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GIS-Based Forest Fire Risk Assessment for the Belait District

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Abstract

Widespread forest fires have been a regular event in the Southeast Asian region particularly during dry periods. Brunei Darussalam, as one of the Southeast Asian countries, loses hundreds of hectares of forests every year, and more. Fire behaviour varies under different conditions and the nature of the forests. The degrees of challenge and impact posed by fires differ with types of forest cover and soil. This paper therefore attempts to assess fire risk in the Belait District by considering different fire contributory factors. This task was assisted by the application of a Geographical Information System (GIS). In this study, factors such as forest cover type, soil types, distance from road, proximity of settlements and population, are derived and classified for the study area. A fire risk map was then developed using Analytical Hierarchical Process (AHP) and Suitability Analysis tools in GIS. The outcomes showed that the high fire risk areas are at the northern part of the district and aligned with the shoreline, whereas low risk areas are found at the lower part of the district. The result also demonstrates the potential of integrating AHP and suitability analysis tools for fire risk assessment studies.

1 Introduction

Widespread forest fires have been a frequent event in Southeast Asian region particularly during dry period. Previously, the region was affected by major fire incidents in 1982-1983, 1987, 1991, 1994, 1997-1998 [1] and more recently in 2013 and 2015. These large fire incidents are often associated with the naturally-occurring El-Nino Southern Oscillation (ENSO) phenomena which involves fluctuating ocean temperatures in the equatorial Pacific Ocean.

In the region, fire is discerned as a major driving factor of deforestation [2]. Brunei Darussalam, as one of the smallest Southeast Asian countries, has lost at least hundreds of hectares of forests every year to fire. However, fire is also a common tool for land clearance in the region particularly in Indonesia [3], while the presence of peat forests poses additional challenges. Peatland is one of the areas severely affected by fire in the region. This is because fires in peatland are not only difficult to extinguish, but peatland is one of the areas that often experience recurrent fires. Peatland contains soils that consist of built-up decayed vegetation or organic matter, in which ground fire usually takes place [4]. Peat forest often also creates smouldering combustion, which burns slowly for long period of time and can also burn repeatedly, as it can proceed under low temperature and with limited oxygen availability. Peat moisture is one factor that helps to impede peat ignition. However, disturbance of peat forest can affect its moisture and may enable fire ignition. Once the fire is ignited, it is difficult to control and may take days, weeks or even months to be extinguished, with the possibility for re-ignition after being extinguished [5].

According to Yeager et al [6], most fires in the region take place in the peat swamp forest in Kalimantan. A disturbed peat forest tends to become susceptible to fire because the disturbance often dries out the peat land and makes it prone to catch fire and burn for long periods of time. While the majority of the peatland in Southeast Asia has been deforested [7], Brunei Darussalam has the highest proportion of intact peat swamp forest in the region. About 80 percent of the peat swamp forest in the country is still good quality, where most of this forest is found in the Belait District [8].

In spite of that, peat fires take place in Belait's peat swamp forest every year [9]. In 2012, about 300 ha of peatland were affected by peat fires, while in 2016, peat fires burned approximately 274 ha of peatland. Between 2012 and 2016, about 21.5% of the total burned areas in the country resulted from peat fires [10]. According to Brunei's Fire and Rescue Department [11], peat fire poses the most challenges to the country as its extinguishment requires great effort. The present paper therefore attempts to assess fire risk in Kuala Belait District on the basis of the extent of peaty soil, forest types, accessibility (closeness to road access), proximity to settlement and population density. These criteria are known to have influence on forest fire. Weightage for each mentioned criterion is derived from Analytical Hierarchical Process (AHP) tool and a fire risk map is developed for the district using suitability analysis.

2 Methodology

2.1 Study area

The region of interest for this study is the Belait District, Brunei Darussalam (Figure 1). It is the largest district in Brunei Darussalam, with more than 80 percent of its area till covered with forests. The forest cover types of the district vary from peat swamp forest, secondary forest, heath forest,

fresh swamp forest and mixed dipterocarp forest (Figure 1). Peat swamp is mainly on the coastal plain of the lower Belait River whilst peat soils are found in lowland swamps. Most forests at southern part of the district are still pristine and conserved under the Heart of Borneo initiative.

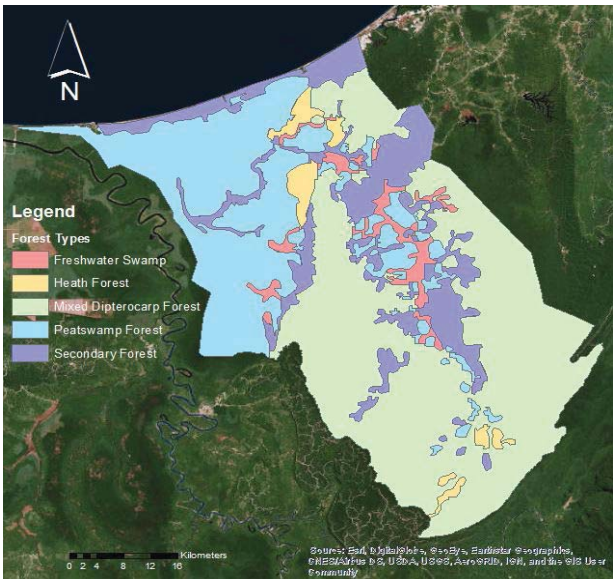

Figure 1: Forest Types within the Belait District study area.

The district has high potential danger of fires, especially in the peat swamp forest, during prolonged dry periods. According to the Brunei Fire and Rescue Department [12], the district recorded the highest number of forest and bush fire calls in the first two months of 2018, in which a total of 25 calls was received. Areas affected by fires in the district are mostly in peatland and often inaccessible [13].

2.2 Criteria considered

In this study, five different parameters were considered, ranging from forest types, extent of peat soil, proximity to settlement, accessibility (distance to road) and population density, in order to produce a fire risk map for the Belait District. Layers for each parameter were overlaid based on its weightage. The weightage for each criterion is determined using Analytical Hierarchical Process (AHP) tool in GIS [14].

Forest types and peat soil: Each forest type has its own characteristics, which affects its susceptibility to fire. According to Mahmud [15], forest such as mixed dipterocarp, freshwater forests are less susceptible to fire due to their ever-moist characteristics, being usually wet throughout the year. Thus, the occurrence of fire in these forest types is minimal. However, during El-Nino dry spells, peat swamp forests and some parts of heath and mixed dipterocarps forests experiences a build-up of forest fuel, as the rate of undergrowth vegetation dying increases with time due to unavailability of water. Hence, they become a source of forest fuels and facilitate the spread of fires.

Based on this, the forest types in the district are weighted based on their flammability, particularly during prolonged dry periods. Peat swamp forest is assigned with highest risk value because it is commonly affected by fire which are usually laborious to extinguish. Secondary forest, which is characterised by its less-developed canopy and dense ground growth, is valued lower than peat swamp forest. Secondary forest usually dries quickly during dry period and therefore catches fire more easily, but the fires are less laborious to extinguish compared to those in peat swamp forest [11]. Its ever-moist characteristics means that the risk value for mixed dipterocarp forest is assigned lower than heath forest.

Moreover, an interview with Brunei Fire and Rescue Department staff revealed that fire-affected areas in the Belait District are usually regarded as large scale, where most of these major fires take place in peatland. In 2016, Brunei Fire and Rescue Department operated continuously over more than two months in order to combat peat fires that took place throughout the district (Table 1). [13]. Hence, the extent of peaty soil throughout the district is considered as one of the criteria in developing the fire risk map.

Table 1: Large scale fire in Kuala Belait District in 2016 [13].

Affected Areas	Type of Forest	Hectares
Badas Pipeline	Bush & Peatland	7.16
Seria bypass	Forest & Peatland	5.2
Anduki / Sg Bera	Forest & Peatland	42.12
Mumong	Forest & Peatland	5.77
Sg Teraban	Bush & Peatland	19.91

Additionally, fire in peatland can go into soil and travel underground. This can make the firefighters task much more laborious and difficult as the fire can surface anywhere [16]. Thus, the fire risk is assigned to be higher as it gets closer to presence of peaty soil.

Accessibility (Distance to road): The presence of roads is associated with the occurrence of forest fires. However, one of the crucial elements required in order to effectively contain and combat forest fire includes accessibility of the affected areas. Brunei Fire and Rescue Department emphasised on the importance of accessibility in combating forest fire. This is because paths allowing pumper trucks and personnel to enter the area facilitates and accelerates fire extinguishing actions [13]. Due to this, larger distances to road access may increase the risks of forest fire.

Proximity to settlement: The fire risk factor decreases further away from human settlements, and therefore, in this study, the fire risk is given a higher rating the closer it is to human settlement. According to Brunei Fire and Rescue Department [11], when forest fire occurs closer to residential area, extinguishing them became a higher priority due to the threat to human safety and property.

Population density: Fires tend to take place where there is presence of human activity. In Brunei, irresponsible acts of open burning, particularly during dry period, is the common culprit that triggers the occurrence of forest fires [17]. In this

study, population densities for different villages and areas in the Belait District were considered, where the higher the density of an area, the risk is given a higher rating.

Table 2: Risk value for each criterion.

Criteria		Risk Value
Forest Type	Peat Swamp Forest	1 (Very High)
	Secondary Forest	2
	Heath Forest	3
	Mixed Dipterocarp	4
	Fresh swamp Forest	5 (Low)
Accessibility	<250m	5 (Low)
	250m – 500m	4
	500m – 750m	3
	750 - 1000m	2
	>1000m	1 (Very High)
Vicinity to Settlement	<1000m	1 (Very High)
	1000m – 2000m	2
	2000m – 3000m	3
	3000m – 4000m	4
	>5000m	5 (Low)
Distance from peaty soil	<1000m	1 (Very High)
	1000m – 2000m	2
	2000m – 3000m	3
	3000m – 4000m	4
	>5000m	5 (Low)
Population Density	< 100 (per sq. km)	5 (Low)
	100 - 500	4
	500 - 1000	3
	1000 - 1500	2
	>1500	1(Very High)

The group of subclasses used in assigning the risk value as shown in Table 2 is in reference to Alemu [18]. The Buffer tool in ArcGIS software was used to produce different buffer distances around each criterion, and risk classes were assigned based on their influence on fire risk.

2.3 Suitability analysis

Suitability analysis is a type of analysis in GIS to determine locations or areas that are suitable for specific use in form of a thematic map. It allows the identification of most suitable sites from a set of candidates, as defined by applying a set of individually-weighted criteria. This method has been widely applied in various situations such in determining suitable locations for agriculture, finding the best site for new facilities, landscape evaluation and planning, and environmental impact assessment [19]. In this study, suitability analysis was utilised for fire risk mapping by taking into account five different criteria, namely: forest type, extent of peat soil, accessibility, and vicinity to settlement and population density. Each criterion was given weight based on its influence on forest fire risk, where the weightages for each criterion are discussed in the following section.

2.4 Weights of factors

The weightage for each criterion was derived from interviews with Brunei Fire and Rescue Department [11] staff, analysed using AHP which addresses preference statements. The degree to which each criterion is more important than others was derived based on interviews conducted with Brunei Fire and Rescue Department staff. By means of pairwise comparison technique in AHP, a weight for each single criterion is derived. Table 3 summarises the weight for each criterion.

Table 3: Weight of factors derived from AHP.

Criteria	Weightage
Forest Types	15.338
Peaty Soil	2.849
Proximity to Settlement	40.704
Accessibility	8.129
Population Density	32.98

3 Results and Discussions

Figure 2 shows the fire risk map for the Belait District, resulting from the suitability analysis tool.

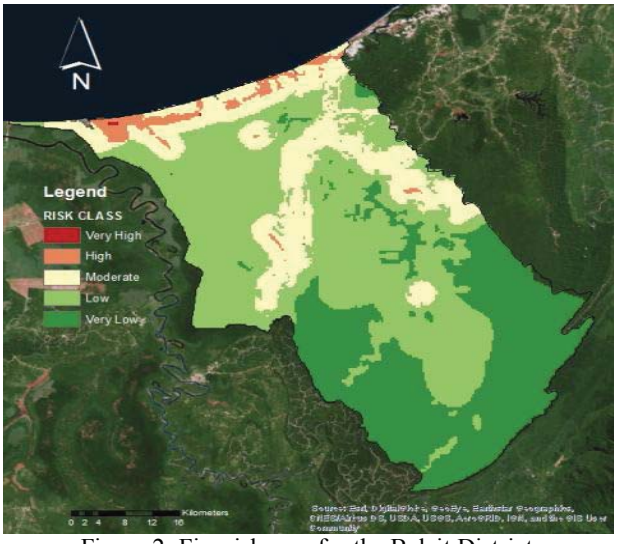

Figure 2: Fire risk map for the Belait District.

The red (Very High) areas are areas with higher risk and which require more attention compared to other areas. It reflects that risk value of criteria in the regions are mostly higher and thus, fire occurrence is very likely and of greater concern. In contrast, green regions (Very Low) require the least attention as criteria's risk values are mostly lower with less likely fire occurrence and therefore not a major concern. The areas that are characterised high, moderate and low require different levels of attention depending on the areas. Based on the figure, it can be seen that majority of the higher risk areas located at the northern part of the District, where about 2.3% of the district has at least a high-risk value (Table 4). Figure 2 and Table 4 illustrates the very high-risk and

high-risk regions, which are found at the northern part of the district. The combined distribution of forest types, peat soil cover, settlement, population density and accessibility show that the very high-risk and high-risk regions are found closer to the shoreline.

Table 4: Area coverage (Sq. km).

Risk Value	Area Coverage (Sq. km)	%
Very High	1.18	0.04
High	63.27	2.3
Moderate	502.01	18.2
Low	1276.32	46.3
Very Low	911.99	33.1

4 Conclusion

Development of fire risk map can be useful for the planning of fire management. This study presents the application and integration of AHP and suitability analysis tool in generating fire risk maps. Suitability analysis was shown to have potential in fire risk assessment studies, as it allows the visualisation and consideration of more than one parameter for developing fire risk maps. A fire risk map for the Belait District was developed in this study with the help of AHP and Suitability Analysis tools in GIS. The results show that high fire risk areas can be found at the northern part of the district, aligned with the shoreline. This indirectly enabled the determination of areas that require more attention from firefighters, particularly during dry periods. However, it should be noted that the accuracy of fire risk map can be further improved by considering other different parameters that influenced forest fire ignition and behaviour.

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References

[1] Tacconi, L., Moore, P. F. and Kaimowitz, D.: 'Fires in tropical forests - What is really the problem? Lessons from Indonesia', Mitig. Adapt. Strateg. Glob. Chang., 2007, 12, (1), pp. 55–66.

[2] Stibig, H. J. and Malingreau, J. P.: 'Forest cover of insular Southeast Asia mapped from recent satellite images of coarse spatial resolution', Ambio A J. Hum. Environ., 2003, 32, (7), pp. 69–75.

[3] World Bank Group: 'The Cost of Fire', 2016, pp. 1–16.

[4] Puttonen, P.: 'Use of prescribed fire in diversity oriented silviculture', Corso di Cultura in Ecologia, 61, pp. 61.

[5] Page, S. E. and Hooijer, A.: 'In the line of fire: the peatlands of Southeast Asia', Philos. Trans. R. Soc. B Biol. Sci., 2006, 371, (1696), pp. 20150176.

[6] Yeager, C. P., Marshal, C., Stickler, M. and Chapman, C. A.: 'Effects of Fires on Peat Swamp and Lowland Dipterocarp Forests in Kalimantan, Indonesia', Trop. Biodivers., 2003, 8, (1), pp. 121–138.

[7] Othman, A.: 'Brunei hailed for perfectly preserved peat bogs,' Borneo Bulletin, June 2017.

[8] http://www.brudirect.com/news.php?id=17954, accessed June 2018.

[9] Abdullah, A. and Ibrahim, S.: 'Conserving and Restoring The Brunei Wetlands'. Commuication & External Affairs, Brunei Shell Petroleum, 2015, (1).

[10] https://www.data.gov.bn/pages/datalist.aspx?k=forest fire, accessed September 2018.

[11] Shahrin Bin Hj Mohd Jawie: 'Interviewed on Forest Fire in Brunei', Brunei Fire and Rescue Department, Fire Department Headquarter, April 2016.

[12] https://borneobulletin.com.bn/fire-and-rescue-dept-recommendations-to-public-regarding-forest-bush-fires/, accessed March 2018.

[13] Fire and Rescue Department: 'Briefing on 'Meeting of Forest and Bush Fire Fighting Operations Nationwide for the year 2016'. Fire and Rescue Department Brunei, Fire Department Headquarter', 2016.

[14] Saaty, T. L.: 'A Scaling method for priorites in heirarchical structures', J. Math Psychol, 1977, 15, (3), pp. 234-281.

[15] Mahmud Y.: 'Seasonal tropical forest and bush fires behaviour: The Brunei Darussalam experience'. Proceedings on the workshop on minimising the impact of forest fire on biodiversity in ASEAN, Brunei Darussalam, March 2001, pp. 58-72.

[16] http://www.innovateus.net/alternative-energy/what-are-peat-fires, accessed June 2018.

[17] Wood, D.: 'Forest fire rise in Belait', The Brunei Times, March 2015.

[18] Alemu, G.: 'Forest cover change detection and fire risk susceptibility mapping using GIS and remote sensing: Case of Goba Woreda'. Phd Thesis, Addis Ababa University, 2008.

[19] Malczewski, J.: 'GIS-based land-use suitability analysis: A critical overview', Prog. Plann., 2004, 62, (1), pp. 3–65.