Spatio-temporal distribution of forest and land fires in Labuhanbatu Utara District, North Sumatera Province, Indonesia

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Abstract. Labuhanbatu Utara District, is one of the most prone area of forest and land fire in North Sumatera Province, Indonesia. Spatial and temporal distribution of forest and land fire are needed to determine for managing fire effectively. The objectives of this study are to determine the period of forest and aland fires and to determine the relationship between land cover and hotspot. Utara District. The method used is spatial analysis of the relationship between hotspot and monthly rainfall and distribution hotspot based on land cover type. The results found that the highest hotspot number occurred in 2005 while the lowest occurred in 2017. Forest and land fires occurred two periods in every year in Labuhanbatu Utara District namely on February-March and June-August. Land cover type has the highest percentage of the hotspot located at plantation area. Shrubs is land cover that have stable detected hotspot percentage every year. Based on the research, the factors causing land and forest fires are human activities such as land clearing activity for converting forest to rubber plantation and oil palm plantation.

1. Introduction
Forest and land fires in Indonesia occurred almost yearly during the dry season with the various frequency and level of risk. In the last two years Indonesia is highlighted by the International world because of haze disaster from forest and land fires in Sumatra and Kalimantan region. The impact of forest fires will more severe if they occur in peatlands. The big fire from peatland area in Indonesia in 1997/1998, contributed 13-40% emissions of global carbon emissions. [1-3]. Analysis from study by [4] noted that fires occurrence in 2015 have generated about IDR 221 trillion. The study also reported that fire occurrence in 2015 has also impacted to the deaths of 19 people and more than hundreds of thousands cases of respiratory infections were be declared.

Forest and land fires have spread to various regions including Labuhanbatu Utara District in North Sumatera Province. One of the government policy to manage forest and land fires is determine characteristics of the forest and land fires including spatial and temporal distribution. The policy related to forest and land fires which is on Forestry Minister (Minister) No. 12 The year 2009 on Forest Fire Management. Regulation No. 12 2009 was elaborated on the scope of control of forest fires include prevention, extinction and post-fire program. The vulnerability of forest and fires can be made using spatial modelling of the relationship between forest and land fires with the factors that influence it. Due to these factors largely referenced spatial, then the model can be developed in a geographic information system. Related research of determining spatio-temporal also demonstrated by several studies. Research by [5], which made the prediction model of prevention of fires in North Sumatra found Labuhanbatu
Utara is one of the most prone area in North Sumatera Province. Furthermore, study [6] that found that fires occurred in various forest type and found that peatland fires occur in remote access. Based on study by [7] also found that shrubs and remote area that have minimum access usually become source of fires. Forest and land fires in North Sumatra Province is currently quite got attention in local, national or international. In 2016, forest and land fires in North Sumatra have damaged land and forest area of more than 5000 hectares. Forest and land have also spread to various areas including Labuhanbatu Utara District in North Sumatera Province. The objectives of this study are to determine the period of forest and land fires and to determine the relationship between land cover and hotspot Labuhanbatu Utara District.

2. Materials and method

2.1. Study area
This study was carried out in Labuhanbatu Utara District, North Sumatera Province. The study was conducted over six months in June - November 2017. The field survey to observe land cover and human activities. We also were conducted interviews with people were located in some villages targeted in Labuhanbatu District area.

2.2. Data analysis
Hotspot data is obtained from Satellite Terra Aqua MODIS 2001-20017. Hotspot data can be collected from Fire Information for Resource Management System (FIRMS) that is free downloaded at link https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data. Hotspots data to build relationship with rainfall and land cover are hotspot with confidence criteria above 50%. According to [8], the confidence above 50 % include in nominal-confidence. The confidence of hotspot is quite varied in different parts of the world. In North Sumatera Province, hotspot with a confidence above 50% have strong indication with fire occurrence [5].

The data of rainfall and hotspot are cross-tabulated to get relationship graph between them. The hotspot data converted to hotspot density that represent the fire activities in the field. Then, hotspot is overlaid by spatial analysis tool with various map i.e. land cover, and district boundary.

The location of the ground-check was determined through visual analysis of hotspot density and information from the Kapuas and Plantation Forestry Office and Manggala Agni Regional Operation (Daops) North Sumatera. Ground-check and in-depth interview with communities were conducted to confirm land cover type, community activities land based and causes of fire at fire indicated sites based on hotspot distribution and technical agency information. The data of ground-check that are collected consist of hotspot coordinates (GPS point), land cover, fire incident information from year to year, causes of fire and community activities.

Determination relationship between hotspot and rainfall by field rainfall data analysis and number of annual hotspots and monthly hotspots by spreadsheet software. Hotspot density represent fire indication or fire activity in the field. Spatial and temporal analysis is made descriptively to see the indications of forest and land fire from time to time and its distribution based on various factors. The result of temporal analysis is compared with the history of forest and land fires originating from the results of community interviews. Analysis of fire location distribution indication based on hotspot distribution overlaid with land cover map. These processes are calculated by Spatial Join and Kernell Density using ArcGIS software.

3. Results and discussion
Hotspot is one of indicator of the occurrence of forest and land fires in the field. According to hotspot data from the Terra/Aqua Satellite, it can be seen the pattern of the distribution of hotspots in the area of North Labuhanbatu District, North Sumatra Province. The number of annual hotspots in Labuhanbatu Utara District is presented in Figure 1.
Figure 1. Hotspot number in Labuhanbatu Utara District 2001-2017

Figure 1 show the number of hotspots fluctuated annually. The highest number of hotspots in 2005 reached 245 points, while the lowest hotspots were in 2017, around 14 hotspots. It can be seen in 2001 was detected 19 hotspots, and increasing in 2005 as much 245 hotspots.

In 2006, hotspot number detected by 123 hotspots then decreased to 2011 with 47 hotspots. In 2012 very high hotspot found 133 hotspots which then decreased in 2013 and in 2014. Hotspot number increased until 119 hotspots and in 2015 then decreased in 2017. In Figure 2 the hotspot number also can be described monthly. Based on Figure 2, it can be seen the hotspot pattern through the number of hotspots monthly.

Figure 2. Monthly hotspot in Labuhanbatu Utara District 2001 - 2017

The highest number hotspot number in Labuhanbatu Utara District occurred in 2002, 2004 and 2008. There was a steep increase in the number of hotspots in months where rainfall below normal or negative anomaly as displayed in Figure 3. The highest hotspot number per month occurred in February – April and August - October. This mean that Labuhanbatu Utara District happen two periods in peak hotspot number condition. This pattern is almost similar pattern every year. Increased hotspots were sharply
related to community activities associated with land clearing in the dry season. Study [9] mentioned that farmers and smallholders in Central Kalimantan cleared the land during that time (June - September), because the biomass dried faster. They clean up the land by burning so that in that time period more fires occurred.

![Graph](image)

**Figure 3.** The pattern of rainfall anomaly and hotspot number in Labuhanbatu Utara District 2006-2015

Generally, hotspot number increase in June – August in Labuhanbatu Utara District. Based on Figure 3 shows that fires occur two periods each year, namely in February - March and June - August, where when the rainfall is very low, the hotspots will increase sharply during the dry season. During these months, land clearing activities by burning were generally carried out by the community and several plantation and forestry companies. Study of [10] found that the factors of human activity around the forest have a significant effect on the incidence of forest and land fires with a positive correlation. The opposite, when rainfall above normal or positive anomaly, the hotspot number will decrease. The months that have below normal or negative anomaly, hotspot number will be increase. This shows that rainfall affects the water content of the fuel [7].

Study by Tata et al. [11] also found the similar pattern in Pelalawan District of Riau Province that the mostly of hotspots usually detected in June to August. Rainfall is very influential on the water content of fuel. When rainfall increases, water storage in peatland also mount so that the water content of the fuel increases. Otherwise, when the rainfall decreases, the water content of the peat decreases. Peat with low moisture is very easy to burn. Study [12] and [13] found that rainfall greatly impact to the dynamics of groundwater and groundwater level. Both fluctuations are influenced by the dynamics of rainfall that flooding the soil. In low rainfall season, water level fall on critical thresholds that cause highly flammable peatlands [14].

Spatially, hotspot distribute not fixed every year in Labuhanbatu Utara District. As shown in Figure 4, hotspot distribute almost the entire area in Labuhanbatu Utara District. In 2001-2005, hotspot detected predominantly in Northern area, but after 2005, hotspot also detected in almost all region in Labuhanbatu Utara District.
Figure 4. The map of hotspot distribution in Labuhanbatu Utara District 2001-2017

In the last 10 years, Labuhanbatu Utara District have an extensive palm oil plantation. For example, the northern region, Air Hitam village used to have quite extensive peatland, but over time conversion of land to oil palm plantations have been done massively. Air Hitam Village is located in Kuala Ledong Sub-district of Northern Area of Labuhanbatu District. After that, 2011-2017, hotspots were distributed to western and southern area. Based on ground check, in western and southern area still available big area to convert to plantation while northern areas mostly have been managed as oil palm plantation.
Figure 5. Percentage of hotspot number average in Labuhanbatu Utara

Based on the Figure 5, the percentage of hotspot number average shown that in the high percentage is located in 4 sub-districts namely Aek Natas, Kualuh Hulu, Kualuh Leidong and Na IX-X. All of these areas are generally forest and land fires due to the change of land to oil palm plantations.

Table 1. Hotspot percentage each land cover type in Labuhanbatu Utara District in 2003 - 2017

| Land cover type          | Year/percentage of hotspot number (%) |
|-------------------------|---------------------------------------|
|                         | 2003  | 2006  | 2009  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  |
| Shrubs                  | 8     | 12    | 14    | 21    | 22    | 26    | 21    | 44    | 24    | 33    |
| Swamp shrubs            | 0     | 5     | 2     | 2     | 0     | 5     | 1     | 0     | 0     | 0     |
| Primary dryland forest  | 0     | 0     | 0     | 0     | 22    | 0     | 0     | 0     | 0     | 0     |
| Secondary dryland forest| 3     | 14    | 23    | 28    | 0     | 22    | 16    | 22    | 5     | 8     |
| Secondary swamp forest  | 10    | 0     | 2     | 9     | 0     | 0     | 0     | 0     | 0     | 0     |
| Settlement              | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Plantation              | 63    | 52    | 31    | 23    | 24    | 15    | 37    | 9     | 35    | 25    |
| Dryland agriculture     | 8     | 4     | 23    | 26    | 8     | 15    | 16    | 16    | 22    | 25    |
| Mixed dryland agriculture| 5     | 6     | 1     | 0     | 3     | 2     | 3     | 0     | 3     | 0     |
| Paddy field             | 1     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| Open land               | 3     | 7     | 2     | 0     | 12    | 13    | 7     | 9     | 5     | 8     |

Fires can occur when the fire triangle is in the same condition namely fuel, oxygen, and ignition heat. The load of fuel can be represented by land cover type. According to Table 1 can be presented about relationship between land cover and percentage of hotspot number. The high percentage of hotspot number is found in shrubs and plantation. These results is also shown by Figure 6 that the highest
average percentage of hotspot located in shrub and plantation. Shrubs and plantations are land cover that source of fire in Labuhanbatu Utara District.

Almost every year in 2003 - 2017, hotspot show in these land cover. Study by [15] states that land cover is the dominant factor in determining the level of fire vulnerability in North Sumatera. Land cover of shrubs and grassland has the highest score related to the density of hotspots. High percentage of hotspot number in plantation related to land conversion activities from mixed plantation to rubber plantation.

Based on study by [7], unmanaged land such as shrubs and grassland generally become source of fire in Kapuas District. Unmanaged almost burnt in every drought season. In the field, unmanaged that are shrubs, purun grass, secondary swamp forest and shrub in former agricultural land [7]. Research of [16] in the Kapuas peatland area found that the sources of land fires also came from farmers and fishers. In addition, swamp shrubs in peatland area was also sources of fire that many people mentioned as study by [18].

![Average percentage of hotspot number per land cover in 2003 - 2017](image)

**Figure 6.** Average percentage of hotspot number per land cover in 2003 - 2017

According to ground check, fires are caused by the preparation of garden land by burning, which is considered the most effective, easily and low cost. Land preparation activities with slash and burning method generally find in conversion land from rubber plants to oil palm plantations by local people as well as companies. Research by [17] also found that fire is applied by the community or companies for land clearing activities.

4. Conclusion

High level fire activities among last 10 years in Labuhanbatu Utara District occurred in 2015. Labuhanbatu Utara District have two period of fire season every year namely February – March and June – August. Hotspot generally increase when rainfall anomalies are below average. Land cover which has the highest percentage of hotspot number average is found in plantation which is 32% and shrub which is 23% of total of all land cover type.
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