The Use of Hotspot Spatial Clustering and Multitemporal Satellite Imagery to Facilitate Peat Land Degradation in West Kalimantan, Indonesia (Case Study in Mensiku Miniwatershed of Kapuas River)

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Abstract. Peat land in Indonesia is currently a matter of interest to economic activity. In addition to having the uniqueness of the ecosystem which is reserve a huge of biodiversity and carbon storage, peat land is grow an alternative expansion of agriculture and plantation. Mensiku miniwatershed is a subset of Kapuas Watershed with the domination of the peat soil type. It located in the upstream from the Kapuas River and supporting for the continuation of the river ecosystem. The research objective is to facilitate peat land degradation by using hotspot spatial clustering and multitemporal satellite imagery. There have three main processes which are image processing, geoprocessing and statistical process using DBSCAN to determine hotspot clustering. The trend of LUC changes for 14 years (2002 to 2016) shows that the downward occurred in secondary peat forest (0.9% per year) and swampy shrub (0.6% per year). The upward occurred in mixed farms (0.6% per year) and plantations (0.8% per year). degradation rate of peat land over 14 years about 4.6 km^2 per year. Hotspot predominantly occurrence in secondary peat forest with 200-250 centimeter depth and Saprists type. DBSCAN clustering obtain 2 clusters in 2002, obtain 4 clusters in 2009 and obtain 1 clusters in 2016. Regarding LUC platform, average density value over 14 years about 0.063 hotspot per km2. DBSCAN is common used to examine the cluster and perform the distribution and density with spatial analysis

Keyword: peat land degradation, LUC change, clustering, hotspot clustering

1. Introduction

Peat land in Indonesia is currently a matter of interest to economic activity. In addition to having the uniqueness of the ecosystem which is reserve a huge of biodiversity and carbon storage, peat land is grow an alternative expansion of agriculture and plantation. It intensified after the depletion of mineral land reserves for intensively agricultural and plantation. This activity led to the spread of peatlands in Indonesia, particularly in Sumatra and Kalimantan islands increasingly degraded both located in the forest concession area and non-forest concession area.

Nevertheless, the peatlands of Sumatra and Kalimantan continue to have numerous ecological, hydrological and biochemical functions and societal values [1] as much at local as at regional level. In recent years, the remaining peatland forests have also become an increasingly important refuge for endangered animal species [2], due to shrinking area of lowland forests on mineral soils [3].

Based on Center for Agricultural Land Resources Research and Development, Ministry of Agriculture in 2014, total peat land about14.9 Mha. In 2000, peat forest covered 57% of peat land, and decreased 4% until 2005 and so become 49% covers in 2010 [4].

Peat is undecomposed plant material that has accumulated over thousands of year. Due to the absence of oxygen in water-saturated environments, the decomposition of this material has been halted. Through drainage, the dry peat is in contact with the air and starts oxidating, decomposing, and emitting carbon dioxide. This process happens very rapidly in the tropics, and is often accelerated by wildfires. These fires can last for weeks, sometimes even months, burning thick layers of peat over large areas. The peat fires in South-east Asia can burn millions of hectares in one dry season and can last for weeks, sometimes even months, burning thick layers of peat and covering the region in thick smoke. Of the 21 million hectares of peatland in Indonesia 9 million hectares are drained and are decomposing or even burning. [5]

Degraded peatlands is a source of environmental problems as they are a source of greenhouse gas (GHG) emissions and fire prone. These land are unproductive, while the need for the expansion of agricultural land is very high. Research of the Indonesian Climate Change Trust Fund II was carried out to delineate the degraded peatlands, developed methods of management, evaluate the management impacts on crop yields, profitability and GHG emission reduction as well as analyzing the cost (opportunity cost) of emission reduction. The experiment was conducted from September 2012 to August 2013 in the provinces of Riau, Jambi, West Kalimantan, Central Kalimantan and Papua. The results showed that there are about 3.7 million ha (26% of total area of 14.9 million ha) of degraded peatland covered by shrubs plus about 0.6 million ha of bareland from open mining. Most of these lands have the potential for expansion of agriculture. In addition to increasing the economic value, the rehabilitation of degraded peatlands to agriculture tends to reduce GHG emissions and simultaneously improve the condition of the land. Degraded peatland are distributed in various areas of land allotment including non-forest production area (APL), protection forest (HL), convertible production forest (HPK) and forest production (HP) areas. It takes an allotment area rationalization and repositioning policies that degraded land inside the forest area can be rehabilitated for agriculture and forest land in the APL can be conserved to maintain the environmental function [6].

Hotspot is one of forest and land fire indicators that is widely used for developing fire early warning system in the purpose of preventing, controlling and monitoring of wildfire in the area that has high fire risk such as peat land [7].

Initially the hotspot is associated with the point of fire, but in fact not all hotspots indicates a fire points. The term of hotspot is more accurately when it synonymous with the spot of a hot point. A hotspot with high surface temperature value can be indicated of fire existence. This term is widely used in various countries to detect and monitor forest fires and land fires from satellite observation. Hotspot only provide little information and should be supported by further analysis and advanced interpretation. Groups of hotspot and come up continuously is an indicator for the fire occurrences. The determination of the fire-prone areas can be accessed through to landuse and cover change approach from open access of logged forest stand to alternation agriculture and plantations with a massive burned land clearing system.

Mensiku miniwatershed is a subset of Kapuas Watershed with the domination of the peat soil type. It located in the upstream from the Kapuas River and supporting for the continuation of the river ecosystem. Based on the landuse history, most part of forest stand in Mensiku miniwaterhsed had exploited as forest concessions business for 30 years. Secondary peat forest area has degraded into shrub, swamp and open land. This condition may lead the emergence of hotspot that can encourage dangerous condition of fire.

The research objective is to facilitate peat land degradation by using hotspot spatial clustering and multitemporal satellite imagery of Mensiku miniwatershed. This research is useful to examine the pattern and density of the hotspot emergence due to peat landuse change (LUC).

2. Method

Provision of the early vulnerability information of forest fires and land fires is one of the important efforts that need to know the threat of fire and tool of fire controlling. Hotspot spreading data detected by satellite remote sensing are indicators of forest fires and land fires so that analysis of the data needs to be done. Some recent research has been conducted to integrate sophisticated techniques remote sensing, spatial data mining, Geographical Information System, and smoothing algorithms for the new processing and analyzing spatial data such as hotspot data and other supporting data so that it can be obtained by spatial model, map detection and prediction in order to achieve level of forest fires and land fires vulnerability. Some related research has been implementing clustering approach on data mining to perform clustering on a large spatial hotspot data [7].

This research applies some analysis which is hotspot clusters analysis and peat LUC analysis. Hotspot cluster analysis using the DBSCAN algorithm for determining density and spatial pattern. Meanwhile, LUC analysis obtained with comparing landuse cover the period of 7 years of 2002, 2009 and 2016. The tendency focus on the rate of national peatland degradation.

2.1 Location

This research is located at 111°32’35’’ E and 0°13’42’’ N in Mensiku miniwatershed of Kapuas Waterhsed of 638.64 km2, in administrative of Sintang Regency (West Kalimantan Province), consists of Kelam Permai Sub-districts (10% of Mandiri Jaya Village), Binjai Hulu Sub-districts (10% of Binjai Hulu Village, 12% of Mensiku Village, and 9% of Ampar Bedang Village), Ketungau Hilir Sub-districts (11% of Tanjung Baung Village, 20% of Nanga Ketungau Village, and 27% of Setungkup Village).

2.2 Spatial Dataset

This research required spatial data such as i) Landsat images path 120 Row 60 (1 scene of Landsat 7 acquition in 2002, 1 scene of Landsat 5 acquition in 2009, and 1 scene of Landsat 8 acquition in 2016) with free download at USGS Global Visualization Viewer (http://glovis.usgs.gov/); ii) West Kalimantan administrative boundary with scale 1:250000 produced by BIG in 2010; iii) National peat land deliniation with scale 1:250000 produced by Ministry of Agriculture in 2011; iv) Hotspot data point (acquition in 2002, 2009, and 2016) produced by Ministry of Environment and Forestry and combined with Terra/Aqua MODIS of NASA (https://earthdata.nasa.gov/data/near-real-time-data/firms; v) Peat survey with 40 log point (depth, type). Data processing required particular software such as Quantum GIS 2.12.3 Lyon and R Statistic.

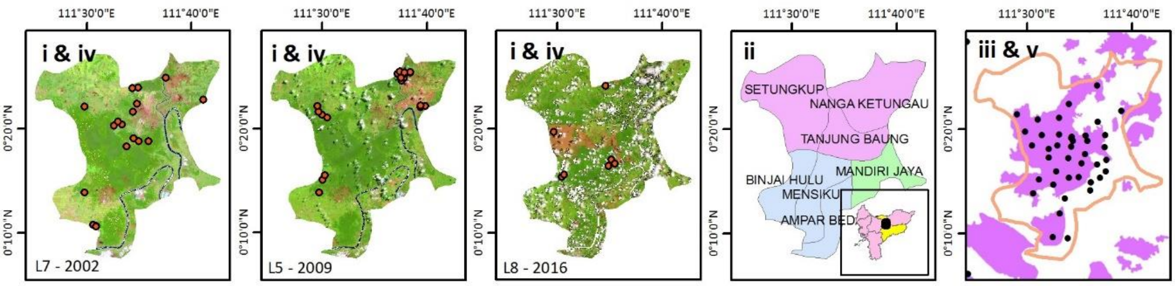

Figure 1. Spatial dataset

2.3 Process Flow

The process flow of this research described in Figure 2, where all the data will be confined by study location (AOI) thus data only be focused on the national peat boundary as actually AOI (AOI_peat). Commonly there has three main processes which are image processing, geoprocessing and statistical process.

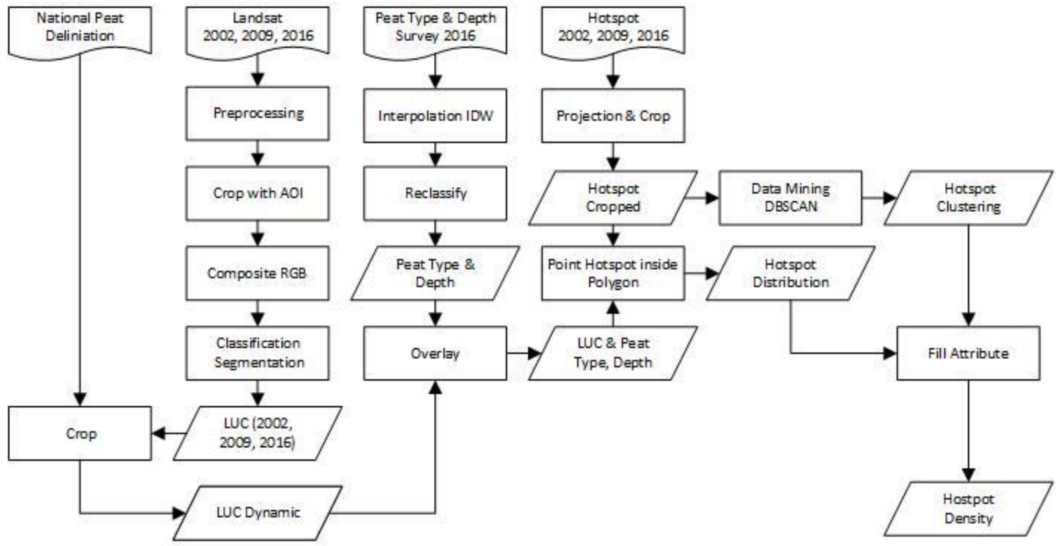

Figure 2. Data processing flow

Performing first step is preprocessing of Landsat imagery which are acquisition 2002 (Landsat 7/L7), 2009 (Landsat 5/L5), and 2016 (Landsat 8/L8). Preprocessing consists corrections (radiometric and geometric) and enhancement (contrast adjustment). The, cropping images in accordance with AOI (Mensiku miniwatershed) and RGB composition (RGB 542 to L7 2002, RGB 542 to L5, 2009 and RGB 1702 to L8 2016) required for unsupervised classification. The classification is based on object segmentation and refer to the Indonesia landuse cover standard (SNI Number 7645 year 2010). As the result, LUC (2002, 2009, 2016) geospatial data will match with national peat delineation (AOI_Peat) to adjust the dynamic rate of landuse cover change in peatland.

In the other side, performing interpolation by using IDW method is needed to map peat survey data (type and depth). Regarding the national interpretation of peat ripeness is grouped as Fibrists (immoldy), Hemists (half-moldy) and Saprists (moldy). In this study, peat type and depth is combined into several group such Peat Group One (< 150 centimeter, D2, Fibrists); Peat Group Two (150-200 centimeter, D2, Hemists); Peat Group Three (200-250 centimeter, D3, Saprists); Peat Group Four (250-300 centimeter, D3, Saprists); Peat Group Five (300-350 centimeter, D4, Saprists); Peat Group Six (350-400 centimeter, D4, Hemists); and Peat Group Seven (> 400 centimeter, D4, Hemists).

Overlay geospatial data is the next stage which are peat type-depth data, LUC data and hotspot data in order to gain the amount of hotspot in each landuse type and period. Statistical clustering approach applied by DBSCAN method in R software to obtain number of hotspot cluster in properly condition such as low of noise, little cluster, well-balanced of epsilon (eps), little minimum points in cluster (MinPts) and small number of error (SSE). The last stage is overlay hotspot cluster and mixed geospatial data to perform hotspot density in each peat group and landuse type.

Clustering algorithms are attractive for the task of class identification in spatial database. However, the well-known algorithms suffer severe drawbacks when applied to large spatial database. The main reason of recognizing the clusters is to promote typical density of points within each cluster which is considerably higher than outside of the cluster. The density within the areas of noise is lower than the density in any of the clusters [8].

Density-Based Spatial Clustering Algorithm with Noise (DBSCAN) is a clustering algorithm that is based on data density. For example, if the amount of data within an epsilon radius is more than or equal to the MinPts (the minimum amount of data within a radius Eps) then the data is included in the category of desired density, where the amount of data within the radius including the data itself. These algorithms perform well on the high density of data and it can find well for any form of groups, so it can separate between the high data density and the low data density of points as well as resistant to noise [9].

3. Result and Discussion

3.1 Landuse cover classification

LUC classification in Mensiku miniwatershed generated 8 classes in 2002, 8 classes in 2009, and 9 classes in 2016, which are Secondary Peat Forest (HRS), Mixed Farms (KBC), Plantation (PKB), Settlement (PMK), Mining (PTB), Agriculture (PTN), Swamp (RWA), Swampy Shrub (SBR), and Water Body (TBA). LUC in 2002 was dominated by HRS about 39.7%, followed by SBR about 26.2% and by 16.5% of agricultural land. LUC in 2009 was dominated by HRS about 37.4%, followed by SBR about 26.7%, agriculture about 16.8% and by 10.1% of swamp area. Meanwhile, LUC in 2016 was dominated by HRS about 27%, followed by SBR about 18.5%, agriculture about 17.1%, mixed farms about 12.2% and plantations about 10.8%.

The trend of LUC changes for 14 years (Figure 3) shows that the downward trend occurred in secondary peat forest about 0.9% per year and swampy shrub about 0.6% per year. The upward trend occurred in mixed farms about 0.6% per year and plantations over 0.8% per year. This condition showed in Mensiku miniwatershed, peat forests has been degraded into plantations and mixed farms.

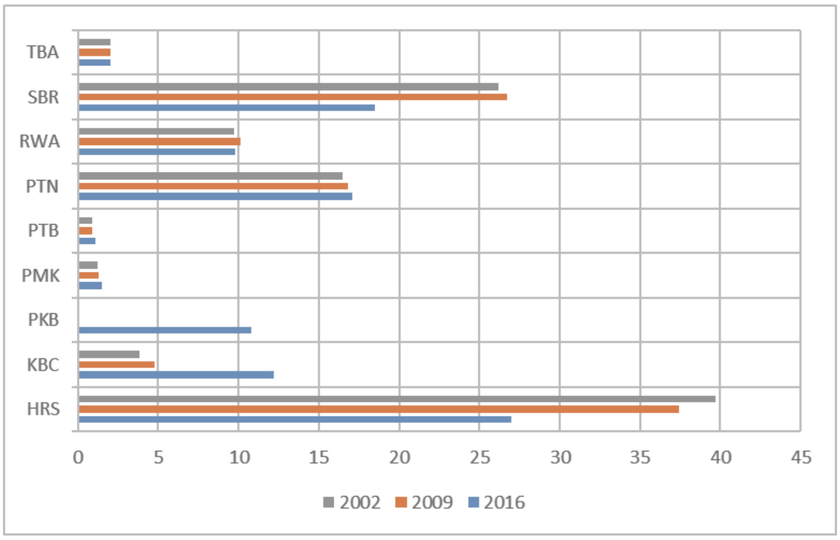

Figure 3. Percentage of LUC 2002, 2009, 2016

3.2 Change detection

More detailed explanation of land cover change detection for particular secondary peat land can be obtained by comparing among periods. During the period 2002 to 2009, secondary peat forests has been converted into other types of LUC such mixed farms about 21.34 ha, swamp area over 134.01 ha and swampy shrub over 488.36 ha. Degradation rate of peat land in period 2002 to 2009 over 91.96 ha per year or 0.92 km^2 per year (Table 1).

Table 1. LUC comparison period 2002 and 2009

		LUC 2009 (Ha)								
		HRS	**KBC**	**PMK**	**PTB**	**PTN**	**RWA**	**SBR**	**TBA**	**Total**
LUC 2002 (Ha)	**HRS**	19520.05	21.34				134.01	488.36		20163.76
	KBC		183.82							183.82
	PMK			35.76						35.76
	PTB				3.02					3.02
	PTN					716.71				716.71
	RWA						1264.92			1264.92
	SBR		13.66				67.18	2109.99		2190.83
	TBA								0.46	0.46
	Total	19520.05	218.82	35.76	3.02	716.71	1466.11	2598.35	0.46	24559.26

During the period 2009 to 2016, secondary peat forest has been converted to other types of LUC in the form of mixed farms about 223.64 ha, plantation over 5079.85 ha, settlement about 13.37 ha, agriculture about 16.44 ha, amount to 61.76 ha of swamp area and swampy shrub about 396.41 ha. HRS degradation rate of peat land in the period 2009 to 2016 amounted to 827.35 ha per year or 8.3 km^2 per year (Table 2). Definitely the degradation rate of peat land over 14 years (period 2002 to 2016) about 4.6 km^2 per year.

Rapid population growth in Indonesia leads a peat land converted into agricultural land in order to support food security, paper industry raw materials, plantations and bioenergy development. Most of peat lands utilization is the conversion for agricultural land, pulp plantations and oil palm plantations. One of the main trigger is the government program to look for an alternative energy by utilizing palm oil as renewable alternative energy. Human activities in the peat ecosystem has increased rapidly in the last two decades so that many areas of peat land become degraded an easier to burn [11].

Table 2. LUC comparison period 2002 and 2009

		LUC 2016 (Ha)									
		HRS	**KBC**	**PKB**	**PMK**	**PTB**	**PTN**	**RWA**	**SBR**	**TBA**	**Total**
LUC 2009 (Ha)	**HRS**	13728.59	223.64	5079.85	13.37		16.44	61.76	396.41		19520.05
	KBC		206.76		12.06						218.82
	PMK				35.76						35.76
	PTB					3.02					3.02
	PTN			0.42			716.29				716.71
	RWA		20.53	50.52				1395.06			1466.11
	SBR		331.96	106.63		10.25	123.66	13.24	2012.61		2598.35
	TBA									0.46	0.46
	Total	13728.59	782.88	5237.42	61.19	13.27	856.39	1470.06	2409.02	0.46	24559.26

3.2 Peat detection

A simple spatial analysis or geoprocessing is used to overlay LUC and peat type and depth in each period (2002, 2009 and 2016) in order to obtained a description of peatland conversion trends associated with peat group. Figure 4 presents the information of each peat group that had been developed. It shows the conversion occurrence over 14 years (2002 to 2009) of secondary peat forest. Large quantities occurred in Group Three (200-250 centimeters, D3, Saprists) and Group Five (300-350 centimeters, D4, Saprists).

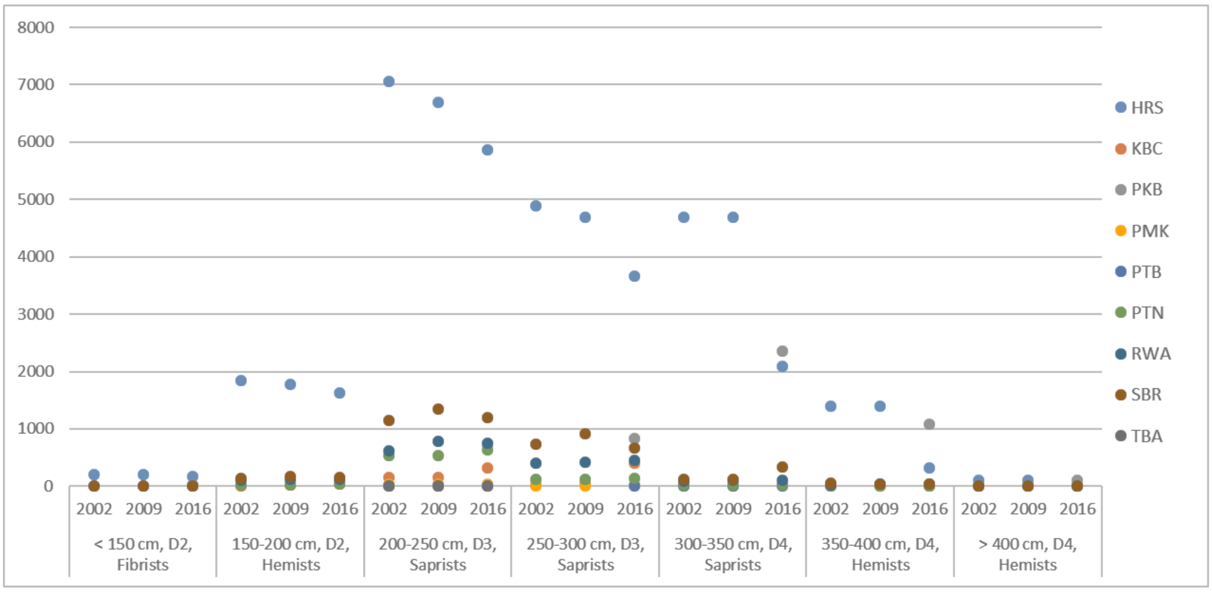

Figure 4. Peat type-depth and LUC comparison in 2002, 2009, 2016

3.3 Hostpot distribution

Hotspot data acquisition actually had recorded in daytime satellite orbit during 02-18 UTC. Regarding national peat boundary in Mensiku miniwatershed, there has 18 hotspot data occurred in 2002 and 25 hotspot data occurred in 2009 and 7 hotspot data occurred in 2016. Figure 5 presents the information of hotspot distribution in each LUC and peat group. It shows the predominantly occurrence along 3 periods (2002, 2009, and 2016) in secondary peat forest with depth over 200-250 centimeter and Saprists type.

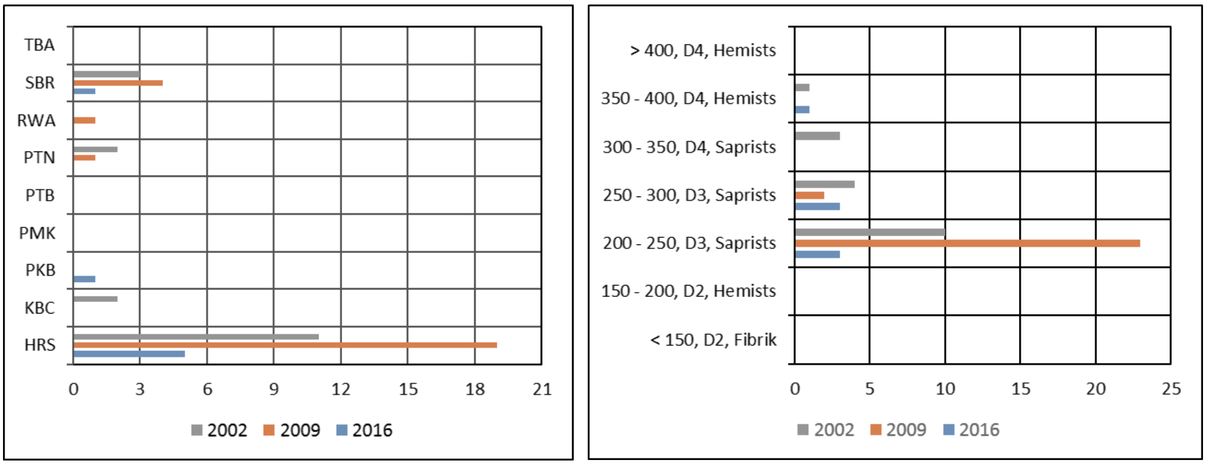

Figure 5. Hotspot distribution in LUC and peat type-depth (2002, 2009, 2016)

The highest density of hotspots often occurs in the farms, the closest distance to the river, the longest distance of the downtown and the closest distance to the road. The fact in Indonesia, any natural forest hardly of forest fires occurrence due to tropical climate with heavy rainfall and high humidity boost the hotspot and another fuel difficult to arise [10]. Secondary peat forest in Mensiku miniwatershed particularly in national peat delineation inside vegetation conditions is uncompact. It accompanied by a number of irregular open access may cause unscrupulous easily enter and exploited forest stand.

Many People assume that the weather or climate can cause forest and land fires. Basically, humans are the main driving factors n fire incidents. When doing burning activities, humans tend to not care about the surrounding environmental condition, so that often found the fire that hard to extinguish or quickly spread to the other land and become uncontrollable. These events have been severely aggravated by improper burning time. People who burns may think low rainfall a high temperature as a help so that burning activities can be done faster and easier. But on the other side, it also makes the effect worse [11].

3.4 Hotspot clustering

Some text Hotspot clustering by using DBSCAN algorithm with appropriate condition obtain compromised result due to determine parameters. DBSCAN clustering for 18 hotspots in 2002 obtain 2 clusters and 0 noise points with 0.07 Eps (epsilon), 2 minPts (minimum points in cluster) and 0.043 SSE (sum of squared errors). DBSCAN clustering for 25 hotspots in 2009 obtain 4 clusters and 0 noise points with 0.025 Eps, 2 minPts and 0.002 SSE. DBSCAN clustering for 7 hotspots in 2016 obtain 1 clusters and 0 noise points with 0.08 Eps, 2 minPts and 0.014 SSE.

3.5 Hotspot density

Hotspot density is composed to adjust the distribution and density of hotspot with LUC and peat type-depth platform. Regarding LUC platform particularly of secondary peat forest, the density value in 2002 obtained of 0.055 hotspot per km^2 (occupied by 201.638 km^2 peat area with 11 hotspot objects) and the density value in 2009 obtained of 0.097 hotspot per km^2 (occupied by 195.20 km^2 peat area with 19 hotspot objects), and the density value in 2016 obtained of 0.036 hotspot per km^2 (occupied by 137.286 km^2 peat area with 5 hotspot objects). The average density value over 14 years (2002 to 2016) about 0.063 hotspot per km^2.

Regarding peat type-depth platform particularly of 200-250 centimeters deep and Saprists peat type, the density value in 2002 obtained of 0.105 hotspot per km^2 (occupied by 95.39 km^2 peat area with 10 hotspot objects) and the density value in 2009 obtained of 0.0241 hotspot per km^2 (occupied by 95.39 km^2 peat area with 23 hotspot objects), and the density value in 2016 obtained of 0.031 hotspot per km^2 (occupied by 95.39 km^2 peat area with 3 hotspot objects). The average density value over 14 years (2002 to 2016) about 0.126 hotspot per km^2.

The study revealed that in 2002, the highest density of hotspot found in Riau province with the density value of 0.226 km2 and South Sumatra province with the density value of 0.201 km2. Distribution of hotspot in Riau province were mostly found in the area that has peat types of Hemists/Saprists (60/40) with very deep peat, and Hemists/Saprists (60/40) with moderate depth and spread evenly on the area with a moderate depth (100-200 cm), in the deep peat (200-400 cm), and very deep peat (> 400 cm) consecutively. Hotspot distribution in South Sumatera province were mostly found in peat land area that has peat types of Hemists/mineral (90/10) and mostly found in areas with moderate depth (100-200 cm). Land covers of peat land in both regions are dominated by peat swamp forest. In the year of 2013, the highest density of hotspots on peat land area of Sumatra was found in Riau province with the density value of 0.056 km2, where most of the hotspot was on peat types of Hemists/Saprists (60/40), and very deep peat land. Land covers of peat land are dominated by peat swamp forest. It seems that there were changes in the pattern of distribution of hotspot and land cover of peat land from 2002 to 2013, where in 2002 the distribution of hotspot are mostly found in moderate depth (100-200 cm) peat land, whereas in 2013, the distribution of hotspot were mostly found in very deep (> 400 cm) peat land area [12].

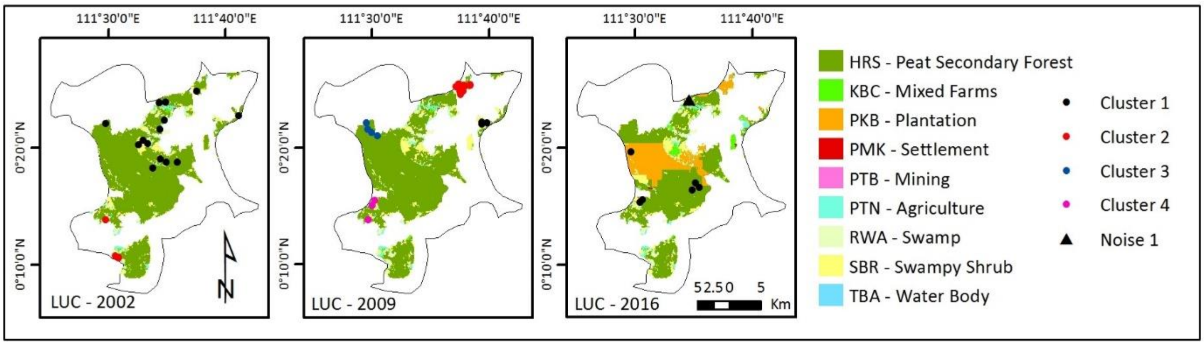

Figure 6. Hotspot spatial clustering in LUC platform (2002, 2009, 2016)

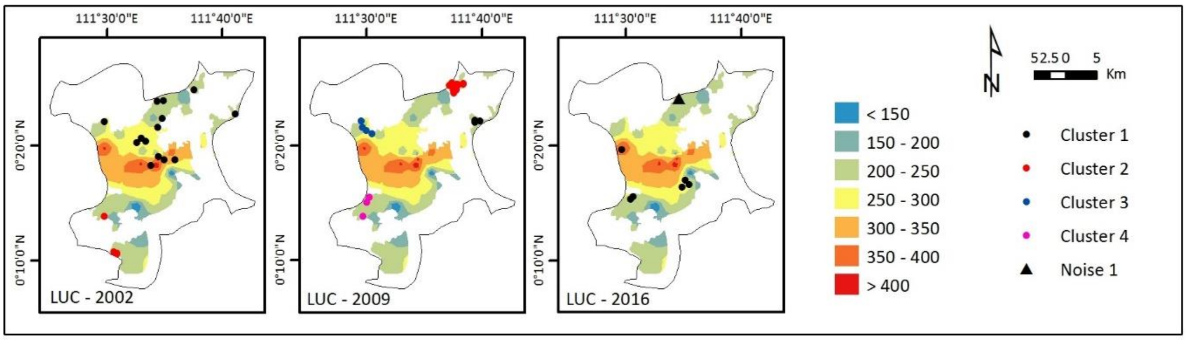

Figure 7. Hotspot spatial clustering in peat depth platform (2002, 2009, 2016)

4. Conclusion

This study demonstrates the enormous potential hotspot clustering and multi temporal imagery to facilitate peat land degradation. DBSCAN is common used to examine the cluster and perform the distribution and density with spatial analysis. Future study could be held to investigate hotspot spatial clustering considering degradation level for achieving clearly result of peat degradation.

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