Sequential Pattern Analysis of Hotspots based on Peatland Characteristics in Sumatra and Kalimantan

Sitanggang, I. S.,[1]* Putri, L. U. I.,[1] Khotimah, H.[1] and Syaufina, L.[2]
[1]Department of Computer Science, Faculty of Natural Science and Mathematics, Bogor Agricultural University, Indonesia, E-mail: imas.sitanggang@apps.ipb.ac.id, laniputriui@gmail.com, husnul.khotimah@apps.ipb.ac.id
[2]Department of Silviculture, Faculty of Forestry, Bogor Agricultural University, Indonesia
E-mail: syaufina2016@gmail.com
** Correspondence Author*

Abstract
Peat fires become a yearly tradition, so that necessary precautions are needed in order to minimize the destruction of peatlands. Peatland fires can be detected through hotspots occurrence in the region, but not all hotspots indicate fires. However, hotspots consecutively found in a certain area in the period of two to five days are strong indicators for forest and land fires. This study aims to obtain characteristics of hotspot sequential patterns in peatland using data mining approach. The algorithm used is Sequential pattern Discovery using Equivalent Class (SPADE) that applies a vertical format in sequential pattern mining to extract frequent sequences on datasets. This study involves spatial data including hotspot data from FIRMS NASA, peatland characteristics from Wetland International to enrich our analysis, and the district border layer to determine the location of hotspot sequences. Data transformation was performed to prepare datasets before applying SPADE. There are 316 sequences found in Kalimantan and Sumatra in 2014 and 2015 with a minimal of two days occurrences and minimum support of 1%. This study shows that hotspot sequences in Kalimantan 2014 and 2015 are frequently occurred in peatland that has the type of Hemists/Fibrists (60/40) and depth of 400-800 cm. In addition, hotspot sequences in Sumatera 2014 and 2015 are typically occurred in peatland that has the type of Hemists/Saprists (60/40), landuse of swamp forest and depth of 100-200 cm.

1. Introduction

Peatlands have a major role in the environment because of its ability to absorb and to store carbon of the world. When peatlands burn the carbon is released into the atmosphere. This situation triggers the acceleration of global warming and if peat burning happens continuously, it will cause global climate change. Peatland fire in Indonesia is largely due to human behavior that practices inappropriate land management. Peatland fire prevention is needed to avoid negative effects of peat fires. Fire prevention can be performed by identifying the location of a hotspot as one of the indicators of forest and land fires. Hotspot data generally consists of location and time of hotspot occurrence. Data mining is one of the approaches that has been used to analyze hotspot data. Our previous studies have applied clustering algorithms namely Poisson Clustering Process and DBSCAN to group hotspots in peatland in order to identify distribution patterns of hotspot clusters in the study area in Sumatra (Kirana et al., 2015, Usman et al., 2015 and Hermawati and Sitanggang, 2016). Moreover, the study by Sitanggang et al., (2014) proposed a spatial decision tree model to classify hotspot occurrences in Rokan Hilir, Riau Province. Although hotspots are frequently used to indicate forest and land fires, not all hotspots indicate real fires. However, hotspots that are occurred consecutively in two to five days in a certain location are considered as the strong indicator of forest and land fires. The sequences of hotspot can be found using the sequential pattern mining. Sequential pattern mining method is divided into two main classes, namely Apriori-based approach, which consists of Generalized Sequential Pattern (GSP) and Sequential Pattern Discovery using Equivalent Class (SPADE) algorithms and projection-based approach which consists of PrefixSpan and Closed Sequential Pattern Mining (Clospan) algorithms (Han et al., 2005).

A study by Agustina and Sitanggang (2015) applied the sequential pattern mining algorithm namely Closed Sequential Pattern Mining (Clospan) on the hotspot and weather dataset in Riau Province, Indonesia for the period of 2001 to 2010. This study obtains hotspot sequence patterns at minimum support of 1%, 2%, 3%, 4%, 5%, 10%, 15% and 20%. This study results hotspot sequences that were found in locations with temperature ranging from 28.33 °C to 30 °C. However, the study by Agustina and Sitanggang (2015) does not provide time span between hotspot occurrences in sequence patterns. Another study by Nurulhaq and Sitanggang (2015) identifies sequential patterns on hotspots that become a strong indicator of forest fires in Riau Province in 2014. This study used the PrefixSpan algorithm to find hotspot sequences with the occurrence period of 2 to 3 days (Nurulhaq and Sitanggang, 2015). For example, the sequential pattern <(June 19, 2013) (June 21, 2013)> means that hotspots occurred on June 19, 2013 in a certain location and then this pattern is followed by other hotspot occurrence in the same location on June 21, 2013. This pattern is supported by 8.88% of sequence dataset. The study by Nurulhaq and Sitanggang (2015) reports that as many 16.95% hotspots that sequentially occurred in time period of 3 to 5 days. These hotspots are considered as strong indicator of forest fires in Riau Province in 2014.

SPADE is one of sequential pattern mining algorithms that facilitate the search for sequential patterns in a database. SPADE produces better performance in terms of computation time than frequent sequences search algorithms such as AprioriAll and GSP (Kumar et al., 2012). This study aims to generate sequence patterns of hotspots in Sumatra Island and Kalimantan in 2014 and 2015 using the SPADE algorithm. In addition, the characteristics of hotspot sequences in the study area are identified. It is expected that the results of this study can be used in peat fires prevention.

2. Research Method

2.1 Data

The data used in this study are hotspot data in Sumatra and Kalimantan in 2014 and 2015 as well as peatland data. Hotspot data were obtained from the National Aeronautics and Space Administration (NASA) Fire Information for Resource Management (FIRMS) http://earthdata.nasa.gov/ whereas peatland data were collected from Wetland International. Hotspot data are divided into 4 datasets as follows:

1. Dataset of Kalimantan 2014 consisting of 6,011 records
2. Dataset of Kalimantan 2015 consisting of 12,962 records
3. Dataset of Sumatra 2014 consisting of 14,237 records
4. Dataset of Sumatra 2015 consisting of 16,720 records

Hotspot data consist of several attributes as characteristics of hotspot occurrence. Those attributes include latitude, longitude, brightness temperature, scan, track, acq_date, acq_time, satellite, confidence, version, bright_t31, and fire radiative power. In order to generate sequence patterns of the hotspot, this study uses latitude and longitude representing hotspot location as a spatial characteristic of the dataset. In addition to latitude and longitude, acq_date, the day when a hotpot was acquired by the NASA satellite, is used as a temporal characteristic of the dataset.

2.2 Preprocessing Data

Preprocessing data include data selection, data transformation, and sequential data generation. Data selection was done to select attributes of hotspot and peatland that are used in this study as well as to select hotspots that have confidence value greater than or equal to 70%. Data transformation was performed to convert date of hotspot occurrence into an integer which is called date_code. In addition, location of hotspot occurrence is also replaced by integer which is called SID. Integer type of date and location of hotspot is required in the sequential dataset format as input of the SPADE algorithm. The next step in preprocessing data is preparing sequential datasets. In a hotspot sequential dataset, location of hotspot, which is represented by longitude and latitude, is encoded as sequence ID (SID). The date of hotspot occurrences is represented as event ID (EID). Figure 1 illustrates the format of a sequential dataset. In Figure 1, column of size contains a number of hotspot occurrence at the same location (SID) and the date (EID).

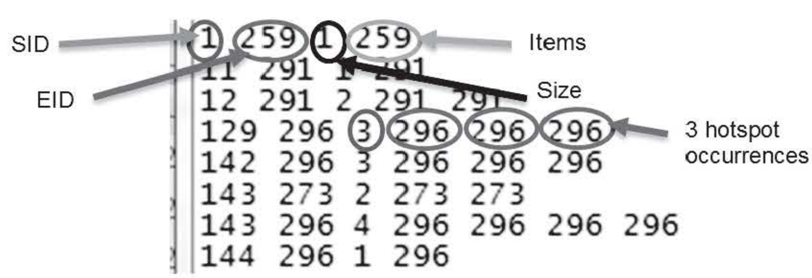


Figure 1: Format of sequential dataset as input of the SPADE algorithm

2.3 Sequential Pattern Mining on Hotspot Dataset

Hotspot occurrences are daily recorded based on the sequence of times composing the time series datasets. There are several patterns that we can extract from the time series datasets including trend analysis, similarity search, sequential pattern, and periodical pattern (Zhao and Bhowmick, 2003). In addition to the temporal aspect, a hotspot has a spatial aspect which is the location of its occurrence represented in longitude and latitude. This study adopts sequential pattern mining approach to discover sequence patterns on hotspot datasets based on the spatial and temporal aspects. The previous studies by Agustina and Sitanggang (2015) and Nurulhaq and Sitanggang (2015) have shown that the sequential pattern mining approach has been able to discover sequence patterns on large hotspot datasets.

There are several algorithms in sequential pattern mining such as AprioriAll, GSP, and SPADE. We adopt SPADE because this algorithm has better performance in term of computation time compared to other algorithms such as AprioriAll and GSP (Kumar et al., 2012). The SPADE is more efficient than AprioriAll and GSP because it uses the vertical data format in which the data are mapped to <itemset : (sequence ID, event ID)>. The vertical data format can be generated by transforming from a horizontally formatted sequence database in just one scan (Han and Kamber, 2006). In addition, the SPADE is already implemented on R statistical package. SPADE find patterns on a sequential dataset by dividing main problems into sub-problems that can be solved separately (Zaki, 2001). The first step in SPADE is to determine frequent 1-sequences (F1). Frequent 1-sequences are all items that have support value greater than or equal to defined minimum support (min_sup). Support value of an item is number of different SID in the dataset that contains the item. In this study, an item represents an event which is a hotspot occurrence. All items in frequent 1-sequences will be a parent class in the formation of frequent k-sequences for k = 2, 3, .., so on. All frequent sequences (S) generated are also known as frequent atoms. Frequent k-sequences are generated by combining frequent (k-1)-sequences with other frequent (k-1)-sequences. The algorithm to generate all possible frequent sequences using the function of *Enumerate-FrequentSequences* can be seen in Figure 2.

3. Results and Analysis

3.1 Hotspot Sequential Pattern

Sequential patterns on hotspot datasets were generated using the SPADE algorithm that is available in R statistical package with minimum support of 1% and 0.1%. Table 1 shows the number of sequences generated from four datasets namely Sumatra 2014, Sumatra 2015, Kalimantan 2014 and Kalimantan 2015. This research analyzes 2-sequence patterns with time span more than or equal to 20 days meaning that the time interval of the first hotspot occurrence and the second hotspot occurrence is less than or equal to 20 days.

```
SPADE (min_sup, D) :
        F1 = {frequent items or 1-sequences};
        F2 = {frequent 2-sequences};
        Ɛ = {equivalence classes[X]θ1};
        for all [X] ∈ Ɛ do Enumerate-Frequent-Seq([X]);
Enumerate-Frequent-Seq(S):
        for all atoms Ai ∈ S do
                Ti = Ø;
                for all atoms Aj ∈ S, with j ≥ i do
                        R = Ai ∨ Aj;
                        if (Prune(R) == FALSE) then
                                L(R) = L(Ai) ∩ L(Aj);
                                if σ(R) ≥ min_sup then
                                        Ti=Ti∪{R}; F|R|= F|R|∪{R};
                end
                if (Depth-First-Search) then Enumerate-Frequent-Seq(Ti);
end
If(Breadth-First-Search) then
        for all Ti ≠ Ø do Enumerate-Frequent-Seq(Ti);
```

Figure 2: SPADE algorithm (Zaki, 2001)

Table 1: Number of sequential patterns for minimum support of 1% and 0.1%

Dataset		Minimum support = 1%			Minimum support = 0.1%		
	k-sequential pattern			Total	*k*-sequential pattern		Total
	k=	1	2		1	2	
Kalimantan 2014		30	2	32	127	175	302
Kalimantan 2015		44	7	51	106	295	401
Sumatra 2014		61	24	85	149	295	444
Sumatra 2015		62	71	148	149	686	835

Table 2: Examples of interesting 2-sequence patterns of hotspot

Sequence in date code	Sequence in date of hotspot occurrence	Support
Kalimantan 2014		
<{266},{296}>	<{2 Oct 2014},{1 Nov 2014}>	0.0057
<{250},{296}>	<{16 Sep 2014},{1 Nov 2014}>	0.0040
<{259},{298}>	<{25 Sep 2014},{3 Nov 2014}>	0.0026
Kalimantan 2015		
<{250},{284}>	<{10 Sep 2015},{14 Oct 2015}>	0.0186
<{188},{250}>	<{10 Jul 2015},{10 Sep 2015}>	0.0106
<{38},{284}>	<{10 Feb 2015},{14 Oct 2015}>	0.0085
Sumatra 2014		
<{42},{67}>	<{14 Feb 2014},{11 Mar 2014}>	0.0037
<{33},{67}>	<{5 Feb 2014},{11 Mar 2014}>	0.0022
<{67},{206}>	<{11 Mar 2014},{28 Jul 2014}>	0.0022
Sumatra 2015		
<{9},{68}>	<{10 Jan 2015},{10 Mar 2015}>	0.0282
<{68},{129}>	<{10 Mar 2015},{10 May 2015}>	0.0250
<{9},{271}>	<{10 Jan 2015},{29 Sep 2015}>	0.0170

Table 2 shows some examples of interesting 2-sequence patterns of hotspot that have high support values. The sequence <{266},{296}> in Table 2 means that hotspots occurred on 2 October 2014 in a certain area in Kalimantan and it is followed by other hotspot occurrences on 1 November 2014 at the same location. Moreover, the interesting hotspot sequence found in the dataset of Kalimantan 2015 is <{250},{284}> meaning that hotspots were found in a certain area in Kalimantan on 10 September 2015 and it is followed by other hotspot occurrences on 14 October 2015. This study obtains different patterns on hotspot sequences of Sumatra. Interesting sequences on the dataset Sumatra 2014 and 2015 are occurred at the beginning of year ranging from January to March, as shown in Table 2.

3.2 Characteristics of Hotspot Sequences

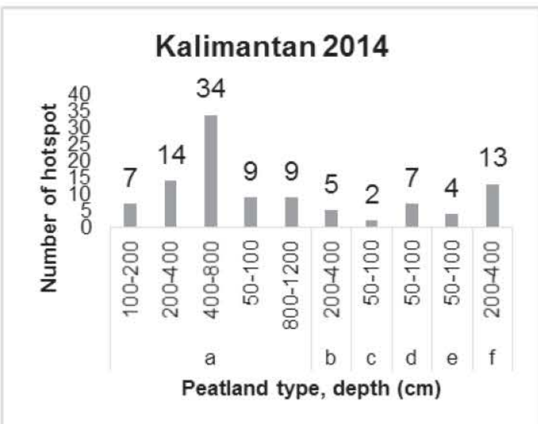
This study focuses on identifying hotspot sequences that have a time interval between one event to others more than or equal to 20 days. In addition, we analyze only the sequences that have high support values. Furthermore, on these sequences we select the subsequences that have time interval 3 to 5 days which are considered as a strong indicator of peatland fires. Spatial operations were performed to determine characteristics of interesting hotspot sequences based on peatland type and peatland depth. An interesting hotspot sequence is a hotspot sequence that has high support value. Table 3 summarizes the peatland characteristics where hotspot sequences commonly occur in Sumatra and Kalimantan in 2014 and 2015.

Table 3 provides long hotspot sequences in which time interval between the first hotspot occurrence and the second hotspot occurrence is greater than or equal 20 days. A long sequence in Kalimantan 2014 is <{266},{296}> with support value of 0.0057 in which date code 266 represents 2 October 2014 and date code 296 denotes 1 November 2014. In addition, an example of a long sequence in Kalimantan 2015 is <{250},{284}> with support value of 0.0186 in which the date code 250 means 10 September 2015 and the date code 284 denotes 14 October 2015. These two sequences are found in the peat type of Hemists/Fibrists (60/40) and peatland depth of 400-800 cm. The label in the peatland type, for example: "Hemists/Saprists (60/40)" is described as follows: Hemists and Saprists are peatland types, the value 60 and 40 respectively represent 60% of Hemists and 40% of Saprists covering the area. Figure 3 shows number of hotspot on (a) sequence <{266},{296}> in Kalimantan 2014 and (b) sequence <{250},{284}> in Kalimantan 2015 based on peatland type and depth. Most of the hotspots on the sequences are located in peatland in Kalimantan with type of Hemists/Fibrists (60/40) and depth of 400-800 cm.

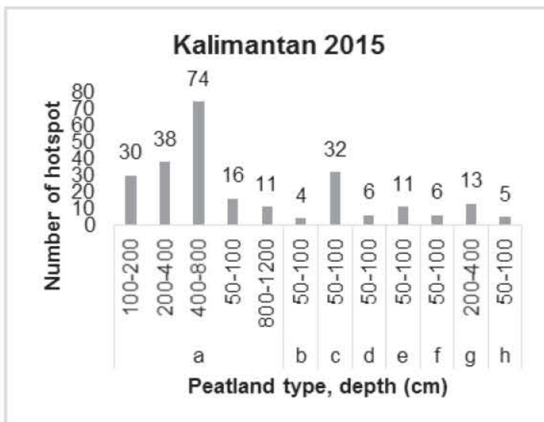
Table 4 shows characteristics of several hotspot locations that are occurred on the sequence <{266},{296}> in Central Kalimantan 2014 and on the sequence <{250},{284}> in Central Kalimantan 2015. According to Table 4, some hotspots are found in four villages in Central Kalimantan Paduran Sabangau and Mantangai Hulu in Kapuas District, as well as Kuala Pembuang Dua and Tanjung Rangas in Kota Waringin district in October and November 2014. In September 2015, sequences of hotspot are also detected at those four villages. Related parties should give more attention to those villages to prevent peatland burning activities in the future. Kapuas is one of districts in Central Kalimantan where forest and land fires were frequently occurred and number of hotspots annually in this area is high enough (Samsuri et al., 2012). Moreover, the research by Thoha (2014) shows that Mantangai is one of sub-districts in Kapuas which has high vulnerability level of forest and land fire.

Table 3: Characteristics of interesting hotspot sequences

Dataset	Sequence	Peatland Characteristic		
		Peatland type	Peatland depth	Land use
Kalimantan 2014	<{266},{296}>	Hemists/Fibrists (60/40)	400-800 cm	No data
Kalimantan 2015	<{250},{284}>	Hemists/Fibrists (60/40)	400-800 cm	No data
Sumatra 2014	<{42},{67}>	Hemists/Saprists (60/40)	100-200 cm	Forest swamp
Sumatra 2015	<{9},{68}>	Hemists/Saprists (60/40)	100-200 cm	Forest swamp



(a)



(b)

Remark:
- a Hemists/Fibrists(60/40)
- b Hemists/Fibrists/Mineral(50/30/20)
- c Hemists/Mineral(20/80)
- d Hemists/Mineral(80/20)
- e Hemists/Saprists/Mineral(40/30/30)
- f Saprists/Hemists/Mineral(30/30/40)

Remark:
- a Hemists/Fibrists (60/40)
- b Hemists/Fibrists/Mineral(50/30/20)
- c Hemists/Mineral(20/80)
- d Hemists/Mineral(50/50)
- e Hemists/Mineral(80/20)
- f Hemists/Saprists/Mineral(40/30/30)
- g Saprists/Hemists/Mineral(30/30/40)
- h Saprists/Mineral(20/80)

Figure 3: Number of hotspot in sequences based on peatland type and depth in (a) Kalimantan 2014 and (b) Kalimantan 2015

An example of a long sequence of hotspot in Sumatra 2014 is <{42}, {67}> (support value of 0.0037) meaning that hotpots occurred on 14 February 2014 followed by the occurrence on 11 March 2014. This pattern is found on peatland type of Hemists/Saprists (60/40) and peatland depth of 100-200 cm. Table 5 provides the peatland characteristics in which hotspots in this area are included in the sequence <{42}, {67}> in Sumatra 2014 and the sequence <{9},{68}> in Sumatra 2015. According to Table 5, some hotspots are found in February and March 2014 in Dedap village and Lukit village, Merbau sub district, Bengkalis Riau Province. On the same villages, hotspots were also detected in February and March 2015. Most of hotspots in those villages are located on thicket swamp.

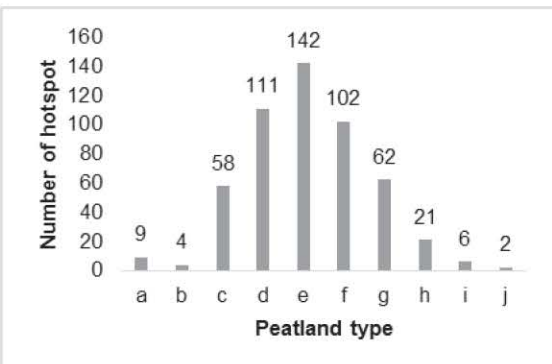
Figure 4 shows number of hotspots on these two sequences based on peatland type and depth. Most of hotspots on the sequences are located in peatland in Kalimantan with type of Hemists/Fibrists (60/40). In Sumatra 2014, hotspots in sequence <{42},{67}> are commonly occurred in peatland with type of Hemists/Saprists (60/40) and Saprists/Hemists (60/40) and depth of moderate (100-200 cm), deep (200-400 cm), and very deep (>400cm). In addition, in Sumatra 2015, hotspots in sequence <{9},{68}> commonly occur in peatland with type of Hemists/Saprists (60/40) and depth of moderate (100-200 cm) and deep (200-400 cm).

Table 4: Peatland characteristics of hotspot sequence in Central Kalimantan

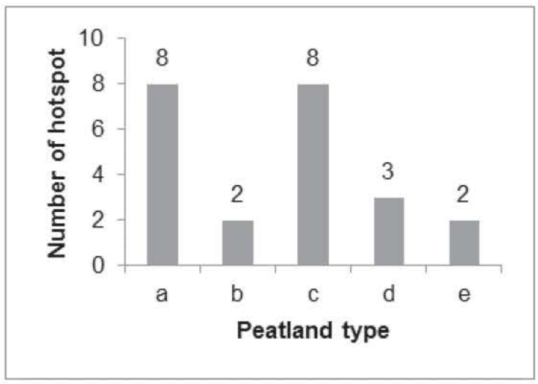
Location (Village, Sub-district, District)	**Date code (Date)**	**Characteristic of peat land**	
		Type	**Depth (cm)**
Year 2014			
Paduran Sabangau, Kahayan Kuala, Kapuas	277 (13 Oct 2014), 282 (18 Oct 2014)	Hemists/Fibrists (60/40)	800-1200
	291 (27 Oct 2014), 293 (29 Oct 2014), 296 (1 Nov 2014)	Hemists/Mineral (80/20)	50-100
Mantangai Hulu, Mantangai, Kapuas	272 (8 Oct 2014), 275 (11 Oct 2014)	Hemists/Fibrists (60/40)	200-400
	267 (3 Oct 2014), 268 (4 Oct 2014), 272 (8 Oct 2014)	Hemists/Fibrists (60/40)	400-800
Kuala Pembuang Dua, Seruyan Hilir, Kota Waringin	291 (27 Oct 2014), 296 (1 Nov 2014)	Hemists/Saprists/ Mineral (40/30/30)	50-100
Tanjung Rangas, Seruyan Hilir, Kota Waringin	291 (27 Oct 2014), 296 (1 Nov 2014)	Hemists/Saprists/ Mineral (40/30/30)	50-100
Year 2015			
Paduran Sabangau, Kahayan Kuala, Kapuas	256 (16 Sep 2015), 261 (21 Sep 2015), 265 (25 Sep 2015)	Hemists/Fibrists (60/40)	100-200
	254 (14 Sep 2015), 259 (19 Sep 2015), 263 (23 Sep 2015), 268 (28 Sep 2015)	Hemists/Fibrists (60/40)	400-800
	256 (16 Sep 2015), 261 (21 Sep 2015)	Hemists/Fibrists (60/40)	800-1200
Mantangai Hulu, Mantangai, Kapuas	258 (18 Sep 2015), 260 (20 Sep 2015), 261 (21 Sep 2015), 263 (23 Sep 2015)	Hemists/Fibrists (60/40)	400-800
Kuala Pembuang Dua, Seruyan Hilir, Kota Waringin	254 (14 Sep 2015), 255 (15 Sep 2015), 259 (19 Sep 2015), 261 (21 Sep 2015), 264 (24 Sep 2015)	Hemists/Fibrists (60/40)	50-100
	261 (21 Sep 2015), 264 (24 Sep 2015)	Hemists/Saprists/ Mineral (40/30/30)	50-100
Tanjung Rangas, Seruyan Hilir, Kota Waringin	255 (15 Sep 2015), 259 (19 Sep 2015)	Hemists/Fibrists (60/40)	200-400

Table 5: Peatland characteristics of hotspot sequences in Sumatera

Location (Village, Sub-district, District, Province)	Date code	Characteristic of peatland	
		Type, Depth (cm)	Land Use
Year 2014			
Dedap, Merbau, Bengkalis, Riau	64 (8 Mar 2014), 67 (11 Mar 2014)	Hemists/Saprists (60/40), 100-200	Thicket swamp
	64 (8 Mar 2014), 67 (11 Mar 2014)		Coconut plantation, previously swamp forest > 5
Lukit, Merbau, Bengkalis, Riau	49 (21 Feb 2014), 53 (25 Feb 2014)	Hemists/Saprists (60/40), 200-400	Coconut plantation, previously swamp forest > 5
	48 (20 Feb 2014), 51 (23 Feb 2014), 53 (25 Feb 2014), 56 (28 Feb 2014), 57 (1 Mar 2014), 58 (2 Mar 2014), 62 (6 Mar 2014), 63 (7 Mar 2014)	Saprists/Hemists (60/40), 200-400	Thicket swamp
	64 (8 Mar 2014), 65 (9 Mar 2014), 67 (11 Mar 2014)	Saprists/Hemists (60/40), 200-400	Thicket swamp
Year 2015			
Dedap, Merbau, Bengkalis, Riau	53 (23 Feb 2015), 58 (28 Feb 2015), 61 (3 Mar 2015)	Hemists/Saprists (60/40), 100-200	Thicket swamp
Lukit, Merbau, Bengkalis, Riau	53 (23 Feb 2015), 58 (28 Feb 2015), 61 (3 Mar 2015)	Saprists/Hemists (60/40), 200-400	Thicket swamp



(a)



(b)

Remark:

- a Hemists/min (30/70),shallow
- b Hemists/min (30/70),moderate
- c Hemists/Saprists (60/40), deep
- d Hemists/Saprists (60/40), very deep
- e Hemists/Saprists (60/40), moderate
- f Saprists/Hemists (60/40), deep
- g Saprists/Hemists (60/40), very deep
- h Saprists/Hemists (60/40), moderate
- i Saprists/min (50/50), moderate
- j Saprists/min (90/10), moderate

Remark:

- a Hemists/Saprists (60/40), deep
- b Hemists/Saprists (60/40), very deep
- c Hemists/Saprists (60/40), moderate
- d Saprists/Hemists (60/40), deep
- e Saprists/Hemists (60/40), moderate

Figure 4: Number of hotspot in sequences based on peatland type and depth in (a) Sumatra 2014 and (b) Sumatra 2015

According to Presidential Decree No. 32 in 1990, because managing and maintaining the productivity of peatland are not easy to performed, peatland which has depth greater than 300 cm should not be opened to agricultural development. According to the manual of preparation of the National Spatial Plan which is in line with Law No. 21 of 1992 regarding Spatial Planning, peatland with thickness of 3 meters or more, which is located upstream of rivers and swamps, is designated as a protected area. Peatland protection is done to control hydrology of the area, to serves as fastening water and flood prevention, as well as to protect unique ecosystems in the region (Wahyunto et al., 2005).

Number of hotspots in sequences were found on peatland in Kalimantan with thickness 400 - 800 cm and is dominated by peat type of Hemists/Fibrists (60/40). This result indicates that there were activities on peatland as protected area. This situation needs special attention because these hotspot locations are generally located on the outskirts of the peat dome and close to the settlement that makes it easier to be opened as agricultural land. Similar situation is found in Sumatra in 2014 and 2015. Interesting sequences show that hotspots are commonly occurred on peatland with type of Hemists/Saprists (60/40) and depth ranging from moderate (100-200 cm), deep (200-400 cm), and very deep (>400cm). This situation leads to peatland damage. Peat dome is part deepest peat that has the high hydrologic function. If water in the peat dome is missing, then peat experience leakage and hydrological functions become damaged (Syaufina, 2008).

A hotspot sequence especially in two to five days duration potentially corresponds to real fire occurence. However, verification need to be conducted in order to evaluate whether the hotspot sequences become real fire incident. Hotspot sequence verification can be performed through field visit to burnt area in 2014 and 2015. In addition, a classified satellite image can be used to identify whether hotspot sequences are located on burnt area or not. Secondary data of fire suppression activities conducted by local government are required to verify hotspot sequences. Our future work focuses on hotspot sequence verification using classified satellite image, field visit and secondary data of fire suppression activities.

4. Conclusion and Recommendation

Hotpots that are occurred sequentially in two to five days in a certain area indicate strong indicator for peatland fires. This study discovered sequence patterns on hotspot data in Kalimantan and Sumatra in 2014 and 2015. In Kalimantan, interesting sequence hotspots are mostly found in October and November 2014 and September 2015, whereas in Sumatra sequence hotspots commonly occur in February and March 2014 and 2015. Peatland type in Kalimantan where hotspot sequences detected are Hemists/Fibrists (60/40) with the depth of 400 - 800 cm. Four villages in Central Kalimantan namely Paduran Sabangau, Mantangai Hulu, Kuala Pembuang Dua and Tanjung Rangas should be monitored by the related parties, because according to this study, hotspot sequences are found in those villages in 2014 and 2015. In Sumatra, most hotspots are detected sequentially in peatland types of Hemists/Saprists (60/40) and Saprists/Hemists (60/40) and depth of moderate (100-200 cm), deep (200-400 cm), and very deep (>400cm). There are two villages in Riau province namely Dedap village and Lukit village, Bengkalis district where hotspot sequences occurred in February and March 2014 and 2015. Peatland has important roles to the environment. Especially peatland with thickness greater than 300 cm should be prevented because it has high hydrologic function. However this study found hotspot sequences in deep peatland indicating burning activities that were performed by communities. In addition, the occurrences are repeated in two to five days and some sequences have the similar period of occurrences in 2014 and 2015. Therefore prevention efforts on the peatland need to conduct in order to minimize the damage of peatland because of fires.

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References

Agustina, T. and Sitanggang, I. S., 2015, Sequential Pattern for Hotspot Occurences Based Weather Data using Clospan Algorithm. *Proceedings of International Conference on Adaptive and Intelligent Agroindustry*, 301-305.

Han, J., Pei, J. and Yan, X., 2005, Sequential Pattern Mining by Pattern-growth: Principles and Extensions. *StudFuzz*, 180, 183-220.

Han, J. and Kamber, M., 2006, Data Mining: Concepts and Techniques, Second Edition. The Morgan Kaufmann Series in Data Management Systems.

Hermawati, R. and Sitanggang, I. S., 2016, Web-Based Clustering Application using Shiny Framework and DBSCAN Algorithm for Hotspots Data in Peatland in Sumatra, *Procedia Environmental Sciences*, 33, 317-323.

Kirana, A. P., figure, I. N. S. and Syaufina L., 2012, Spatial Model of Level Vulnerability of Forest Fires (Case study Central Kalimantan). *FORESTA Indonesian Journal of Forestry*, I(1), 12-18.

Sitanggang, I. S., Yaakob, R., Mustapha, N. and Ainuddin, A. N., 2014, A Decision Tree Based on Spatial Relationships for Predicting Hotspots in Peatlands. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, 12(2), 511-518.

Syaufina, L., 2008, Kebakaran Hutan dan Lahan di Indonesia, Bayumedia Publishing. (in Bahasa)

Thoha, A. S., 2014, Institutional Strengthening Risk Management Model of Forest and Land Fires based on Society. Master Thesis, Bogor Agricultural University.

Usman, M., Sitanggang, I. S. and Syaufina, L., 2015, Hotspot Distribution Analyses Based on Peat Characteristics using Density-Based Spatial Clustering. *Proceedings of the 1st Intl. Symposium on LAPAN-IPB Satellite for Food Security and Environmental Monitoring*, 24, 132-140.

Wahyunto, Ritung, S. and Subagjo, H., 2005, Map of Peatland Distribution Area and Carbon Content in Sumatera. *Wetland International Indonesia Program and Wildlife Habitat Canada.*

Zaki, M. J., 2001, SPADE: An Efficient Algorithm for Mining Frequent Sequences. *Machine Learning*, 42, 31-60.

Zhao, Q. and Bhowmick, S. S., 2003, Sequential Pattern Mining: A Survey. *Technical Report CAIS No.2003118. Singapore.*