customary reason (calling for rain).

Research conducted by [20] in Kapuas which was area of peatland found that sources of land fires are also from farmers and fishers. This is in accordance with the descriptions in Table 1 that most fires originate from community activities for dry agriculture land clearing that many are found in Simalungun, Labuhan Batu Utara, Tapanuli Utara, Karo, Padang Lawas Utara and Dairi Districts. Research conducted by [8] in Kapuas District, Central Kalimantan, found the causes of forest and land fires from human activities generally derived from shrubs and grassland that are unmanaged land. This was consistent with the results of research that the land of shrubs and grassland are often become source of fire which then spread to plantations and
forests as found in Simalungun, Padang Lawas and Padang Lawas Utara.

4 CONCLUSION

Based on temporal distribution, the hotspots of fires in North Sumatra have increased considerably every five years. There are two periods in a year where hotspots are increasing from February to March and June-August. The highest percentage of hotspots occurred in July. The causes of forest and land fires in North Sumatra are not the same across regions. The most common causes are fires due to land clearing activities for plantation areas, whether coffee plantations, rubber plantations or oil palm plantations. Other causes are grazing, negligence of the community, conflicts with companies and customary reasons.

Table 1. Causes of Forest and Land Fires in North Sumatra

No.	Causes/sources of fire	District									
		Sim	Tos	Huh	Asa	Lau	Kar	Plu	Tau	Dai	Total
1.	Land clearing for dry agricultural land	1	0	0	0	1	1	0	1	1	5
2.	Land clearing for paddy fields	1	0	0	0	0	0	0	0	1	2
3.	Wildfire from shrub and grassland (unmanaged land)	1	1	1	1	1	1	1	0	1	8
4.	Burning peatland	0	0	0	1	1	0	0	0	0	2
5.	Land tenure claim	1	1	0	0	0	0	1	0	1	4
6.	Customary (adat) reason	0	0	0	0	0	1	1	0	0	1
7.	Converting Pine Forest to coffee farming	1	1	0	0	0	1	0	1	0	4
8.	Burning for grazing	0	0	0	0	0	1	1	0	1	3
9.	Negligence of the community	0	0	1	0	0	0	1	1	1	4
10.	Converting to rubber plantation	0	0	0	1	1	0	1	0	0	3
11.	Conflict between community and company	1	0	0	0	1	0	0	0	0	2
12.	Conversion from secondary forest to oil palm plantation	0	0	0	1	1	0	0	0	0	2

Remark : 1 (present), 0 (absent), Sim (Simalungun), Tos (Toba Samosir, Huh (Humbang Hasundutan), Asa ((Asahan), Lau (Labuhan Batu Utara), Kar (Karo), Plu (Padang Lawas Utara), Tau (Tapanuli Utara), Dai (Dairi),
Source: interview with villagers and BKSDA, 2016-2018

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