PEAT FIRE MAPPING USING GIS BASED MULTI-CRITERIA DECISION MAKING: STUDY AREA OF KUALA LANGAT, SELANGOR

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ABSTRACT

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Peat fire is a geological disaster that causes damages to nature, human activities and environment. It is a geological phenomenon that involves a wide range of forest fire, vegetation burnt surface and smouldering fire underground. Besides that, there are other contributing factors affecting the peat fire and can lead to the forest fire disaster. In this study, GIS and MCDM Technique were used as a tool to generate the prediction of peat fire potential area map at Kuala Langat, Selangor. All the input is then being analyse in ArcGIS software. Many criteria may contribute to the peat forest fire incident such as land use, temperature, pH value, and soil type criteria. The main benefit for analysing the potential area is the possibility to prevent and predict peat fire occurrences in future other than as a precaution step to face the problems.

Keywords: *Peat Fire, Geographical Information System, Multi-Criteria Decision Making, Prediction Peat Fire, Kuala Langat District*

INTRODUCTION

Peat fires or peat forest fires are commonly known happened in our neighbouring country, which is Indonesia (Usup et. al., 2004). Peninsular Malaysia were not of the same enormousness as them, but the caused similarly destroy the vegetation, property, wildfire, public health and also the environment (Rostam et al., 2010). Peat fire being known as foremost disaster that brought peat swamp forest damage in a few regions of Malaysia (Setiawan et. al., 2004). Due to lacking acknowledgement of prevention peat forest fire fighting technique and understanding the place to qualifying potential are made the disaster become worse. Most of the fires involving the location of heath and peat forest plus in the bush areas. The fires easily widespread even it is burned in a slow and inconsistent. According to Fire and Rescue.

Department, thick peat layers are given away the fires spread slowly. It is hard to extinguish the smouldering fire underground and also to detect them. An excessive water has to be used for completely wet the surface area of peat because peat soil underground will continue to burn. Subsequently, lack of necessary tools and deficiency of gaining experience by training to handle peat fire makes the extinguishment of fire is difficult. So, monitoring and training necessary to prevent the symptoms of forest fire is spreading in some parts of the region affected by the causes of fire.

There are five criteria that will investigate in order to predict the potential area of peat fire happen. There is land surface temperature, soil type, PH value of soil, and land use (Ellery et al., 1989). These five criteria will show the x y location and weightage to describe the potential area might happen in scope of study area. Land surface temperature related with climate change which effected the peat fire

burst by itself (Fanin et. al., 2016). When land surface temperature becoming too hot at noon, the fire easily smouldering below on the ground and spread faster in surrounding of peat land. Using soil type as reference, the compound of the soil is one of the causes that ignition of fire from moderate to strongly flames (Cervarich et al., 2016). Soil type environment responsible to ignite the fire with a small spark from any fuel around. Properties of soil can be used to find the peat area. There are a lot of soil type in area of Kuala Langat. For precisely identified the location of peat soils may be easy and clearly recognize (Rostam et al., 2010). According to Department of Agriculture (DOA), PH value of soils are important to knowing the acidity of the soils. Peat soils contains the highest acidity compare to the other type of soils and large amount of acid in soils may easily get burn by any fire sparks. By investigate the highest PH value of soils, the peat soil may be recognized and can be located to a potential area of peat fires (Cervarich et al., 2016). All of the criteria cannot support the fire burn without any human activities (Marle et al., 2017). Land use data is very useful to know the surrounding of potential area involved the human activities such as residential and factory operation (Noojipady et al., 2017).

Multi-Criteria Decision Making (MCDM) is one of the techniques collection that can be defined for analysing depending on the spatial arrangement of the events by Geographic events results (Mäkelä, 2007). Weightage will be conduct with calculation due to the criteria chosen. The criteria used in this study is depending on the suitability of the data. Overlaying the data or maps by using these technique is really helpful and easy to understand to implement of the method. There are three methods under this technique which are rating method, ranking method and pairwise comparison method.

METHODOLOGY

This research to verify the peat fire potential area using Geographical Information System (GIS) and remote sensing technique. The peat fire potential area map derive from this project then may be used as a guide to monitor peat forest fire occurrences in the location specified thus preventing or lessen the peat forest fire activities in the area. The methods are explained from phase 1, phase 2, phase 3 and phase 4. It includes the data acquisition, data processing, the planning process and lastly the details of methodology used to generate the peat fire potential area map. The procedures including with the first steps which is preliminary studies. Second with the data collection. Third will be the processing of the data and lastly, the analysis. Peat fire potential area map will be produced it the final output after proceeding the methodology.

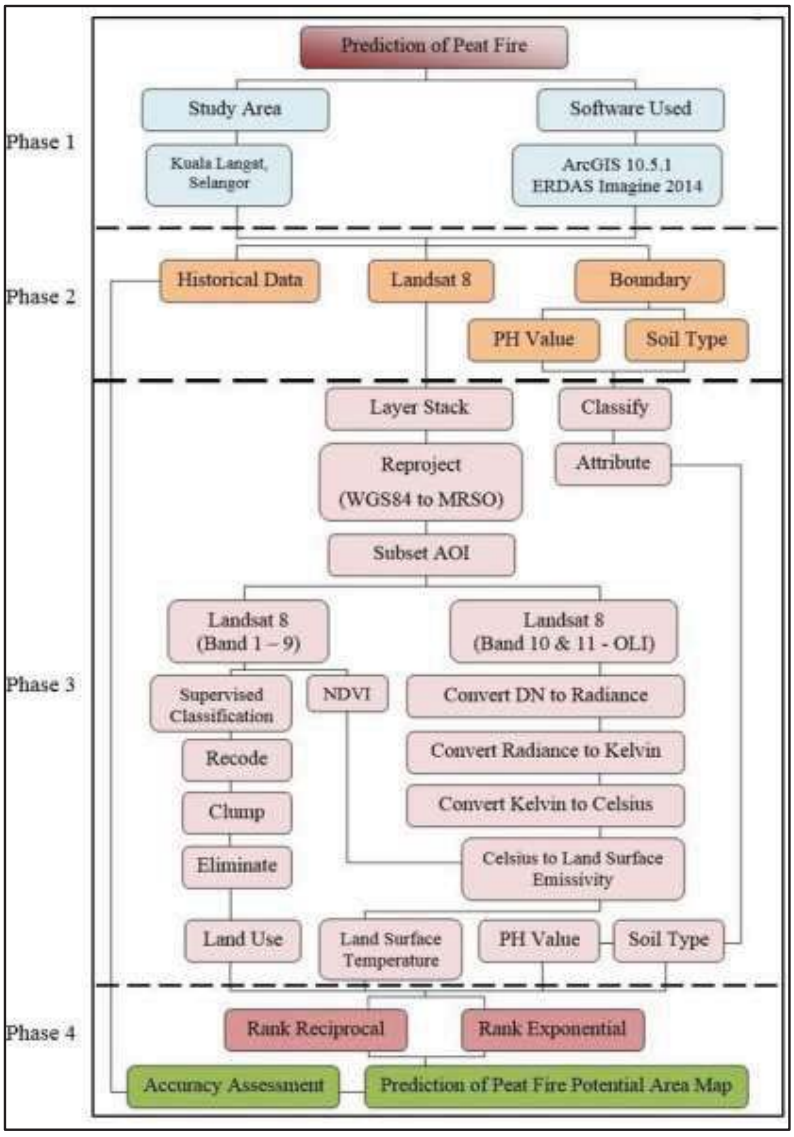

Figure 1: Research Methodology

Site Study

Kuala Langat is one of the nine district formally located in the State of Selangor Darul Ehsan within the quadrant of the latitude 2.8038° N and the longitude 101.4951° E. The Kuala Langat District surrounded with 857.65 km² (equivalent to 84,775 hectare). However, the Administration of Local Authorities, Majlis Daerah Kuala Langat governing the area within 62.294 km² meanwhile the administer outskirts measured to 10 km².

Data Collection

Data collection was retrieved from the associated organization that related with this topic. In order to get the correct data, some of that forced to gain from private organization and needed generally permission to obtain. The limitation cannot be prevented due to how many the data were gave by the organization.

The previous research has stated about the criteria. Criteria of this project really important to show the category of risk in the location placed. A lot of criteria peat fire occurrence. But, based on the case study area, the scope has been small to test the suitability of the study area materials. A few data will be used in this project such as Satellite Image Landsat 8 and boundary. From this data, it will extract into four criteria which are land use, land surface temperature, PH value and soil type. The data gaining from related organization and open source.

Peat fire historical data have to be taken due to identified the previous location which occur the peat fire ago. One of the previous study reference is peat swamp forest fire that ever happened in Raja Musa. The historical data is important to show the accuracy assessment after all the criteria produce a map. This data will show as a point and it will locate the previous peat fire occur on the scope area. Historical data gained from a few agencies such as Fire and Rescue Department of Selangor and Selangor State Disaster Management Unit.

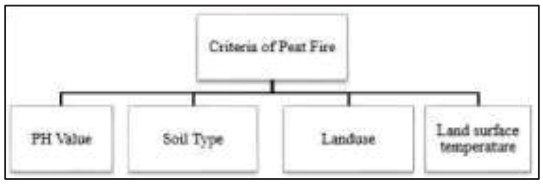

Figure 2: Criteria of Peat Fire Mapping

Data Processing

GIS is frequently used in the previous studies of peat fire. ArcGIS 10.5.1 software will be help to process the data to produce map. The process including overlay, editing tools in layout map classification on each criteria and produce the prediction of peat fire potential area map by using Rank Reciprocal and Rank Exponential Technique for the weightage of each criterion.

The data were processed by using two processing software which is ERDAS Imagine 2014 and ArcGIS 10.5.1. ERDAS Imagine 2014 was used in digital image processing stage where the Landsat imagery is processed to produce land use type for the research.

Land use information is an important factor in determination of peat fire potential area. In order to achieve the final land use classification, several processes are carried out such as layer stacking, image re-project, subset of image, supervised classification, clump and eliminate.

MCDM Techniques

Based on the techniques in methodology, this research using two Multi-Criteria Decision Making techniques which is Ranking Method of Rank Reciprocal (RR) and Rank Exponential (RE). To make calculation of this weightage easier or RE, Rank Sum Technique is needed to simplify the understanding the formula stated. Straight rank is justifying the most probable potentially on peat fire in scope of area. Number 1 is the highest risk of criteria which is soil type and followed by PH value, LST and land use goes to 4.

After processing the calculation data, the sub-criteria of each criterion must be in normalized weightage value by using Linear Scale Transformation. A short brief about Linear Scale Transformation, it is being rank from 0, the minimum potential to the peat fire n value for maximum risk of peat fire. The n value justifies as the number of sub-criteria in selected criteria.

Table 1: Weightage of the criteria using Rank Reciprocal

Criteria	Weight (RR)	Sub-Criteria	Weight Sub Criteria
PH Value	0.24	0	0.4
		0.1 – 3.7	0.3
		3.8 – 4.5	0.2
		4.6 – 5.1	0.1
		5.2 – 7.2	0
Soil Type	0.48	Clay	0.3
		Peat	0.4
		Sandy Clay	0.1
		Sandy Clay Loam	0
		Silty Clay	0.2
Land use	0.12	Agriculture	0.3
		Bare Land	0.2
		Forest	0.4
		Urban Land	0.1
		Water Bodies	0
LST	0.16	20 – 24	0
		25 – 28	0.1
		39 – 32	0.2
		33 – 36	0.3
		37 – 40	0.4

Table 2: Weightage of the criteria using Rank Exponential

Criteria	Weight (RE)	Sub-Criteria	Weight Sub Criteria
PH Value	0.30	0.0	0.4
		0.1 – 3.7	0.3
		3.8 – 4.5	0.2
		4.6 – 5.1	0.1
		5.2 – 7.2	0
Soil Type	0.53	Clay	0.3
		Peat	0.4
		Sandy Clay	0.1
		Sandy Clay Loam	0
		Silty Clay	0.2
Land use	0.03	Agriculture	0.3
		Bare Land	0.2
		Forest	0.4
		Urban Land	0.1
		Water Bodies	0.4
LST	0.13	20 – 24	0
		25 – 28	0.1
		39 – 32	0.2
		33 – 36	0.3
		37 – 40	0.4

RESULTS AND ANALYSIS

The most important criteria of peat fire potential area map are the spatial distribution of peat forest fire occurrence. Based on the information from previous research, it is control by soil type, PH value,

land surface temperature and land use. These four criteria represented before calculating the weightage then, merged together using union on MCDM techniques.

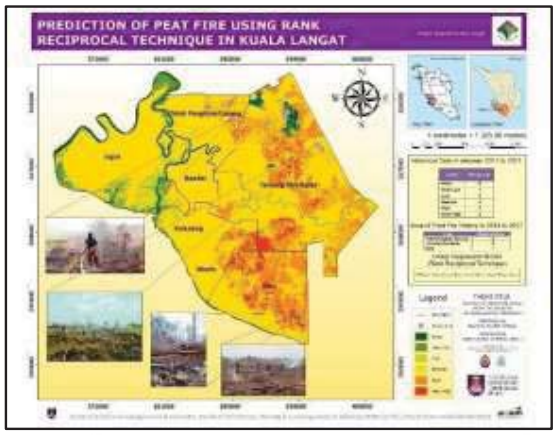

Figure 3: Mapping of Peat Fire Using Rank Reciprocal

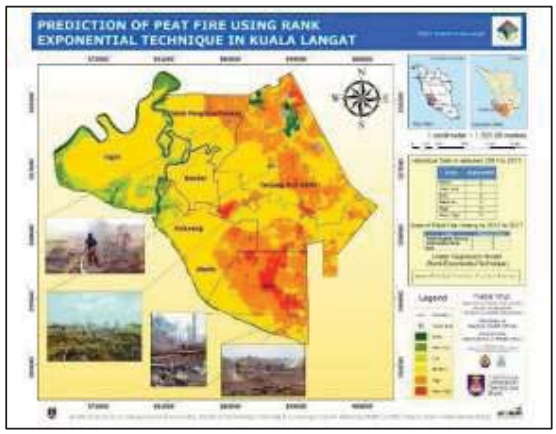

Figure 4: Mapping of Peat Fire Using Rank Exponential

Table 3: Percentages historical point using Rank Reciprocal

Class	Historical	Percentages (%)
None	0	0
Very Low	1	8.3
Low	2	16.7
Medium	4	33.3
High	3	25
Very High	2	16.7

Table 4: Percentages historical point using Rank Exponential

Class	Historical	Percentages (%)
None	0	0
Very Low	1	8.3
Low	2	16.7
Medium	3	25
High	4	33.3
Very High	2	16.7

DISCUSSIONS

From these two techniques (Rank Reciprocal and Rank Exponential), this research may analyse the comparison between Rank Reciprocal Map and Rank Exponential Map weighted in the most potentiality classes which are High Class and Very High Class.

There are 5 counts on High and Very High Class in Rank Reciprocal Techniques after merged with historical data in map. While the Rank Exponential Technique, the value of High Class and Very High Class after sum all of the points, it consists of 6 counts.

In the Southern area of Kuala Langat, the occurrence of peat fire may harm the area until 2017. Based on the JBPM case file, they struggling to extinguished the fire in Dengkil and nearby to Sepang.

The fire did not extinct in exact time in one places. But, the fire beneath underground was smouldered from place to another place by only showing the smoke on the ground without any clear fire appear. This is very difficult situation for them to find the next location the fire will occur since they did not know the prediction of fire may happen.

Table 5: Analysis of Historical Points

Point	Historical Data			
	Reciprocal		Exponential	
	Class	Location	Class	Location
1	Medium	Telok Panglima Garang	Very High	Telok Panglima Garang
2	High		High	
3	Very High		Medium	
4	High	Tanjung Dua Belas	High	Tanjung Dua Belas
5	High		Very High	
6	Medium		Medium	
7	Very Low		Very Low	
8	Low		Low	
9	Low		Low	
10	Medium		High	
11	Medium		Medium	
12	Very High	Batu	High	Batu

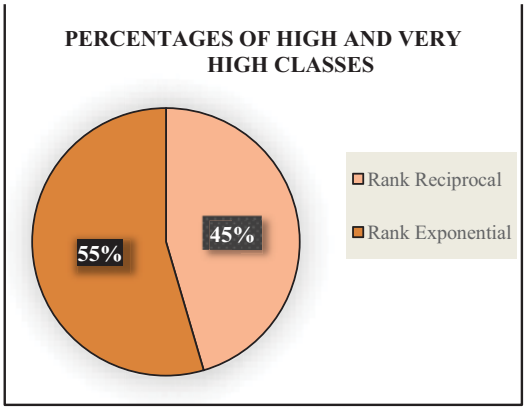

Figure 5: Percentages of High and Very High Classes of

Historical Data (RR and RE)

In a nutshell, Rank Exponential Technique is the most precision to use as a reference for the prediction of peat fire in the future since it is shows 55% accurate than Rank Reciprocal Technique which is 45% after analysing the historical data points in map.

CONCLUSIONS

The analysis of peat fire criteria which consists land use, land surface temperature, PH value and soil type are complete to determine. Rank Reciprocal and Rank Exponential model was produced with the series of weighted map derivation to achieve the first objective of this research. The findings of this objectives analyse the sub-criteria of each criterion to be put in MCDM technique (Ranking Method). This is important to discuss because it explains thoroughly about the criterion involved that prone to peat fire occurrences. The first ranking of criteria is soil type since this research is about peat fire, so the identifying the peat soil will be the first one. While it is followed by pH value, land surface temperature and land use respectively. The final analysis is the prediction of peat fire potential area in Kuala Langat that calculated from both predicted area model. The eastern of Kuala Langat more potential area of happening peat fire. This is because that location consists a lot of peat soil and highest PH value. While these two maps, Rank Exponential is more accurate than Rank Reciprocal to shows the potentiality of peat fire after being merged with historical data.

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BIBLIOGRAPHY

Ahmad, M. F., & Samat, A. (2015). Species Composition and Abundance of Peat Swamp Fishes In Selected Areas of Selangor, Malaysia. *Malays. Appl. Biol., 44*(1), 139-145.

Atwood, E. C., Englhart, S., Lorenz, E., Halle, W., Wiedemann, W., & Siegert, F. (2016, August 3). Detection and Characterization of Low Temperature Peat Fires during the 2015 Fire Catastrophe in Indonesia Using a New High-Sensitivity Fire

B., & Oelofse, R. (1989). A peat fire in the Okavango Delta, Botswana, and its importance as an ecosystem process. *Afr. J. Ecol., 27*, 7-21.

Cervarich, M., Shu, S., Jain, A. K., Arneth, A., Canadell, J., Friedlingstein, P., . . . Zeng, N. (2016). The terrestrial carbon budget of South and Southeast Asia. *Environmental Research Letter* (pp. 1-12). Urbana: IOP Publishing.

Ellery, W. N., Ellery, K., McCarthy, T. S., Caincross,

Fanin, T., & Van der Werf, G. R. (2016). Precipitationfire linkages in Indonesia (1997-2015). *Biogeosciences Discuss* (pp. 1 - 21). Amsterdam: Vrije Universiteit Amsterdam.

Fillkov, A. I., Sinyutkina, A., & Kharanzhevbkaya, Y. A. (2015). Geoinformation systems for prediction of peat fires and its validation. *15th International Multidisciplinary Scientific GeoConferences SGEM2015* (pp. 863-870). Tomsk: Siberian Research Institute of Agriculture and Peat, 3 Gagarin Str.

Giuseppe, F. D., R'emy, S., Pappenberger, F., & Wetterhall, F. (2016). Improving GFAS and CAMS biomass burning estimations by means of the Global ECMWF Fire Forecast system (GEFF). In *Technical Memorandum.* ECMWF Publications.

Hazard Zonation," Procedia: Social and Behavioral Sciences 35, 595-602 (2012). *Malaysian Journal of Society and Space, 6*(2), 37 - 50.

Marle, M. J., Kloster, S., Magi, B. I., Marlon, J. R., Daniau, A., Field, R. D., Van der Werf, G. R. (2017). Historic global biomass burning emissions based on merging satellite observations with proxies and fire models (1750-2015). *Geoscientific Model Development, 1*(6), 1-56.

Mer, J. L., & Roger, P. (2001). Production, oxidation, emission and consumption of methane by soils: A review. *Eur. J. Soil Biol., 37*, 25-50.

Monitoring Satellite Sensor (FireBird). Retrieved from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0159410

Nancy, H. (2016). *Global Forest Watch Climate: Summary of Methods and Data.* Washington: World Resources Institute.

Nazeer, N., & Furuoka, F. (2017). Overview of ASEAN Environment, Transboundary Haze Pollution Agreement and Public Health. *Transboundary Haze Agreement, 13*(1), 73 - 94.

Noojipady, P., Morton, D. C., Schroeder, W., Carlson, K. M., Huang, C., Gibbs, H. K., . . . Prince, S. D. (2017). Managing fire risk during drought: the influence of certification and El Niño on fire-driven forest conversion for oil palm in Southeast Asia. *Earth Syst. Dynam. Discuss, 1*(10), 1 - 23.

Othman, A. N., Naim, W. M., and Surip, N., "GIS Based Multi Criteria Decision Making for Landslide

Poh, T. C., Yi, K. J., Sing, L. K., Bahari, S., Tat, E. H., & Teik, C. H. (2006). Applications of Remote Sensing in The Monitoring of Rice Crops. *The Institution of Engineers, 67*(4), 2-11.

Rein, G., Cleaver, N., Ashton, C., Pironi, P., & Torero, J. L. (2008). The Severity of Smouldering Peat Fires and Damage to the Forest Soil. *BRE Centre for Fire Safety Engineering* (pp. 304-309). United Kingdom: University of Edinburgh.

Rosdi, M. A. H. M., Latif, Z. A., Othman, A. N., and Nasir, N. M., "Sinkhole Susceptibility Hazard Zones Using GIS Framework and Heuristic Method," In: Advances in Remote Sensing and Geo Informatics Applications. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham., pp. 261-264 (2018).

Rosdi, M. A. H. M., Othman, A. N., Zubir, M. A. M., Latif, Z. A., and Yusoff, Z. M., "Sinkhole Susceptibility Hazard Zones Using GIS and Analytical Hierarchical Process (AHP) – A Case Study of Kuala Lumpur and Ampang Jaya," In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences-ISPRS Archives, 42(4W5), pp. 145-151 (2017).

Rostam, K., Rosul, M., Choy, E. A., Mohd Nor, A. R., Sakawi, Z., Hashim, N. M., & Muhammad, A. E. (2010). Urbanisation and urban sprawl in the fringe areas of Klang-Langat Metropolitan Region.

Setiawan, I., Mahmud, A. R., Mansor, S., Mohamed Shariff, A. R., & Nuruddin, A. A. (2004). GIS-gridbased and multi-criteria analysis for identifying and mapping peat swamp forest fire hazard in Pahang, Malaysia. *Disaster Prevention and Management: An International Journal, 13*(5), 379-386.

Suliman, M. D., Mahmud, M., & Reba, M. N. (2014). Mapping and Analysis of Forest and Land Fire Potential Using Geospatial Technology and Mathematical Modeling. *Earth and Environmental Science* (pp. 1-6). Skudai: IOP Publishing.

Usup, A., Hashimoto, Y., Takahashi, H., & Hayasaka, H. (2004). Combustion and thermal characteristics of peat fire in tropical peatland in Central Kalimantan, Indonesia. *Tropics, 14*, 1-16.

Van der Werf, G. R., Randersion, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., . . . Van Leeuwen, T. T. (2010). Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmospheric Chemistry and Physics* (pp. 11708 - 11735). Amsterdam: Copernicus Publications.

Yukili, L., Nuruddin, A. A., Abdul Malek, I. A., & Mohamad Razali, S. (2016). Analysis of Hotspot Pattern Distribution at Sabah, Malaysia for Forest Fire Management. *Journal of Environmental Science and Technology, 9*(3), 291-295.