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Spatiotemporal distribution of peatland fires in Kapuas District, Central Kalimantan Province, Indonesia

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Abstract: Peatland fires occur almost every year in Indonesia and their impact is harmful to human life and the environment. The objective of this study was to determine the distribution of peat fires, including hotspot characteristic, fire period and spatial distribution according to biophysical factors and human activities. Characteristics of peatland fires were determined through spatial analysis between hotspots and rainfall and factors affected peatland fires such as land cover, distance from the river, distance from road, spatial plan and peat thickness. The study found that strong indication of peat fires in Kapuas is indicated by the hotspot with a confidence value of more than 50%. August to October is the hotspot increasing time in Kapuas because the rainfall is low. The densest hotspots are generally found in swamp shrubs, close to the river, close to the roads, in the very deep peat, with a spatial planning of peatland conservation area. We concluded that peatland conservation area and unmanaged land in Kapuas District were in vulnerable condition of the fire. We suggest to the government to improve unmanaged land utilization and protect peatland conservation area in Kapuas District.

Keywords: Hotspot, Fire Period, Spatial Analysis, Fire Management

1. Introduction

Peatland fires occur almost every year in Indonesia and their impact is harmful to human life and the environment. A peatland fire in 1997/1998, when the El Nino occurred in Indonesia, contributed 13-40% emissions of global carbon emissions [1,2,3]. In Kapuas district, there are hundred thousand hectares of peatland located in the former of a million hectares of Peatland Development Project, the famous one was Mega Rice Project (MRP), which was proposed since 1995. The MRP opens the peatlands massively including swamp forests with thick peat with the construction of thousand kilometers canals that have an impact on the drying of peat ecosystem. The drying of peat ecosystem makes the area very prone to fire which results in massive carbon emissions [4]. It has been shown by [5] that carbon emissions from fires will be even greater when the peatland is burnt. Fires from tropical peatlands produce carbon dioxide emissions 4-40 times greater than other tropical habitats.

The factors causing peatland fires of various studies are related to climate and human activity. As in the study by [6] found that there is a close relationship between the rainfall data from the satellite to fire hotspot activity in Central Kalimantan. Rainfall anomaly during the dry season in June to October is a critical moment in determining the activity of fire. Human activity factors, for example distance from the village, distance from roads, distance from the canal or river networks contributed the risk of peatland fires while land cover affected the fire in 48% [7,8].

The efforts of forest fire management aimed at reducing the incidence of fires that can affect the lives and livelihoods. Peatland fires characteristic such as the fire period, relationship with the weather factors and the fire distribution indication according to biophysical factors and human activities are needed as suggestions for the development of early warning systems of forest and land fires in certain areas. The objective of this study was to identify the distribution of peatland fires, including hotspot characteristic, periods of fire and the spatial distribution according to biophysical factors and human activities. The results of this study are expected to evaluate the characteristics of peat fires that occur in Kapuas, Central Kalimantan Province by both time and location distribution.

2. Material and Methods

2.1. Study Area

The study was conducted in the Kapuas District of Central Kalimantan Province (Fig. 1) from April to December 2012. Data collection and ground check location of peat fires conducted in 15 villages in 6 sub districts in Kapuas. Six sub districts are namely Mantangai, Dadahup, Basarang, Kapuas Timur, Kapuas Murung, and Kapuas Barat. Based on the results of the fire occurrence identification, Kapuas district is one of the areas which is monitored as the place with the frequent forest and land fires, mainly in peatlands. As reported by the report [9] and [10] it was mentioned that the fires in 2002, 2007 and 2011 in the Ex-MRP area interfere human activities and exacerbate the peatland ecosystem damage. The research [7] also mentioned that the Kapuas district is an area that belongs to a risk class or a very high flammability class (extremely risk) in Central Kalimantan because most of the million hectare areas of ex-MRP were in Kapuas.

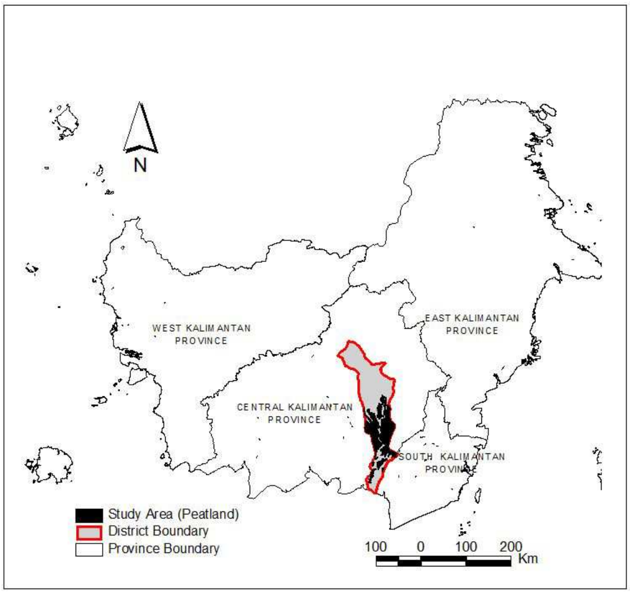


***Figure 1**. The map of study area*

2.2. Data Collection

The hotspot data from the Terra/ Aqua satellite by MODIS (Moderate - resolution Imaging Spectroradiometer) sensor in 2001-2012 was obtained from the Fire Information for Resource Management System (FIRMS), which can be accessed free of charge at the link https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data. The map of the district and sub-district administrative boundaries obtained from the Regional Development Planning Agency (Bappeda) of Kapuas. The land cover map, the river network map, the road network map, the spatial plan map of the province and the peat thickness map are collected from the Ministry of Forestry that is used for the analysis of spatial and temporal distribution of fire activity. Hotspot is also used as the basis for determining the location of ground check. Monthly rainfall data of 2001-2011 year sourced from the station of rainfall originating from the Department of Horticultural Agriculture and Food Crops is used to analyze the relationships between hotspots and rainfall.

The main software for doing this study was ArcView 3.3, Microsoft Excel and Minitab. All of analysis uses a personal computer (PC). To obtain the coordinates of the location of the fire in the field, the researcher uses the Global Positioning System (GPS).

2.3. Data Analysis

Determination of hotspots that have a strong indication as the peat fire location is by taking hotspot with confidence values more than 50, more than 70 and more than 90. The hotspots with those confidence values are compared with the forest fire spots and the actual land (2012) from the ground check results. A confidence value is used to separate the weak to the strong indication of fire. The confidence value ranges from 0-100 %. The use of confidence values in separating hotspots and real fire spot will be different in different locations. Comparing hotspots to different confidence values with the results of a ground check of the fire will find the hotspot characteristics which are close to the real fire incident in the field.

The determination of the fire temporal pattern is performed with spatial analysis of monthly hotspots which are in the peatland areas. The hotspot data in peatland areas are separated by months and years of time and through geoprocessing process that is clipping and spatial joint. Monthly hotspots are tabulated and described to see the trend patterns of the fire season. Temporal hotspot analysis is done to see the indication of land and forest fires from time to time and its relationship with rainfall.

The analysis of the indication distribution of the fire location based on the hotspot distribution in the peatland areas based on biophysical and human activities factor which is being overlaid with maps are; land cover, distance from the river, distance from the road, the peat thickness. Each map of factors affecting peatland fires were classified in several classes as shown in Table 1 and Fig.2.

Table 1. *Factors classes used in spatial analysis*

Factors	Class
Land cover	Secondary dry land forest, Shrubs, Dry land agriculture, Water body, Paddy field, Secondary swamp forest, Open land, Swamp shrubs
Distance from river	Buffer with interval 1000 m (1km)
Distance from road	Buffer with interval 1000 m (1km)
Spatial land use plan *)	Limited production forest (HPT), Production Forest (HP), Transmigration (T1), Area for settlement (KPPL), Agriculture land “Handil” (KHR), Water bodies (DS), Area for agricultural and plantation production development (KPP), Area for conservation of hydrology (KH), Area for conservation of flora and fauna (KFF), Deep peat conservation (KGT), Black water conservation (KEAH)
Peat depth	Non-peat, Very shallow, Shallow, Medium, Deep, Very deep, Very very deep

*) These classes are derived from Spatial land-use planning of Kalimantan Tengah Province.

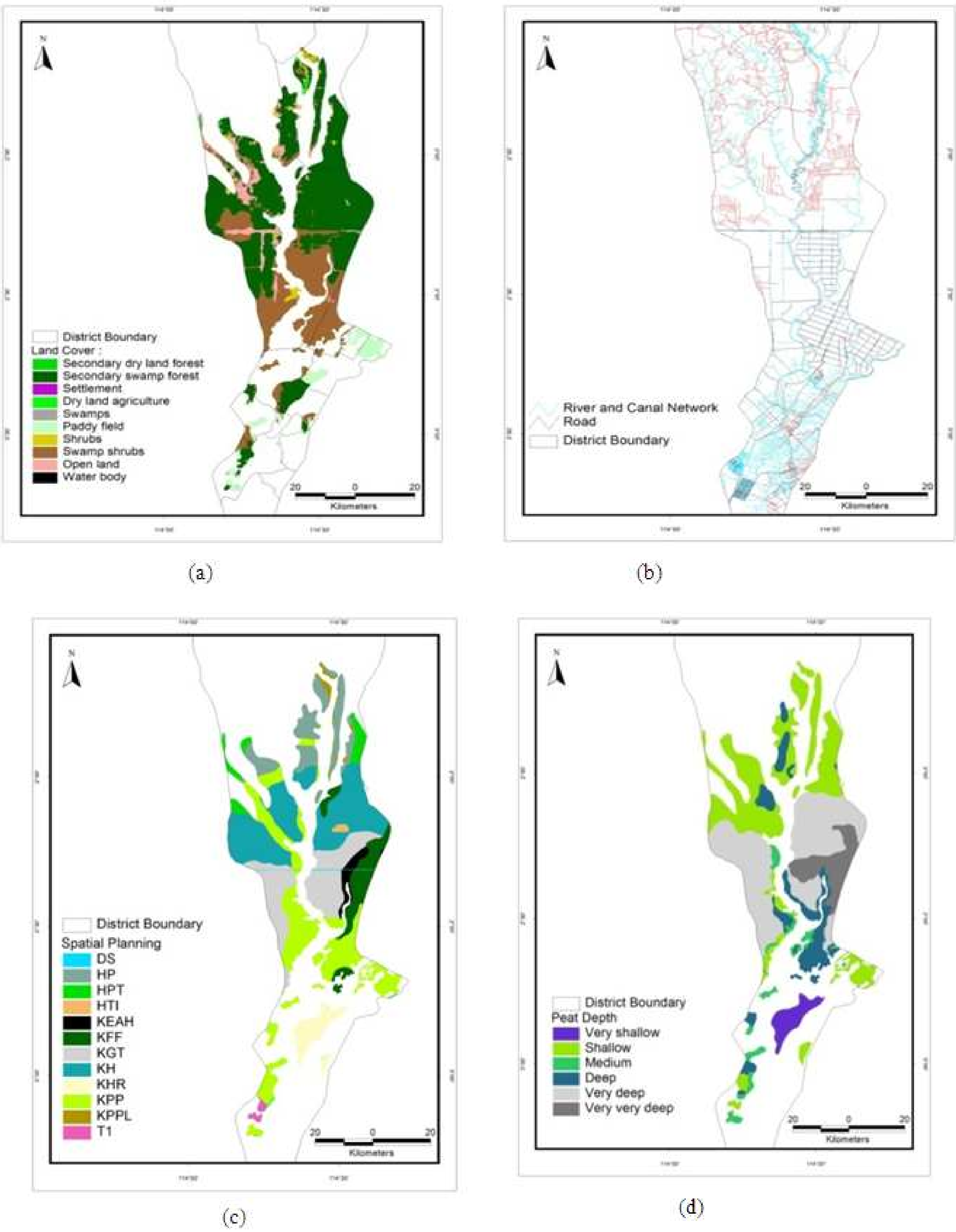


Figure 2. *Map of biophysical and human activities factors; land cover (a), river and road (b), spatial planning (c) and peat depth (d).*

3. Results and Discussions

3.1. Hotspot Confidence

The monitoring data and the detection of forest and land fire in Indonesia today still rely on the hotspot data. Hotspot characteristics that have strong relationships with the fires need to be determined because not all the hotspots detected in the peatland are the location of the fire.

Table 2. *The comparison between the fire location based on ground check and hotspot number in peatlands of Kapuas District 2012)*

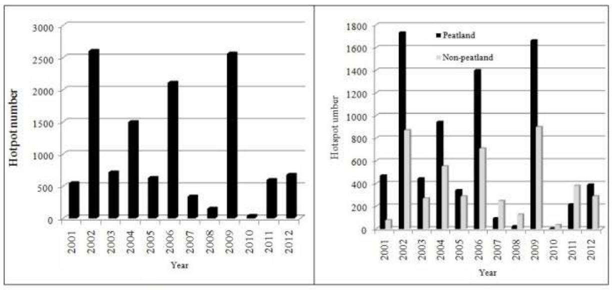
No	Sub District	Numbers of fire location in 2012	Hotspot numbers in 2012		
			C 50	C 70	C 90
1	Basarang	13	25	10	0
2	Dadahup	6	19	11	7
3	Kapuas Barat	3	27	11	1
4	Kapuas Murung	2	12	5	0
5	Kapuas Timur	1	1	0	0
6	Mantangai	2	8	4	0

Description (remarks): CX (hotspots with confidence values more than X %)

Hotspot which has a confidence value of more than 50% (C50) represents all fires result from the ground checks (Table 2). The hotspot with confidence more than 70% and more than 90% have the vacuum of hotspots on the actual fire location in the field. It shows that the hotspot that can be used to indicate a strong relationship with the peat fire incidence in Kapuas district is a hotspot that has a confidence value above 50%. Therefore, a spatial analysis, which is related to peatland fires using MODIS hotspot is a hotspot which data that has a confidence value above 50 %. The confidence level is used to determine the classes of low confidence (> 30 %), nominal-confidence (30%-80%) or high-confidence (> 80 %) in all the fire pixels [11]. The confidence value of a hotspot is highly variable in different places in the world. In Kapuas district, a hotspot with confidence values above 50% quite describes the peat fire in the field.

3.2. Peatland Fires Period

Based on the temporal analysis of 2001-2012 years through a number of hotspots of Terra/ Aqua MODIS, the descriptive relationship of the number of annual hotspots for 12 years in all of Kapuas regions was acquired (Fig. 3).



(a) (b)

Figure 3. *The Numbers of annual hotspots in Kapuas 2001-2012*

During the 12 -year period as shown in Fig. 3-a, the highest hotspot occurred in 2002 and then repeated in 2006 and 2009. At the height of the fire in 2002, 2006 and 2009 the hotspots were observed in peatland much more than in non-peatland (Fig. 3-b). Peatlands in Kapuas are mostly in the area of ex PLG. Based on the field observations and interviews with the society, the area of ex PLG is almost every year has a case of fire. Peatland become combustible after experiencing repeated fire every year. This phenomenon is reinforced by [12] that repeated fires in 2002, 2006 and 2009 occurred in the area of ex MRP.

The burning peat experiences irreversible drying so that it can no longer absorb water. The burning peat is also difficult to be extinguished and fire can creep under the surface so that it could extend uncontrollably. The dry peat with very low moisture, in the dry season will be a fuel that is very combustible. In addition, the land cover in the peatland is generally a wasteland overgrown by shrubs and grasslands. This is also confirmed by [12] that the dried peat cannot absorb any water when it was watered and it is inflammable. The burning peat generates heat energy greater than the burning wood or charcoal.

The peatland area covers 26.55% of the Kapuas total area. The peatland area is located in the southern part of Kapuas District. A non-peat land is relatively has a lower hotspot density value. The non-peat land covers 73.45% of the Kapuas district, located in the North region of Kapuas with the characteristics of a dry land with the soil minerals, a ramp to steep slope and the land cover is in the form of mixed farms and forests. The peatland condition experiencing drainage has increased the risk of fire in which the fire occurred widely in peatland, especially in the years where the rainfall is below the normal [1].

The increasing hotspot condition in the Kapuas District in 2006 was strengthened by the evidence that in that year the forest and land fire gave impact on the deterioration of air quality in several areas in Central Kalimantan. As shown by [1], in 2006 the air condition is not healthy or harmful, lasting more than 80% of the days during September-November.

The difference of hotspot number observed every year in Fig. 3 related to the rainfall in the area. Based on Fig. 4 calculated from the Terra/ Aqua MODIS data hotspot, it can be seen that the highest peak of hotspot number around the

Kapuas District regions occurred in 2002, 2006 and 2009. When the rainfall condition decreases, hotspots tend to increase. In contrast, the hotspots decreased in the years in which the rainfall increased in 2007, 2008 and 2010.

The rainfall influences much on fuel moisture content, especially in peatlands. As rainfall increases, peatlands store large amounts of water so that the fuel water content increases and it is difficult to burn. When the rainfall decreases, the peat moisture content is to be on the wane. Peat with low moisture content is very susceptible to burn. As in [13,14] explained that rainfall affects the dynamics of moisture content and groundwater levels from peat. Both fluctuations are strongly influenced by the dynamics of rainfall and wet soil. In the seasons with lower rainfall, water level drops to a critical threshold that causes the peat soil is highly flammable [15].

The highest number of hotspots in the peatland occurred in each month from August to October with minimally 100 hotspots (Fig. 4). The monthly hotspots increase when the monthly rainfall decreases. An increasing number of hotspots in August to October is related to people activities that adjust the end of the dry season and the beginning of rainy season. In June-July people who are generally farmers have opened and clean the land for farming preparation. The fuel that has been cut down and cleaned is allowed to dry for one to two months. In the next month from August to October at the end of the dry season, just like their habit, they burn biomass or the waste of the land cleared. Generally, human activities related to land clearing using fire in Central Kalimantan occurred during the dry season from May to September. Farmers clean the land during that time, when the biomass is drier [4].

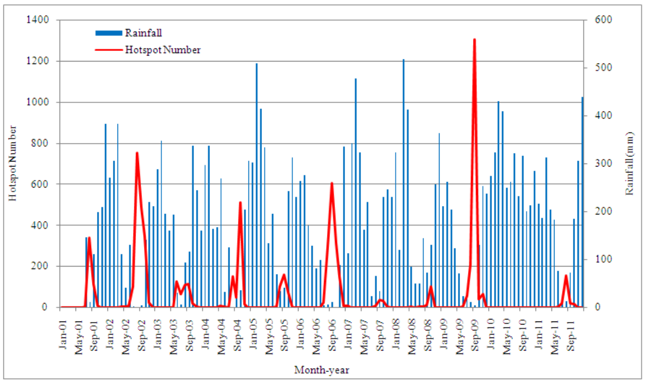


Figure 4*. The Monthly Hotspot and Rainfall in peatland area in Kapuas 2001-2011*

3.3. Peatland Fires Distribution Based on Biophysical and Human Activities Factor

Spatially, the peat fire activity is indicated by the density of hotspots based on the biophysical aspect and human activity. The more dense the hotspot, supposedly the activity caused the fire is getting bigger. Based on land cover, the highest density of hotspots in peatland area occurs largely in the form of swamp shrubs and open land (Fig. 5). Almost every year the hotspots are found in the swamp shrubs and open land with the large density and number. The areas with the lowest density of hotspots are found in the water body cover. A swamp shrubs is an area that is vulnerable to burning because it provides abundant cargo fuel and flammable in the dry season because it belongs to the fine fuel category. Open lands in the field are found in a form of grasslands, the former of burned land. Based on the interviews with villagers, fires often begin from land cover of open ground because it is not managed or an abandoned land. Open lands will be burned by people to hunting and fishing or being burned because of the negligence to throw cigarette butts.

The areas with swamp shrubs and grassland covers are found in the southern region of Kapuas. This area is generally located in the area of Ex MRP. Currently the area is largely a neglected area that is not managed (unmanaged land). In the displaced areas people burn the land more easily because it becomes an open access area and difficult to be monitored the villagers.

The hotspot density decreases as much as the estrangement distance from the rivers and canals in peatland as shown in Fig. 6. The area that closer to the river more dense hotspots area were detected. Conversely, the farther from the river, the density of hotspot is also lower. Descriptively, the number and density of hotspots will be lower and none at all at a distance of more than 5 km from the river. At a distance of more than 5 km from the river, there are only maximum 8 hotspots were observed during 12 years. This has to do with the people access in using the rivers and canals to carry out various activities like gathering and transporting timber, hunting, fishing and farming. People choose the location near the river and canal to perform many diverse activities. Therefore, the location adjacent to the rivers and canals are vulnerable to fire because it is easily accessed for doing activities that cause fires.

As in shown by [6,16], more than 4000 km canals have been built in the peatland area in Ex MRP which provides access allowing many community activities can be done. Existing of canal causing peatland areas surrounding drier than before and are very prone to burning. In the peat swamp forest in the Sugihan River [8] also found that the closer the rivers and canals the higher a chance the fire will occur.

The density of hotspots is higher by closer to the road (Fig. 7). Roads provide access for people and companies to perform a variety of activities that lead to susceptibility for land to be burned. People open a lot of land by burning it and it is generally close to the roads. Activities cause the land fires are like throwing the burning cigarette butts and open land for land tenure. The analysis by [7] also showed that a significant portion of fires occurred close to the road network, which can also suppose important cause of the fire.

The results of the spatial analysis also found that in the years in which the high rainfall and hotspots are less monitored, the farthest hotspots occur at the location 3 kilometers from the road. As happened in 2001 and 2010, where the number of hotspots is relatively low, the hotspots are observed only at a distance of 3 km from the road.

According to the spatial plan distribution, the highest density of hotspots based on the spatial plan in Kapuas is in KEAH area, KGT and KPP as shown in Fig. 8. Most of high density hotspot areas are located in the southern region of the Kapuas that is the transmigration areas and plots of peat in the area of ex MRP. The lowest density area of hotspots is in transmigration areas (T1). Area of KEAH and KGT are planned in the future as the peat conservation area. These locations have depth peat from very deep to very deep (400 – 1200 cm) as shown Fig.2-c. Transmigration areas based on the results of field checks are residential areas or villages. Land allocation for resettlement and cultivation could be pushed a region prone to fires. As in [17] found that the fires in Jambi Province are caused by factors related to human activities such as the existence of transmigration projects and the allocation of land for specific land uses.

Based on the peat thickness (Fig. 9), the highest density area of hotspots is mostly in a medium peat (100-200 cm) and very very deep (800-1200 cm). The lowest density area of hotspots was found in peat with a very shallow depth. In the year with the highest hotspot density, the depth area of peat was shifted to a very deep. In 2002 the highest density of hotspots is found in the peat medium, but in 2006 and 2009 they shifted to the very deep peatlands. The peatland area is becoming widely used by people for farming. By burning peat farmers get additional natural fertilizer from the rest of peat fires. Generally, the medium peat layer areas are also located in an easy access and close to roads, river and canal networks.

According to various peat thickness classifications greater than 3 m is considered to be deep, while 0.5 m is the minimum thickness used in the Indonesian system of peat classification [18,19,20]. Spatial analysis conducted by [21] found area peat dome are located in Block B, northern Kapuas. This area have very very deep peat thickness that is composed of remnant peat swamp forest 'islands' and large burnt areas.

Hotspot can be used to assess peatland fires indication. Hotspot density is one of the indications that can be used to assess fire activity in a region. Based on the spatial analysis, generally the densest hotspots are located in swamp shrubs, close to the river, close to the roads, in the very deep peat as well as in peat conservation area of spatial plan. It also showed that peatland characteristics above tend to be fire prone areas. In contrast, land with low density hotspot indicates that fire activity was also lower in these areas. In Kapuas District, peatland in the form of a water body, far away from the river, far from the road, the spatial plan of transmigration area and non-peat land are more resistant and lower in its hotspot density. This could indicate that the land with those characteristics is relatively more resistant to fire.

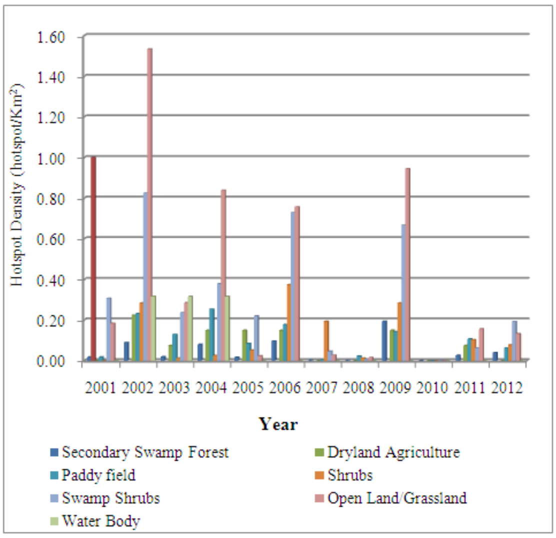


Figure 5. *The hotspot density in various land covers in Kapuas peatlands 2001-2012*

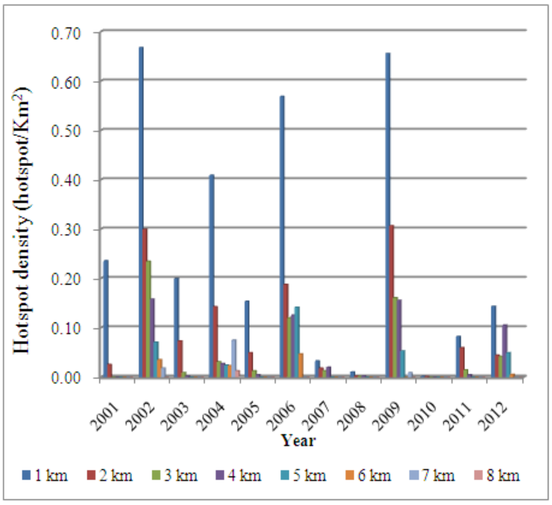


Figure 6. *Hotspot density based on the distance from river in Kapuas peatlands 2001-2012*

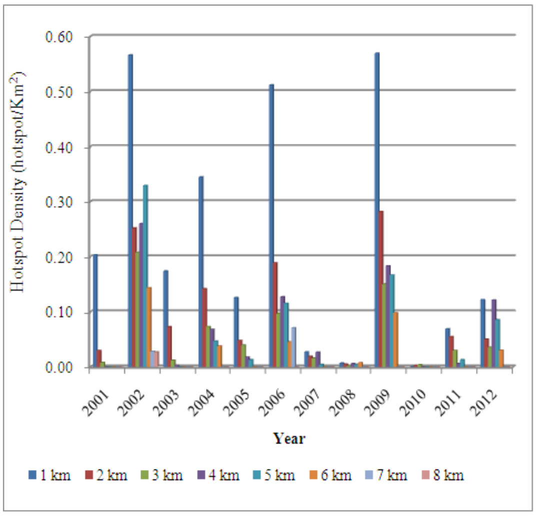


Figure 7. *Hotspot density based on the distance from the road in Kapuas peatlands 2001-2012*

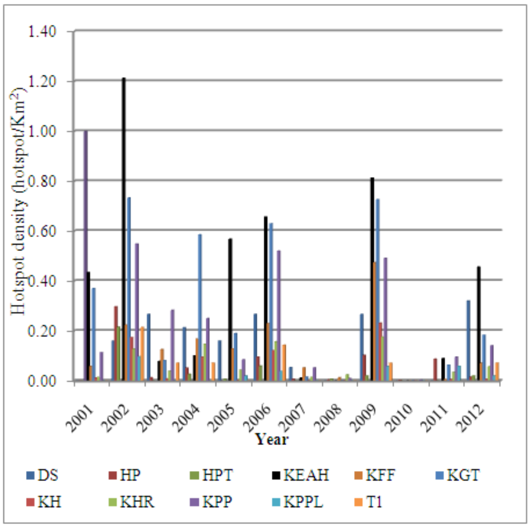


Figure 8*. The hotspot density according to the spatial planning in Kapuas peatlands in the year of 2001-2012*

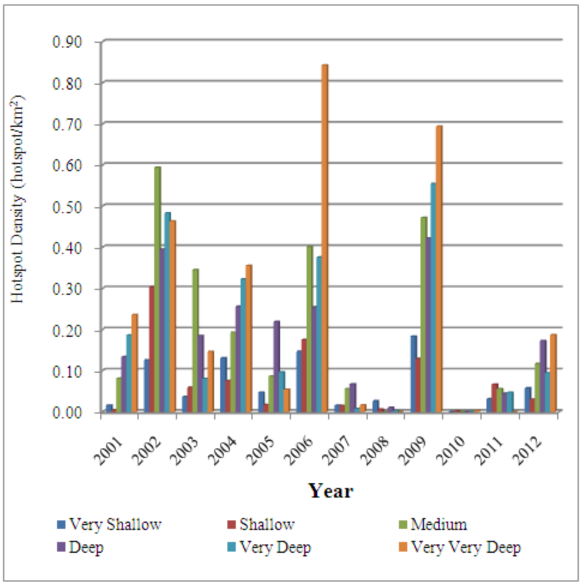


Fig. 9. *The hotspot density at various peat thickness in the peatland of Kapuas in 2001-2012*

4. Conclusion

The strong indication of peatland fires in Kapuas District is shown by hotspots derived from Terra/Aqua MODIS satellite with the confidence value more than 50%. The number of hotspot increases in the year where the rainfall is low. Based on the time, August to October is the time of the increasing hotspots in Kapuas. The densest hotspot in peatland of Kapuas District is generally located in the swamp shrubs, close from the river, close from road, in the very deep peat with spatial planning of the peat conservation area. Based on discussion above can be indicated that peatland conservation area and unmanaged land in Kapuas District were in vulnerable condition of the fire. Government needs intervention to improve unmanaged land utilization and protect the peatland conservation area in Kapuas District.

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