Spatial modelling of anthropogenic based peat land fire case study of the Kepulauan Meranti District

Turmudi, Dewayany Sutrisno, Irmadi Nahib, Jaka Suryanta, Priyadi Kardono, Yatin Suwarno, Ati Rahadiati, Ratna Sari Dewi

Research, Promotion, and Cooperation Centre, Geospatial Information Agency, e-mail: turmudi.pokja@gmail.com

Abstract: Forest fires in Indonesia are 99% due to human intentional factors. The practice of burning forests is done because it is easy, fast, and inexpensive, and the assumption that the ashes produced will fertilize the soil. The practice of burning forests is done primarily for the purpose of clearing agricultural land and plantations. Land and forest fires will be even worse if they occur on peat lands. Fires on peat lands consist of crown fire, surface fire, and ground fire which have a more severe impact on environmental, social and economic impacts. In terms of management, it is also more difficult and longer than fires on mineral land. On the other hand, peatlands in Indonesia, 30%, are peat lands that have the potential for agricultural and plantation cultivation. The main objective of this paper is to use spatial modeling to provide an early warning system for forest fires on peat lands based on anthropogenic aspects in the Meranti Islands Regency, Riau Province. Data compiled based on anthropogenic aspects include: accessibility, population distribution, land clearing patterns, land use, and land status. Spatial analysis was carried out on anthropogenic aspects and the distribution of hotspots that had a level of confident (c> 80%). The results of the paper indicate that anthropogenic aspects that are dominant in the occurrence of forest fires are accessibility of road than river.

1. Introduction

Peatlands in Indonesia are spread over three large islands with the following areas: Sumatra 6.3 million ha (43%), Kalimantan 4.8 million ha (32%), and Papua 3.7 million ha (25%). [1]. Approximately 30% of the area potentially can be converted into agriculture and plantations. [2]. In its use for agriculture and plantations the initial stage carried out is by land clearing. In the process of land clearing is generally done by burning. The practice of burning forests is done because it is easy, fast, and inexpensive, and the assumption that the ashes produced will fertilize the soil [3] and [4]. In this regard, Forest fires in Indonesia are 99% due to human intentional factors [3].

Land and forest fires will be even worse if they occur on peat lands [5]. Considering on fire, inn peatlands have three types of fires can occur. The three types are crown fire, surface fire, and ground fire [6]. Ground fire is specific fire in peat land, and it has a more severe impact on environmental, social and economic impacts [7]. In terms of management, it is also more difficult and longer than fires on mineral land [8].From time to time, there are always ways to overcome forest fires, especially on peatlands. One of them is by developing an early warning system for forest and land fires.

Considering that the human aspect is very dominant in the occurrence of fire, a breakthrough is sought in making early warning from the human aspect or anthropogenic aspects. Anthropogenic aspect is an aspect of human activity that affects the condition of the surrounding natural resources including in this case the existence of land and forests. [9]. Human activities in relation to burning forests are influenced by their accessibility [10]. Components of access for humans include roads and rivers. There is a research question: is it true that the closer objects that can be accessed by humans have an
influence on the occurrence of fire. If that is true, then how many fires occur each year. Is it the same effect of access in the form of rivers and roads to forest burning activities.

With regard to some of these research questions, the main objective of this paper is to use spatial modeling to provide an early warning system for forest fires on lands based on anthropogenic aspects in the Meranti Islands District, Riau Province.

2. Material and Method

2.1. Study Site

Kepulauan Meranti District is one of the regions of Riau Province with a capital in the Selat Panjang, which has an area of 3,707.84 km$^2$ or 4.26% of the total area of Riau Province. Administratively, the area consists of 9 (nine) subdistricts [11]. The location of the Meranti Islands Regency, in the east is bordered by the Malacca Strait, in the west it is bordered by Siak and Bengkalis District. In the north it borders Bengkalis Regency and Malacca Strait, in the south it borders Palalawan District shown in figure 1.

![Figure 1. Kepulauan Meranti District as research area](image)

2.2. Anthropogenic Aspect

Anthropogenic is an aspect of human activity that has the potential to influence environmental conditions [12]. In this case the influence on the environment is human activity that causes fires, especially on peatlands. Data compiled based on anthropogenic aspects include: accessibility, population distribution, land clearing patterns, land use, and land status. In this case the scope of anthropogenic aspects is more focused in accessibility and land cover with the consideration that the accessibility and type of land cover factor are dominant factor, [13]. Study about fire that have correlation with land cover indicate that land cover scrubs is the most land cover type which burn the most. [14]

2.3. Accessibility

Accessibility in this case is the ease of being able to access a place. The ease of access can be in the form of being easily accessible by four-wheeled vehicles, motorbikes (footpaths), or boats. The more accessible, a place has the potential for land and forest fires [15]. Facilities for accessibility are roads and rivers. Based on data from the 1: 50,000 scale RBI map, there are three types of roads in the Meranti Regency: Other roads, local roads, and footpaths. Other roads and are roads that can still be accessed by four-wheeled vehicles. Local road, is a road that can only be accessed by two-wheeled vehicles, but the road has concrete construction. While footpaths are roads that can only be accessed by two-wheeled vehicles and on foot and are generally still in the form of dirt roads.
2.4. Population distribution

Based on administration, the population in the Kepulauan Meranti District is spread in nine districts with a population as shown in Figure 2. From the calculation of the population of 2010 and 2017, it can be seen that the annual population growth is 0.58.

![Figure 2. Distribution of Population Chart of Kepulauan Meranti District](source)

Source : BPS-Statistics of Kepulauan Meranti Regency

2.5. Land Use

Landuse information is used to determine the composition of land use. The information needed is the extent and distribution of settlements, and how broad and spread it is in any area of shrubs. This is important because settlement is related to population distribution, while shrubs are the most potential land cover to be burned. [14].

![Figure 3. Triangle Fire Concept](source)

Source: Cochrane (2009)
Based on triangle fire, fire can occur because there are three components: heat, fuel, and oxygen. In broader conditions, the components of a fire consist of vegetation, landform, and climatology. In that case, vegetation acts as fuel [16].

### 2.6. Hotspot and Fire

Hotspots with level of confident > 80% are used for fire identification.

![Figure 4. Distribution of Hotspot 2005-2016 in Kepulauan Meranti District](image)

Hotspot distribution is used to indicate the location of any area that is on fire. Hotspot data was obtained from USGS and LAPAN, from 2005 up to 2016. Based on spatial analysis, in the period of 2005-2016, the largest number of hotspots occurred in 2014, amounting up to 2921 hotspots from the total 6,125 hotspots.

### 2.7. Spatial analysis

In spatial analysis, the buffer and the accessibility facilities are rivers and roads. The data used includes: Hotspot data for the period 2005 to 2016, road network, river, landcover for the period 2016. The existence of the hotspot for the 2005-2016 time period was analyzed for the existence of rivers, roads. Rivers and roads are a means of access for humans to carry out activities which include burning forests. The buffer uses three distance classes: 500 m, 1000 m and 1,500 m.

Of the three buffer classes overlay (intersection) with the distribution of hotspots for the period 2005-2016 and will produce information on the number and distribution of hotspots in the buffered area. As shown in Figure 5 the buf_road hotspot and buf_River hotspot files are shown. The file is then overlayed with a land cover to get the river buffer area and the distribution path is in any type of land cover and how it is distributed. This information is used for an early warning system for handling land and forest fires.
3. Result and Discussion

3.1. Road Buffer and the number of hotspots

Spatial analysis is carried out on anthropogenic aspects in the form of roads with hotspot distribution in the buffer area. Each searched for the number of hotspots contained in each buffer. The buffer uses three distances: 500 m (near), 1000 m (medium), and 1,500 m (far). The results of spatial analysis produce information on the number of hotspots in each road buffer as in Table 1 and shown in Figure 6.

| Road Class   | Hotspot on buffer 1500 m | Hotspot on buffer 1000 m | Hotspot on buffer 500 m |
|--------------|--------------------------|--------------------------|-------------------------|
| Road         | 41.333                   | 22.142                   | 8.082                   |
| Local Road   | 3.375                    | 2.019                    | 970                     |
| footpath     | 30                       | 8                        | -                       |

Figure 5. Data Processing Stage

Figure 6. Chart the Number of Hotspot on the road buffer 500, 1000, and 1.500 m
3.2. River Buffer and the number of hotspots

Spatial analysis is carried out on anthropogenic aspects in the form of rivers with hotspot distribution in the buffer area. Each searched for the number of hotspots contained in each buffer. The buffer uses three distances: 500 m (near), 1000 m (medium), and 1,500 m (far). The results of spatial analysis produce information on the number of hotspots in each river buffer as in Table 2 and shown in Figure 7.

Table 2. The number of hotspots on the River buffer 1500, 1000, 500 m

| River Class  | Hotspot on buffer 1500 m | Hotspot on buffer 1000 m | Hotspot on buffer 500 m |
|--------------|--------------------------|--------------------------|--------------------------|
| River Channel| 447                      | 240                      | 107                      |
| River        | 427                      | 148                      | 27                       |
| broad river  | 2.794                    | 1.238                    | 387                      |

Figure 7. Chart the Number of Hotspot on the river buffer 500, 1000, and 1.500 m

The map display of the results of spatial analysis of the 2005-2016 hotspot data with river buffer data, and road buffer data, 500 m, 1000 m, and 1500 m are shown in Figure 8.
Hotspot on River buffer 500m  Hotspot on Road buffer 500m

Hotspot River buffer 1000m  Hotspot Road buffer 1000m

Hotspot River buffer 1500m  Hotspot Road buffer 1500m

Figure 8. The map display of the results of spatial analysis of the 2005-2016 hotspot data with river buffer data, and road buffer data, 500 m, 1000 m, and 1500 m.

For the purposes of an early warning system, a spatial analysis is required by using an intersect between hotspot distribution data on the river and road corridors (buffer) 1500 m and land cover. In
this analysis shows that in the 1500 buffer river with shrubs land cover has the highest hotspot, which is 5.401 hotspots, then mangrove forest 3.127 hotspots, and plantation 1.450 hotspots. (see figure 9)

![Figure 9](image-url)

**Figure 9.** Chart distribution of Hotspot in River Buffer 1500 m and its Land cover.

Through spatial analysis (intersect) the distribution of hotspots in the land cover area contained in the buffer road area, shows the following figures. (see figure 10)

![Figure 10](image-url)

**Figure 10.** Chart distribution of Hotspot in River Buffer 1500 nm and its Land cover.
In the spatial analysis of the 1500 meters buffered road area that was overlapped (intersect) with the land cover type and the hotspot distribution from the years 2005-2016, the following results were shown. The highest distribution of hotspots is in the land cover type shrubs of 14,956 hotspots, then plantation: 10,073 hotspots, and Natural open land: 5,384 hotspots. There is an interesting thing to dry land crop in the area of the road with a 1500 meter buffer has a number of hot spots 2,592 higher than in the same land cover (dry land crop), but there is a 1500 m river buffer area that has 322 hotspots only. This shows that accessibility in the form of roads has more potential to cause land and forest fires compared to rivers.

4. Conclusion
The results of the paper indicate that anthropogenic aspects that are dominant in the occurrence of forest fires are accessibility of road than river. Land that has road accessibility, with land cover in the form of shrubs is the area most prone to burning. Therefore the area must get attention in fire prevention.

5. Acknowledgments
We are grateful to Centers for Research, Promotion And Cooperation, Geospasial Information Agency (BIG) for the data and financial support.

6. References

1. Ritung, S. W., K. Nugroho, Sukarman, Hikmatullah, Suparto, C. Tafakresnanto. Peta Lahan Gambut Indonesia skala 1:250.000. 2011.
2. Agus, F. and I.M. Subiksa, Lahan Gambut: Potensi untuk pertanian dan aspek lingkungan. Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF), Bogor, 2008.
3. B.H., S., Pengendalian Kebakaran Hutan dan Atau Lahyan Indonesia. 2016 IPBPRESS: Bogor
4. Subiksa, I., W. Hartatik, and F. Agus, Pengelolaan lahan gambut secara berkelanjutan. Balai Penelitian Tanah, Bogor, 2011. 16.
5. Darmawan, B., et al., Pengelolaan Keberlanjutan Ekosistem Hutan Rawa Gambut terhadap Kebakaran Hutan dan Lahan di Semenanjung Kampar, Sumatera (Sustainable Management of Peat Swamp Forest Ecosystems Toward Forest and Land Fires in Kampar Peninsula, Sumatera). Jurnal Manusia dan Lingkungan, 2016. 23(2): p. 195-205.
6. Noor, M., & Sabilham, S., Lahan gambut: Pengembangan, konservasi, dan perubahan Iklim. 2010, Gadjah Mada University Press.
7. Yulianti, N., H. Hayasaka, and A. Usup, Recent forest and peat fire trends in Indonesia the latest decade by MODIS hotspot data. Global environmental research, 2012. 16(1): p. 105-116.
8. Badri, M., et al., Sistem Komunikasi Peringatan Dini Pencegahan Kebakaran Hutan dan Lahan di Provinsi Riau. Jurnal Penelitian Komunikasi dan Pembangunan, 2018. 19(1): p. 1-16.
9. Amri, K., et al., Dampak Aktivitas Antropogenik Terhadap Kualitas Perairan Habitat Padang Limun di Kepulauan Spermonde Sulawesi Selatan. 2013.
10. Arienti, M.C., S.G. Cumming, and S. Boutin, Empirical models of forest fire initial attack success probabilities: the effects of fuels, anthropogenic linear features, fire weather, and management. Canadian Journal of Forest Research, 2006. 36(12): p. 3155-3166.
11. BPS, Statistik Daerah Kabupaten Kepulauan Meranti 2018. 2018 BPS.
12. Akbar, A., Pengendalian kebakaran hutan berbasis masyarakat sebagai suatu upaya mengatasi risiko dalam redd. Tekno Hutan Tanaman, 2008. 1(1): p. 11-22.
13. Ardiansyah, F., *Kajian Kerawanan Kebakaran Lahan dan Hutan Menggunakan Interpretasi Citra Landsat 8 di Kabupaten Ogan Ilir, Provinsi Sumatera Selatan*. 2017, Universitas Gadjah Mada.

14. Turmudi, T., et al. *Forest and Land Fire Prevention Through the Hotspot Movement Pattern Approach*. in *IOP Conference Series: Earth and Environmental Science*. 2018. IOP Publishing.

15. Thoha, A.S., et al., *Spatiotemporal distribution of peatland fires in Kapuas district, Central Kalimantan province, Indonesia*. Agriculture, Forestry and Fisheries, 2014. 3(3): p. 163-170.

16. Cochrane, M.A. and C.P. Barber, *Climate change, human land use and future fires in the Amazon*. Global Change Biology, 2009. 15(3): p. 601-612.