Spatial Analysis of The Correlation Between Hot Spot Distribution and Land Cover Type in Sumatra, Indonesia

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Abstract. Based on land cover data of 2015, Sumatra is dominated by shrubs, bushes, plantations with hardwoods, and plantations. It is the island with the largest peat distribution in Indonesia. Peatland forest map provided by Ministry of Environment and Forestry in 2015 represent that the total area of peatland in Sumatra is about 9.6 million hectares, mostly located in Riau, Jambi, and South Sumatra Province. Fire incidents can be indicated through hot spots distribution data. The data used is the distribution of hot spot of Sumatra in 2005-2016. The purpose of this study was to analyze the pattern of hot spot distribution and its relations with land cover changes. Overlay results indicate that 31.75% fires occur in shrubs and bushes, 20.87% in plantations with hardwoods, 16.60% in other natural cleared areas, 14.55% in forest crops, and the rest spreads in lowland crops, dry season crops, and swamp / peat forests. The highest hot spots are in 2005 and 2015 due to the El Nino effect that causes prolonged drought. Available land cover data indicates a change during 1990 through 2011. Most of peat land turn into plantation between 1990 to 2000. The result of overlay of hot spot distribution with land cover data from 2006-2015 shows that forest fires mostly occur in industrial plantation forest. This can be seen from the land cover classification where previously a plantation forest, then it is burned into a field and become an industrial plantation forest. Nevertheless, this analysis still need to be validated through ground truth to check the actual land cover and land use in field.

Keywords: Fire, Hot spot, Land cover, Sumatra

1. Introduction

Sumatra is one of five big islands in Indonesia. Based on land cover data in 2015, it is dominated by shrubs, bushes, plantations with hardwoods, and plantations. Also, it is the island with the largest peat distribution based on Ministry of Environment and Forestry in 2015. Peatland forest map provided by Ministry of Environment and Forestry in 2015 represent that the total area of peatland in Sumatra is about 9.6 million hectares, mostly located in Riau, Jambi, and South Sumatra Province. The aim of this study was to analyze the pattern of fires through hot spot distribution and its relations with land cover changes.

Fire incidents of land and forest in Indonesia in big scale started from 1982 until now. Big fire incidents happened periodically which was in 1982-1983, 1991, 1994, 1997-1998, 2006, and 2015 [1].

Forest fires can occur due to natural and / or human factors. Some experts consider that the more burnt-out area since 1991 happened as in consequence of the more natural forest changed into production forest, plantation, and so on. In 2015, fires particularly occurred in Sumatra, Kalimantan, and Papua which caused 80% of Sumatra and Kalimantan covered by thick smoke [1]. Based on research in Palangkaraya City, Central Kalimantan Province, forest and land fires densely happened in shrub and peat/swamp area at a distance about 1-2 km from residential or river and 0-1 km from the road [8]. National Agency for Disaster Management (2015) recorded that fires harmed the environment, caused economic loss, ecosystem destruction, germplasm loss, carbon emission, and the smoke spread through neighbor countries such as Singapore, Malaysia, Thailand, and South Philippine. Thereafter, the President issued an instruction about the enhancement for forest and land fire management (INPRES 11/2015). That involve more than twenty institutions coordinating to control forest and land fire through prevention, extinguish, and post-fire recovery. Furthermore, forest and land fire management had also been regulated in the Regulation of Environment and Forestry Minister (PERMENLHK) Number P.32/MenLHK/Setjen/Kum.1/3/2016 which the activity is organizing, managing the human resources and infrastructures, preventing, extinguishing, recovering, and supporting for evacuation and rescue.

The launch of NASA's Terra satellite in late 1999 marked a significant step forward in the ability to monitor fires from space. The satellite's sensor payload includes the Moderate Resolution Imaging Spectroradiometer (MODIS), an instrument having 1-km middle- and long-wave infrared bands designed specifically for the observation of actively burning fires [6]. The Terra satellite occupies a sun-synchronous polar orbit with local equatorial crossing times of 1030 (descending) and 2230 (ascending). A second MODIS instrument on NASA's Aqua satellite, launched in mid-2002, provides an additional pair of observations at 0130 (descending) and 1330 (ascending) local time [3]. The algorithm of Collection 6 MODIS active fire detection [4] is quite different with Collection 5 to solve the occurrence of false alarms caused by small forest clearings and the omission of large fires obscured by thick smoke [5].

The Aqua and Terra sensor from MODIS provide the information about hot spot and available in time series. It can be used to determine the hot spot distribution in Sumatra and to find out how the pattern changes periodically. The aim of this study was to analyze the spatial distribution of hot spot and the relation with land cover changes.

2. Method and materials

This research located at Sumatra. Data used was hot spot range from 2005 to 2016, base map, and land cover map range from 2006 to 2015. Hot spot distribution was downloaded from FIRMS using MODIS Terra/Aqua Satellite. Base map using 1:50,000 scale source from Indonesian Geospatial Information Agency (BIG). Layer that used from base map was boundary and residential building. Land cover map using 1:250,000 scale source from BIG for 2015 and Ministry of Environment and Forestry (KLHK) for 2006, 2009, and 2011.

Hot spot data was filtered based on the confidence level value to eliminate the outlier. All data over the confidence value of 90 would pass the filtering and the rest would be eliminated. The filtered data from 2005 to 2016 was statistically calculated per year to know when the hot spot mostly frequent. Then, the hot spot was plotted and the attribute table was joined with boundary layer from base map and land cover from BIG or KLHK. The overlay between hot spot, base map, and land cover map was performed for data in 2015, 2011, 2009, and 2009 separately due to land cover map availability. It would be used to perform the density value of hot spot by dividing the number of hot spot with land cover area. So, the area of land cover for each type should be calculated first and then followed by calculating the number of hot spot inside the land cover type boundary. The density value would determine which land cover type that have the most hot spot data in different year. Afterward, the statistic and density result would be used in the analysis process.

The analysis was done descriptively for all data processed by comparing the density in each year and take some sample in the overlayed map visually. The overlayed process was also done per province to find out which province experienced hot spot frequently. The result would refer whether there is a

correlation or no between the region, land cover type, and the number of hot spot. The flow chart of this study is presented in the Figure 1.

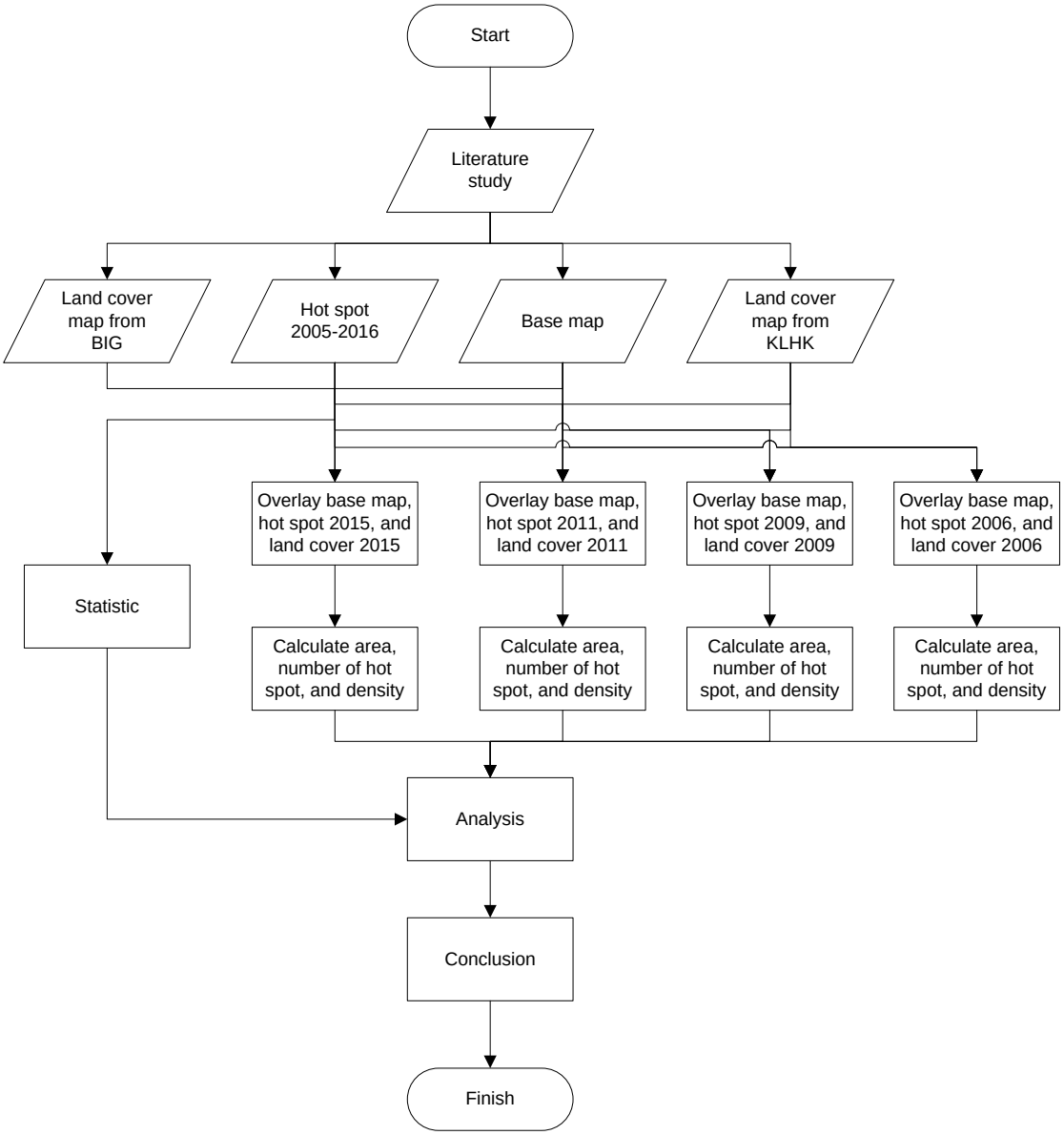

Figure 1. Flow chart of research methods

3. Result and discussion

3.1 Type of land cover in Sumatra

Indonesian Geospatial Information Agency (BIG) and Ministry of Environment and Forestry (KLHK) are government agencies which provide land cover data. BIG produces land cover into 22 classes while KLHK into 23 different classes. However, both of it have the same classification generally. The classification consists of shrub, plantation, forest, swamp/peat, open land, savanna, residential, and water.

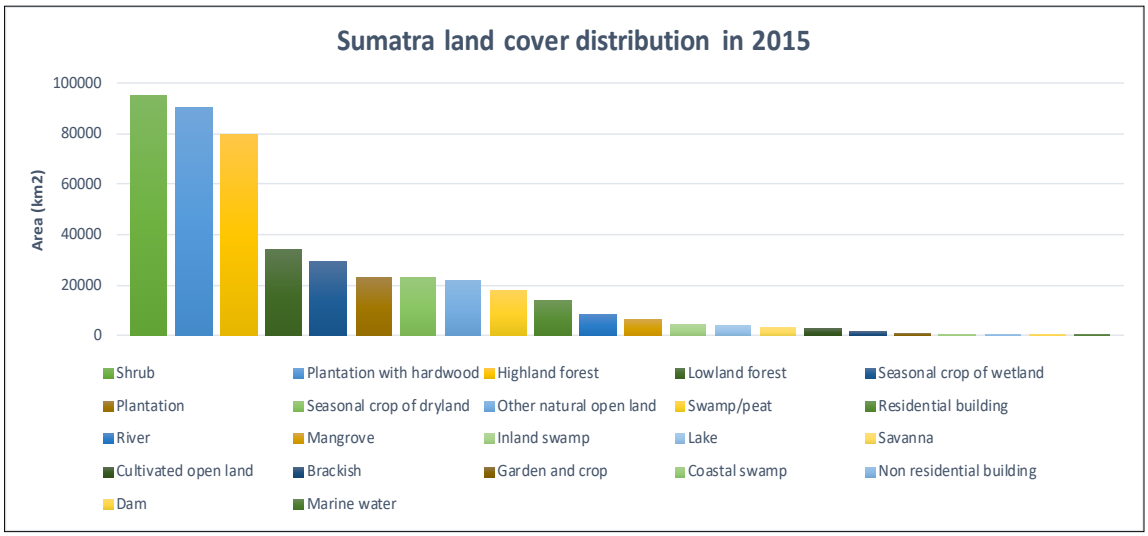

Figure 2. Type of Land cover in Sumatra

Based on land cover data of 2015, Sumatra is dominated by shrub, plantation with hardwood, highland forest, and plantation forest. Available land cover data indicates a change during 1990 through 2011. Most of peat land turn into plantation between 1990 to 2000. Then, some peat lands are classified as shrub in the land cover data.

3.2 Hot spot distribution in Sumatra from 2005 to 2016

Statistically, the number of hot spot varied each year and the most was in two periods that is 2005-2006 and 2014-2015. El Nino phenomenon was happened in those years and effected prolonged drought. It caused the land became easier to burnt so that hot spot detected by the satellite was significantly increase. The number of hot spot in 2014 increase 107.03% or more than twice from 2013.

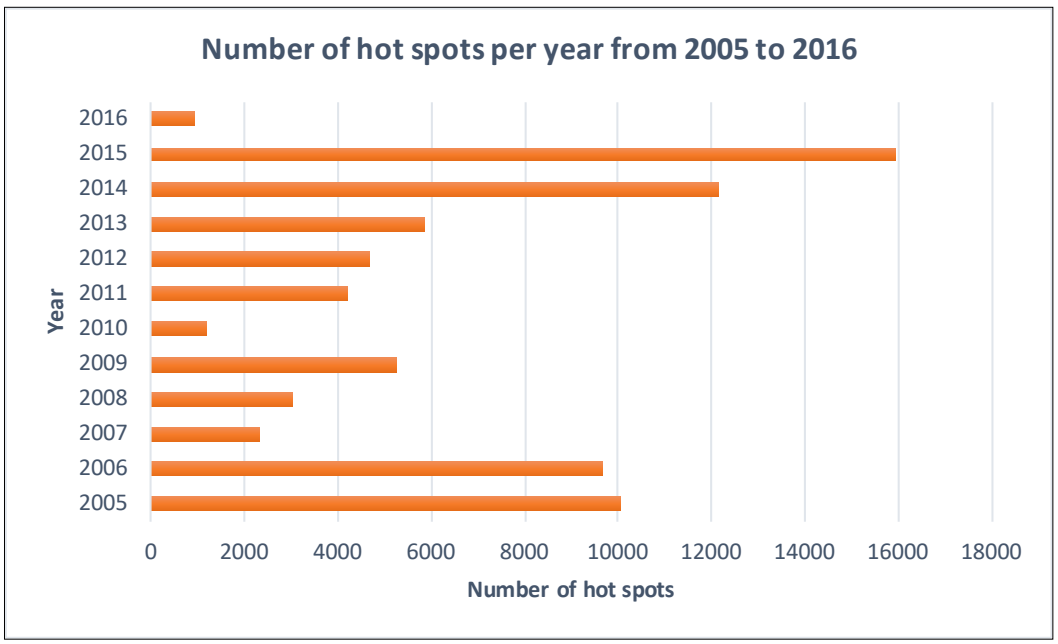

Figure 3. Distribution of hot spot per year from 2005 to 2016

Figure 3 shows that after El Nino phenomenon, the number of hot spot always decrease but increase again in some following years. If the hot spot in El Nino period was ignored, then the average number of hot spot each year detected by MODIS was 3,436 points. One of channel in satellite MODIS Terra/Aqua have resolution 250 m, it means that one hot spot point detected represent an area width 250 m x 250 m. Even though fire happen in the edge of pixel and the area is smaller than the resolution, the satellite will still detect fire in the middle of pixel as one point. If the average number of hot spot was converted into area, then the average of total area burnt was 214.75 km^2 each year.

3.3 Density of hot spot

Overlay results between land cover and hot spot in year 2015 indicate that hot spot mostly detected on plantation, shrub, other natural open land, swamp/peat, and plantation with hardwood. Meanwhile, if the density of hot spot was calculated then the most densities hot spot are on plantation, other natural open land, swamp/peat, shrub, and savanna (Table 1). The similar result was shown by overlay between land cover and hot spot in year 2006, 2009, and 2011. The highest densities hot spot was on swamp, open land, plantation forest, savanna, and shrub (Table 2).

Table 1. Density of hot spot in 2015

Land cover classification	Area (km^2)	Number of hot spots	Density (/km^2)
Plantation forest	23,234	5,286	0.228
Other natural open land	21,922	1,843	0.084
Swamp/peat	17,703	1,477	0.083
Shrub	95,088	4,937	0.052
Inland swamp	4,328	205	0.047
Savanna	3,190	112	0.035
Coastal swamp	341	11	0.032
Cultivated open land	2,690	37	0.014
Plantation with hardwood	90,372	1,212	0.013
Lowland forest	33,792	431	0.013
Seasonal crops of dryland	22,778	109	0.005
River	8,499	37	0.004
Seasonal crops of wetland	29,266	79	0.003
Lake	3,951	10	0.003
Mangrove	6,497	11	0.002
Residential building	13,642	23	0.002
Highland forest	79,607	103	0.001
Brackish	1,851	2	0.001
Plantation and crop	1,306	1	0.001
Non-residential building	66	-	-
Dam	10	-	-
Marine water	1	-	-

Table 2. Density of hot spot in 2006, 2009, and 2011

Land cover classification	Density (/km^2)		
	2006	2009	2011
Open land	0.135	0.071	0.044
Grove of swamp	0.098	0.052	0.032
Mining	0.061	0.018	0.029
Shrub	0.041	0.013	0.024
Secondary swamp forest	0.036	0.012	0.014
Savanna	0.032	0.011	0.011

Land cover classification	Density (/km^2)		
	2006	**2009**	**2011**
Mixed agricultural dryland	0.018	0.010	0.010
Swamp	0.013	0.010	0.006
Plantation forest	0.012	0.009	0.006
Plantation	0.009	0.006	0.005
Transmigration	0.009	0.004	0.003
Secondary dryland forest	0.009	0.004	0.003
Agricultural dryland	0.007	0.003	0.002
Primary swamp forest	0.005	0.002	0.001
Primary mangrove forest	0.003	0.001	0.001
Residential	0.002	0.001	0.001
Water body	0.002	0.001	0.000
Primary dryland forest	0.002	0.000	0.000
Paddy field	0.001	0.000	-
Secondary mangrove forest	0.000	0.000	-
Cloud	-	-	-
Pond	-	-	-
Airport/harbour	-	-	-

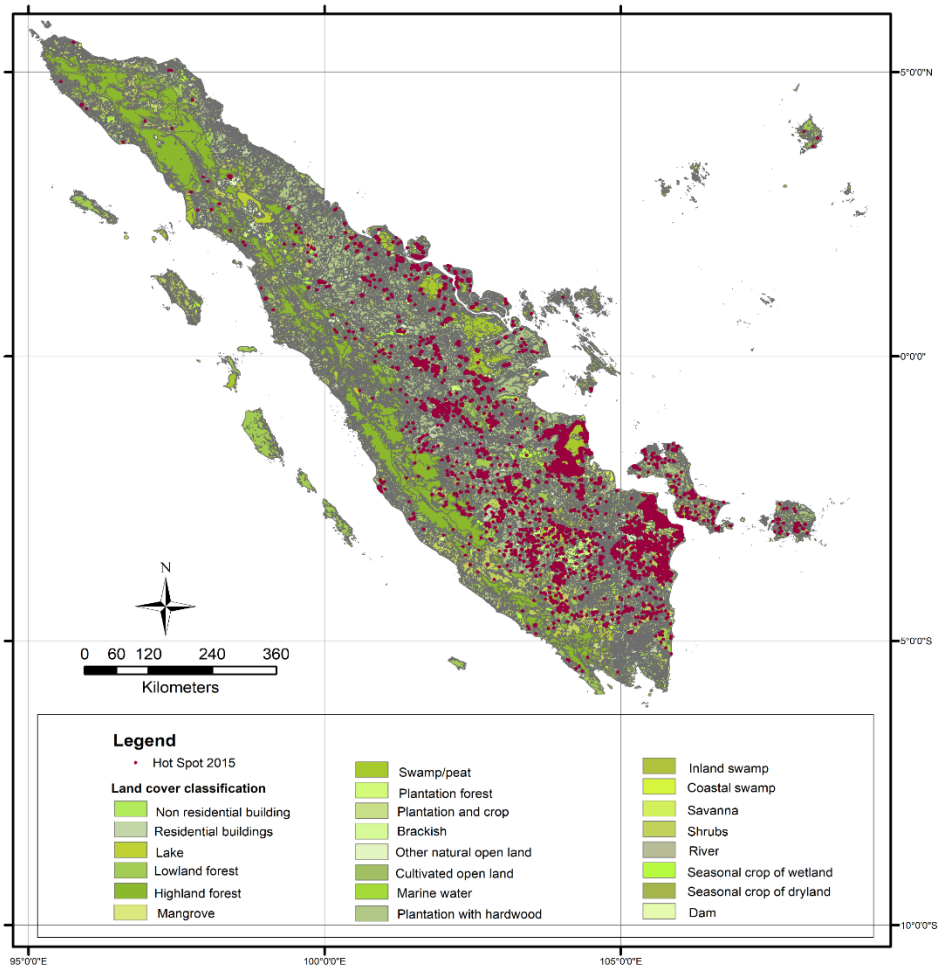

Figure 4. The overlay between land cover and hot spot in year 2015

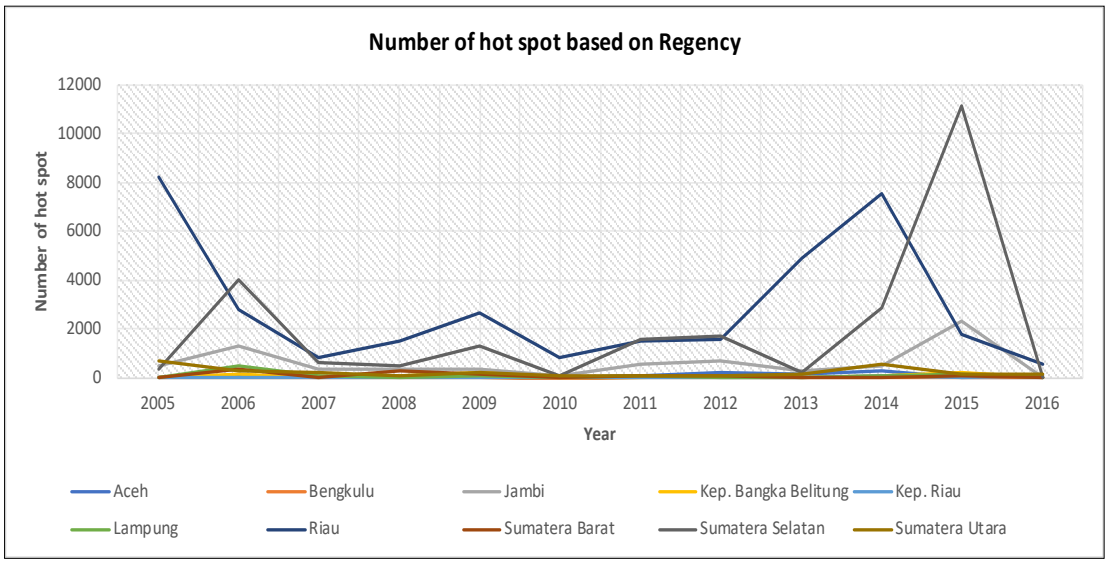

Figure 5. Distribution of hot spot based on Regency

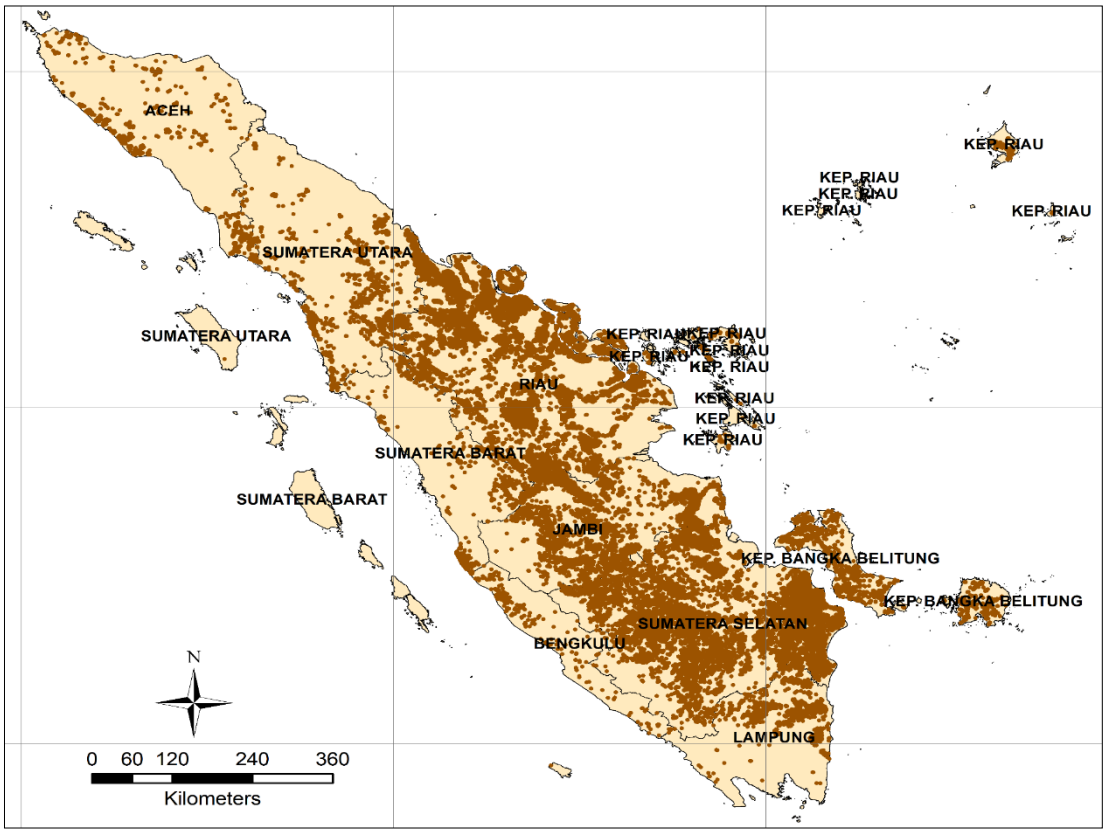

Figure 6. The spatial distribution of hot spot from 2005 to 2016

Hot spot distribution per year was clustered based on Province in Sumatra (Figure 3). The result was there are three from ten provinces in Sumatra that have the most significant number of hot spot, that is Riau, South Sumatra, and Jambi. Overlay results indicate that 31.75% fires occur in shrub, 20.87% in plantation with hardwood, 16.60% in other natural open land, 14.55% in forest crop, and the rest spreads in lowland crop, dry season crop, and swamp/peat forest. As much as 38% land cover in Riau was

plantation with hardwood, 13% shrub, 12% swamp/peat, 10% plantation, 7% other natural open land. Meanwhile in South Sumatra, 30% land cover in the form of shrub, 16% plantation with hardwood, 11% plantation forest. Similar with Riau, Jambi has 22% plantation with hardwood, 17% highland forest, 13% shrub, 10% seasonal crop of dryland, 8% other natural open land.

Based on hot spot detected and land cover type, these three provinces have similarity which was hot spot mostly detected on shrub, plantation forest, other natural open land, and swamp/peat. Currently, the government has been used Satellite MODIS Terra/Aqua to monitor hot spot as initiation to detect fire. Then, the team will check on field whether the fire occurred or not. Some strategies had been applied as a quick reaction if the fire had been detected, such as waterbombing from the air.

Based on interviewed with Manggala Agni (2017), fire incident starts declining. Still, there are obstacle when detecting fire on peat area. It could not be detected through MODIS Terra/Aqua because the fire occurred in the ground and only causes smoke on the surface. Satellite MODIS Terra/Aqua do not detect smoke as hot spot and could not penetrate through thick smoke. Fire suppression on peat is also more difficult when the fire extinguisher should be injected underground. Sometimes when the fire seems to be extinguished, the fire underground has not been completely extinguished and will cause the fire to happen again.

4. Conclusion

Based on the spatial analysis, it can be concluded that fire incidents mostly occurred on plantation, open land, swamp/peat, shrub, and plantation with hardwood. Hot spot distribution in year 2006, 2009, 2011, and 2015 shows that fire happened all the time and on the similar land cover type. This indicate that fire occurred due to human factor. The result of overlay of hot spot distribution with land cover data from 2006-2015 shows that forest fires mostly occur in industrial plantation forest. This can be seen from the land cover classification where previously a plantation forest, then it is burned into a field and become an industrial plantation forest. Nevertheless, this analysis still need to be validated through ground truth to check the actual land cover and land use in field.

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