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# Spatio-temporal pattern analysis of forest fire event in South Kalimantan using integration remote sensing data and GIS for forest fire disaster mitigation

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# Spatio-temporal pattern analysis of forest fire event in South Kalimantan using integration remote sensing data and GIS for forest fire disaster mitigation

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**Abstract.** Forest fire is one disaster that can paralyze various human activities, both in land and air, which can reach hundreds of hectares and is routine in Indonesia. Mitigation is important to reduce the number of fires and the impact will not damage the ecosystem. Spatio-temporal analysis can be used to know the pattern of an event in a certain period. This makes it possible to identify the factors of events that affected by time and see the changes that occur on the surface of the earth. Data that are used include remote sensing data of rainfall, peatland, palm oil plantation, land cover, hotspot in certain period that is processed using Geographic Information Systems (GIS). The methods used include extraction of forest fire event parameter, mapping of hotspot and forest fire parameter, spatio-temporal analysis, forest fire mitigation identification. The extraction result obtained influential parameters, such as land cover, land use, rainfall, climate, river, and road. Structural mitigation such as the construction of canals and ditches can anticipate the spread of fires. Canals can also be used as a control factor for hydrology. Meanwhile, non-structural mitigation can be done through policy planning based on hotspot distribution modelling.

## 1. Introduction

Forest fire is one disaster that can paralyze various human activities, both in land and air. Areas that fires can be in the form of forest trees, bushes, or grass. This phenomenon can occur due to natural factors, such as climate, and human intentional factors. Fires often occur in Indonesia, one of them is on the island of Kalimantan. The great fires that occurred in the island of Kalimantan can affect airport activities and disrupt flights. Besides that, smoke from fires disturbs other countries and threatens health. Based on data from the Ministry of Environment, South Kalimantan Province in 2013 had 1.8 million hectares of forest. However, the forest area has been shrinking due to forest fires.

The level of fires that attack Indonesia, one of them is on the island of Kalimantan, is quite diverse from year to year. The worst condition of forest fire is when the El Nino phenomenon occurred which caused drought in Indonesia. At that time Indonesia was in danger of fire disaster. El Nino occurred in 2014 to 2015. Besides fires, some areas also experienced water deficits. Fires that occur in Indonesia, especially Kalimantan Island continues to occur from year to year. The number of hotspots is relatively fluctuating with various rates of fire each year. Even though the intensity of the fire fluctuating, the losses resulted remains large. Moreover, since the beginning of 2019 in South Kalimantan there have been at least 70 hectares of land and forest areas that have experienced fires [1]. In retrospect, the fire only occurred in the middle of the dry season and could still occur again.

Bad effects that appear due to fires that occur routinely every year are health problems and decreasing supplies of oxygen from plants. In addition, fires also have an impact on the loss of habitat for living things and the smoke can disrupt planes traffic. These routinely occurred fires, can be avoided if the causative factors can be known. These factors need to be assessed so that the authorities can avoid more massive forest fires.

Forest fires that can reach hundreds of hectares and routinely occur in Indonesia, at least require mitigation measures to reduce the fire rates. The importance of mitigation is, at least the number of fires will be reduced, and the impact will not damage the ecosystem. Also, mitigation of forest fires on the island of Kalimantan, one is South Kalimantan Province, is very important to reduce forest ecosystem loss and prevent unhealthy conditions caused by air pollution.

This study focuses on identifying the causes of forest fires, identifying the effect of each factor on hotspot intensity, and identifying fire mitigation. All processes including data access and visualization utilize remote sensing and geographic information system.

## 2. Methods
### 2.1. Literature Study

| Title | Location | Objectives | Method | Result |
|---|---|---|---|---|
| A Spatio-Temporal Analysis on the Forest Fire Occurrence in Central Kalimantan, Indonesia [2] | Central Kalimantan | Identifying the factor that affect forest fires in Central Kalimantan spatially or temporally based on fire data recorded on satellite imagery | The study was conducted by gathering information from the public, experts, and previous research to determine the variables related to the analysis of forest fires. Data used for analysis include topographic conditions, land cover, peatland conditions, daily hotspot data from MODIS, rainfall data, humidity, temperature, wind speed and direction, data collected are data from 2005-2012, based on the El Nino phenomenon. Each factor is used for spatial and temporal analysis. | The result show a link between the El Nino phenomenon and the increased intensity of fire events in Central Kalimantan. When rainfall decreases it will cause drier air and make peatlands more vulnerable to fire. |
| Spatio-temporal Data Mining on Hotspot Data as Indicator for Forest and Peatland Fires in Riau Province [3] | Riau | Analyzing distribution patterns and hotspots intensity on peatlands based on weather, socioeconomic data, and peatland characteristics | The data used are hotspot intensity for 15 years (2000-2014) from FIRS MODIS Fire / Hotspot, as well as digital maps of Riau Province's peatlands. All the data was analyzed with Spatio-Temporal Clustering and Spatio-Temporal Sequential Pattern Mining. | The result of the activity it was seen that hotspots were concentrated in swamp forests. There was an event with the highest occurance time pattern in 2013. |
| Spatio-temporal Analysis of South Sumatera Hotspot | South Sumatera | Knowing the prediction of hotspot distribution for forest fires event based on data | The data used are hotspot intensity from FIRMS MODIS in 2000-2015, administrative boundary of South Sumatera. Then, data is extracted to obtain variables to be selected. | From the analysis it it predicted that Regency of Ogan Komerling Ilir dan Musi Bayuasin have |

| Distribution [4] | with cluster analysis | Cluster analysis is performed to obtain results related to hotspot intensity. | the potential to cause of fire |
| --- | --- | --- | --- |

## 2.2. Data
Data that are used in this research include MODIS imagery containing hotspot distribution and selecting data with a level of confidence above 80% which is assumed to be a fire point, peatland distribution data from peat hydrological unit maps, data on palm oil land distribution, rainfall data from Climate Hazard InfraRed Precipitation with Station Data (CHIRPS), and MODIS Land Cover imagery for extraction of land cover data in South Kalimantan.

## 2.3. Extraction of forest fire event parameter
The parameters that cause forest fires are determined to see the effect of parameters on forest fires. According to [5] there are several parameters of forest fires such as land cover, rainfall and distance from roads and rivers. In addition, there are several parameters that need to be added in this research such as the use of peatlands, oil palm. Generally, parameters related to nature and human activities. This research using natural parameters such as rainfall, El Nino phenomena, rivers and anthropogenic parameters such as land cover, land use (palm oil and peatlands).

## 2.4. Mapping of hotspot and forest fire parameter
Hotspot data each year are combined with other data such as altitude, river, road, land cover, land use, and rainfall data. These data are used for mapping hotspots that occur. Hotspot Mapping aims to identify fire factors based on weather conditions and fuel on the surface of the earth. River and road data are used to analyse appropriate mitigation for forest fire disasters. The results of hotspot mapping can be used to see the distribution of hotspots and conditions around them. Spatial information can also show the linkages between fire incidents each year so that it can be used as a guide for the analysis of factors that influence or trigger fires in a place.

## 2.5. Spatio-temporal analysis
*Spatio-Temporal* Analysis is done by examining hotspot location information and using remote sensing imageries recorded in different times so that they can see changes in a certain period. *Spatio-Temporal* Analysis is useful to see the changes that occur every time and can reduce information on changes that become a causal factor of an incident by looking at the conditions at any time.

*Spatio-Temporal* Analysis can be used to see the influence or factors that cause forest fires. Utilization of remote sensing imagery makes it possible to see the surface conditions of the earth such as land cover information, to the rainfall data in each time with a quite extensive recording area. This can be used for monitoring, especially for monitoring disasters such as forest fires every year. Forest fire monitoring can be analysed in a *Spatio-Temporal* method which it can identifies the cause of fire such as fuel.

## 2.6. Forest fire mitigation identification
Forest fire mitigation modelling is done by correlating forest hotspot data from 2013 - 2017 with weather data and El Nino phenomena that occurred in 2014 to 2015. The distribution of hotspots is also correlated with data on land cover and land use of palm oil plantations and peatlands that play a role as fuel for fire. The results of the analysis are then correlated with road and river data to see the accessibility of disaster mitigation. Disaster mitigation modelling is seen from the location of forest hotspots to roads and rivers. Data of river near peatlands can be considered for the construction of barriers or dams to keep peatlands from drying out.

## 3. Results

*3.1. Rainfall Data and Number of Hotspot*

Weather and climate are some factors that can affect the number of fires in an area. South Kalimantan Province has a location that is quite close to the equator which rainfall in the area is quite fluctuating. Rainfall will affect humidity and water content as a trigger of fire. The table below explains about the number of hotspot and monthly rainfall in South Kalimantan in 2013 - 2017.

**Table 1**. Number of Monthly Rainfall and Hotspot year 2013 - 2017

| Year | Month | Number of Hotspot | Monthly Rainfall (mm) | Rainfall Classification |
|------|-------|-------------------|-----------------------|-------------------------|
| **2013** | August | 6 | 100 – 200 | Medium |
| | September | 71 | 50 – 150 | Low to Medium |
| | October | 120 | 20 – 150 | Low to Medium |
| | November | 5 | 200 – 400 | Medium to High |
| **2014** | August | 44 | 50 – 100 | Low |
| | September | 467 | 20 – 100 | Low |
| | October | 364 | 0 – 150 | Low to Medium |
| | November | 118 | 100 – 300 | Medium |
| **2015** | July | 17 | 20 – 100 | Low |
| | August | 207 | 0 – 100 | Low |
| | September | 968 | 0 – 50 | Low |
| | October | 714 | 0 – 150 | Low to Medium |
| | November | 65 | 50 – 300 | Low to Medium |
| | December | 4 | 200 – 300 | Medium |
| **2016** | January | 26 | 100 – 200 | Medium |
| | September | 4 | 150 – 300 | Medium |
| | October | 5 | 200 – 400 | Medium to High |
| **2017** | July | 5 | 150 – 200 | Medium |
| | August | 4 | 200 – 300 | Medium |
| | September | 43 | 100 – 200 | Medium |
| | October | 9 | 100 - 200 | Medium |

Based on the data above, starting in 2013 - 2017 there were routine fires in September with different quantities of hotspots. The results of rainfall extraction from the CHIRPS data in September 2013, the amount of monthly rainfall ranges from 20 - 150 mm where the amount is included in the classification low to medium with a total of hotspots is 120. In 2014 fires occurred from August - November and in September there were 467 hotspots. This condition occurred in rainfall ranging from 20-100 mm in September which is classified as low. 2015 became a year with more hotspots. Fires occurred from July to December with average rainfall from July to October fairly low. This condition increased the number of fires, from August to October and even continued until January 2016. This condition is different from the previous year which had higher rainfall. Also, in 2017 there were not too many fire incidents, due to higher rainfall.
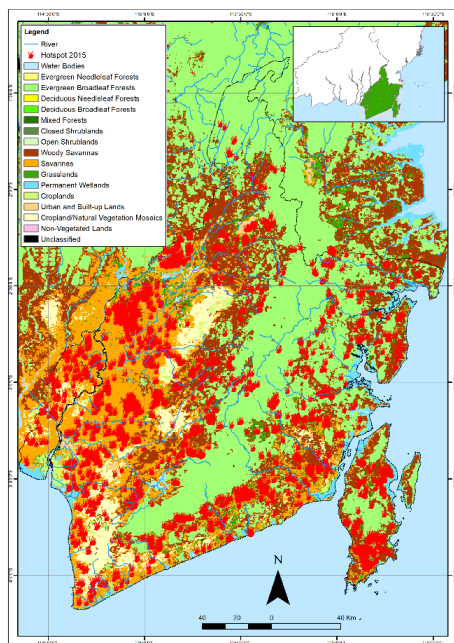
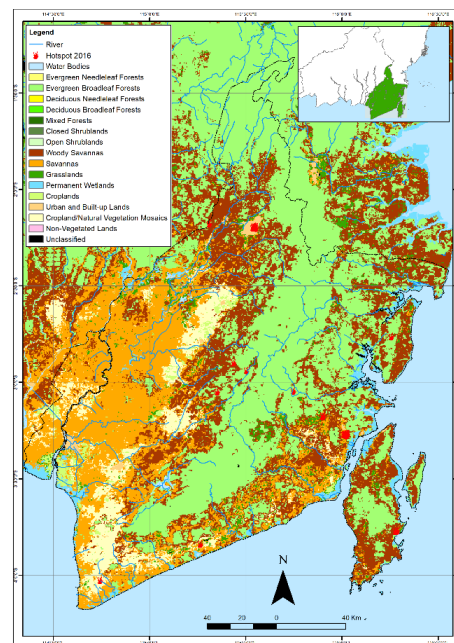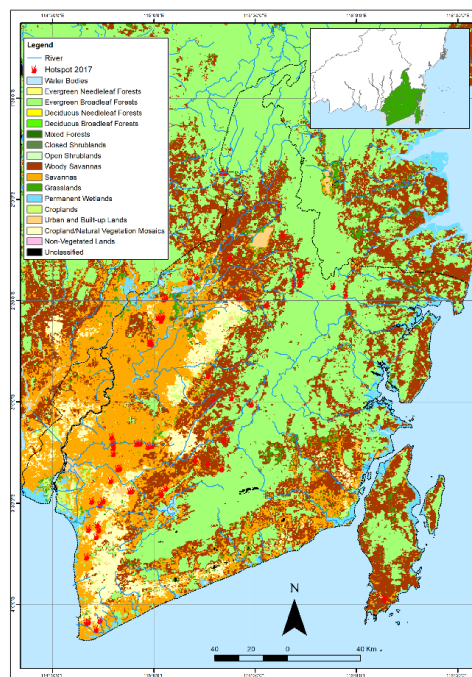*3.2. Aspects of changes in land cover for forest fires*
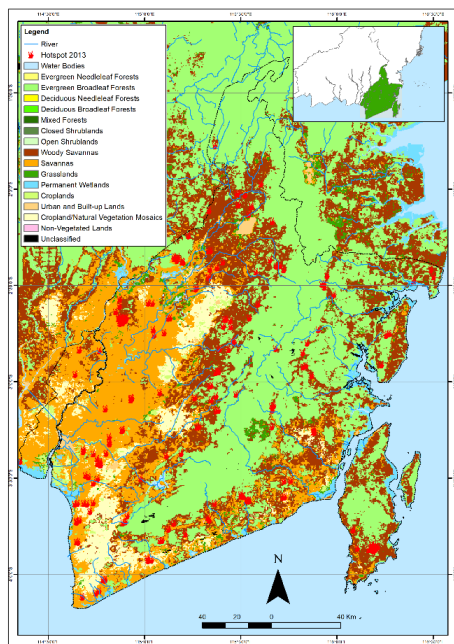


(a)
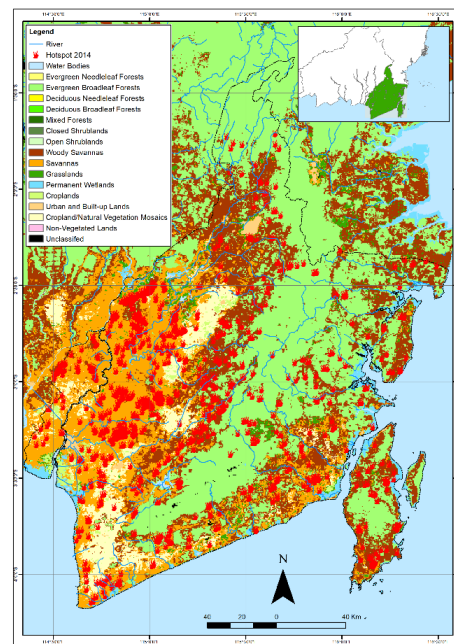


(b)



(c)



(d)

(e)

**Figure 1**. Hotspot Distribution Maps in South Kalimantan (a) 2013, (b) 2014, (c) 2015, (d) 2016, (e) 2017

From the five hotspot distribution maps above, land cover information and altitude information can be seen. Based on the map above land cover changes are not too significant from 2013 to 2015. However, the intensity of forest fires increased in 2014 to 2015 and decreased in 2016. Based on the five maps above, fires often occur in land cover type with low density vegetation in the western part of South Kalimantan Province.

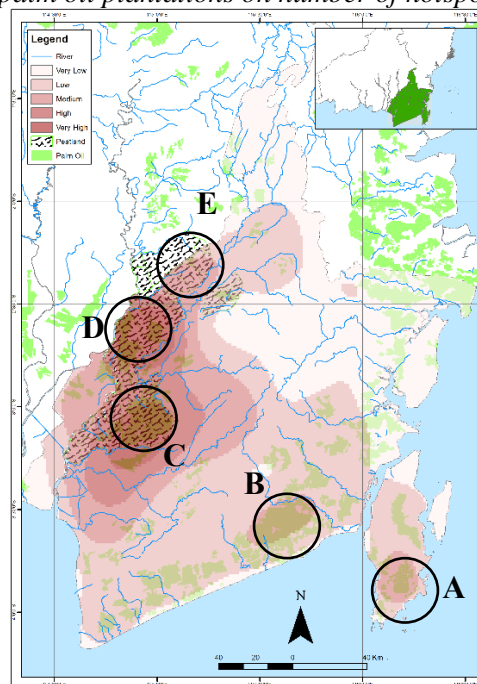*3.3. Aspects of peatlands and palm oil plantations on number of hotspot*



**Figure 2**. Hotspot Distribution Maps in South Kalimantan 2013-2017

When viewed from the map of hotspot, river, peatland, palm oil plantation and road, there are clustering patterns at several points from 2013-2017 and occurred massively in 2013, 2014, and 2015. These hotspots cluster at points A, B , C, D, and E. Groups A and B are centred on oil palm plantations, groups C and D with more hotspots are centred on peatlands that are converted to palm oil plantations, while group E is located in peatlands.
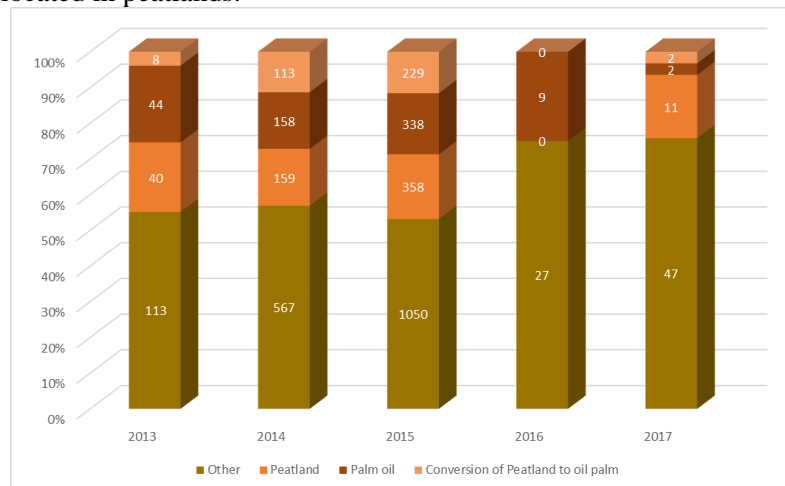


**Graph 1**. Forest Fires on Land Cover in South Kalimantan

Based on the graph above, fires that occurred in conversion peatlands for palm oil plantations such as groups C and D had 352 hotspots from 2013-2017 and, on peatlands itself there were 568 hotspots and in oil palm plantations there were 551 hotspots. Conversion area that is not large has quite a lot number of hotspots. Group A has a quite a lot number of hotspot even though not located in conversion area. Other unconverted area, group E located in peatland have canals that may give an effect for hotspot intensity.

## 4. Discussion

### 4.1. El nino phenomenon on forest fire intensity

The massive fires that occurred in 2014 to 2015 can be seen from the map of hotspots distribution in South Kalimantan due to the strong El Nino phenomenon. El Nino phenomenon is a phenomenon of the warming temperatures of sea surface. This condition can cause dryness, prolonged drought, and decreased water level [6]. El Nino causes an increase in convection currents so that the eastern equatorial Pacific area experiences an increase in rainfall [7]. However, most parts of Indonesia experienced drought and decreased rainfall. Drought due to prolonged dry season is indicated by increased temperature, reduced humidity, and low rainfall conditions. This will increase the probability of a fire because of many flammable materials such as dried plants. The friction between hot air and dry material, is one of the factors that causes fire to appear.

This El Nino phenomenon has affected several regions in Indonesia, one of which is South Kalimantan [8]. Conditions in South Kalimantan in 2014 to 2015 had under average rainfall, only ranging from 0-20 mm / month. This condition caused the South Kalimantan region to experience severe drought, forest fires, and smog due to fire [9]. This El Nino phenomenon had previously occurred in Indonesia in 1997-1998 which caused severe drought in the tropics and massive fires. During 10 months in 1997 the condition of rainfall was under the normal level and decreased until -215 mm [10]. El Nino repeated in 2014 to 2015 and caused many forest fires.

### 4.2. The effect of land cover on forest fires

Land cover becomes an important information in identifying factors for forest fires. Land cover is an influential factor in the availability of fuel which can trigger fires and make fires even more widespread. Land cover types of low-density vegetation have a high risk to burn. This is because low density

vegetation is dominated by dry vegetation. Besides that, in 2014 and 2015 those areas that experienced fires were quite intensive and evenly distributed throughout the region and there were no hotspot data in the centre of the province. This is because the central region is a highland so that it can minimizes the risk of fire. According to [10], higher places are harder to burn. The distribution of hotspots for five years from 2013 to 2017 are only in the surroundings of the highlands. Other land cover information, such as road accesses and rivers as human activities route, also influences the probability of a fire occurring due to human intervention. One of the human activities that can cause fires is disposing cigarette sticks which are still burning carelessly, to the land clearing activities for plantations.

*4.3. The effect of peatlands and palm oil plantations on forest fires*
Other land covers such as peatlands and palm oil plantations are also become factors in forest fires. The condition of peatlands in South Kalimantan coincides with access to several rivers. One of the big rivers that coincide with peatlands is the Barito River. Peatland itself is soil that results from imperfect decomposition of organic material such as vegetation that is flooded with water to become anaerobic conditions. The condition of peatlands bordering with the Barito River has unique conditions. Peat sediment thickness can reach more than one meter that commonly covered with bushes such as wild grasses with weeping paperbark woods [11]. Peat as a land that is quickly absorb and drain water can trigger fires. The existence of canals in peatlands can lower water levels in peatlands, thereby increasing the risk of peatland drought and causing fires [12]. Canals without insulation, which are fluctuating in the dry season, can reduce water content in peatlands. Peatlands that lose their water content make the anaerobic atmosphere change to aerobic [13]. Also, peatlands whose water has been discharged will be difficult to store water again.

Converting peatlands to palm oil plantations requires a process of draining peatlands. Draining peatlands can change the atmosphere of the land into aerobics. Thus, the rate of decomposition of the peat itself will increase and is easier to release $CO_2$ or carbon [13]. Also, based on research conducted by [14] due to the planting of palm oil, the watershed in an area can experience a decrease in water flow of around 30% -40%. Of course, this condition will be very alarming when Indonesia enters the dry season phase. Fires that occurred in the El Nino phenomenon in peatland conversion reaching 113 spots in 2014 and 229 spots in 2015. The minimum water content will make it easier for plants to burn and increase carbon release, further worsening the release of emissions into the air.

Unconverted peatlands such as in the group E have canals that are used for land drainage, thus reducing water content and causing flammability. The amount of rainfall will also affect the level of humidity in the peatland area, that is when rainfall decreases, the probability of peatland will dry up increases highly [2]. This is because the nature of peat is like a sponge that is easy to absorb and release.

Other land uses that are quite often burned are palm oil plantations, for example in group A. Palm Oil plantation fires can usually occur due to land opening or land clearing activities for the rejuvenation phase. However, plantations owned by registered companies would prefer a safer and more sustainable process, compared to illegal companies or even ordinary owners [2]. Burning palm oil land tends to be cheaper and more effective than land clearing safely [15]. Palm Oil farmers who have not yet joined a registered company, have the habit to burn land when going to plant palm oil because it is considered capable of killing pests and adding nutrients [16]. However, the ownership status of each palm oil land cannot be interpreted through imagery. According to [17], it is explained that every business actor is prohibited from cultivating his land by burning, and every business actor has fire control. The result of this burning is when in the dry season with low rainfall will easily spread to other areas and cause massive fires.

Another factor that makes the regulation easy to violate is the ease of access to do the burning. Barito River as a large river and can be used as transportation through peatlands that have been converted into palm oil plantations. Of course, this location is in groups C and D which had massive fires in 2014 and 2015. Access such as roads as the main transportation, is also a factor that can trigger combustion. The eastern side of South Kalimantan province has access to the main road with the distribution of palm oil plantations. Thus, it is possible that palm oil farmers or even companies do open land. Road construction

makes it easier for the community access to convert forest by burning [12]. This is presented in Picture 2. Road access to hotspots is still within the radius of 5 km, so human influence can still occur in some fire cases in South Kalimantan Province.

*4.4. Forest fire mitigation*

Drying land that can cause a decrease in peatland water level and cause the soil to shrink, needs to be improved in its system. The existence of canals that previously functioned as drainage can be converted into water storage canals. Making canal partition to prevent water level decrease on peat so that it can anticipate fires [18]. This canal can be partitioned or dammed. The canal barrier can maintain water level conditions on peatlands. The canal barrier is made in accordance with the Guidelines for Peatland Ecosystem Restoration by the Ministry of Environment and Forestry of 2015. The river dam and canal partition system can regulate water content in peatlands and maintain anaerobic conditions in peatlands. In addition, the existence of the Barito River also facilitates the creation of small canals on peatlands. Small rivers that cross can also be made into artificial canals. This partitioned canal can also be used as a fire control. Fires tend to occur when humidity conditions are low and dry, whereas with the partition of these canals, if a fire occurs its possibility to spread is lower because it is limited by partitioned canals. Building a construction such as partitioned canals to prevent an event is one of structural mitigation.

The existence of this canal can also be used on palm oil plantations. Every canal that is made by plotting area of plantation. Water drainage in the canal during the rainy season can be used as a water storage for palm oil growth. The type of palm oil that tends to require a lot of water, of course, will also be more effective water storage near the plantations. In addition, the process of palm oil rejuvenation which tends to be burned can use this canal as a burning limit.

Making smaller and simpler canals can also be done on agricultural land. The boundary between the agricultural land or plantation that are going to be opened is made in the form of a wet ditch. The condition of this ditch does not have to be always flooded, but in a wet condition and not planted by plants. This ditch boundary can prevent the expansion of land fires. In addition, the existence of this ditch can also be drained by water for irrigation systems for agricultural land. This ditch can function as a firebreak. Actually, the government has also made it clear in the [19] that burning land is permissible on the basis of local wisdom with certain land area restrictions and must be surrounded by firebreaks so that burning does not extend to other areas.

The benefits of canals on peatlands, palm oil plantations, and ditches on agricultural land have almost the same function. Boundaries between fields in the form of canals or ditches tend to be more effective in preventing the spread of fires. However, canals that are not utilized properly can be a cause of drainage on peatlands. Thus, at least the canal has a partition to regulate the outgoing and incoming discharges.

Fire incidents occurring in vegetation areas with low cover mostly due to the presence of fuel under the canopy. Fuel can be either bush or litter. Mitigation that can be done is to clean the combustible material when it starts to enter the dry season [20]. Little fuel can reduce the risk of burning the area. Non-structural mitigation is a mitigation effort that carries out policy planning by enacting regulations or planning modelling for land use [21]. One way to formulate policy is by temporal mapping. Temporal mapping of hotspot distribution is one of the efforts to minimize forest fire disaster. Hotspot distribution maps can be used to analyse the effects or causes of fires such as land cover, rainfall data, roads and rivers. Temporal mapping can be used to see trends throughout the year of these parameters. The results of the analysis can be taken into consideration for development planning and policy by the government. From the distribution map, it can also be seen the dominance of the hotspot distribution so that the area that often causes forest fires can be prioritized for mitigation.

Hotspot distribution maps with road and river data can be used to determine the reachability of fire locations. For areas that are difficult to access, it is used water bombing with aircraft. Rainfall data is used to see the effect of the El Nino phenomenon that affects rainfall intensity. Of course, through remote sensing data, these parameters can be monitored regularly and in *real-time*.

## 5. Conclusion

Utilization of remote sensing data can be used to identify factors that causing fires through spatial hotspot analysis of fire locations. The location of a fire can be seen from the characteristics of land cover and climate or weather characteristics that are considered to play a role in triggering forest fires. There are two types of factors that identified, those are natural factors such as rainfall, topography, land cover and anthropogenic factors such as roads, rivers and land use.

Forest fires that often occur can have an impact on the balance of the ecosystem. The impact of forest fires can influence air quality due to forest fires and the release of emissions so that it adversely affects human health. Land cover can be a potential fuel for the forest fire incident. In addition, it also affects the function of soil and plants as habitat for living things.

Forest fire disaster mitigation can be done by creating insulated canals to balance hydrological factors on peatlands and oil palms. Ditch can also be used as a boundary between agricultural plots. Both function as firebreaks so that the fire does not spread to other areas. Planning the location of canal and ditch establishment can utilize modelling from Spatio-Temporal hotspot mapping. Further research is suggested with longer period data and looking at anthropogenic factors.

## References

[1]  Bahrani 2019 Kebakaran Hutan Tahun Ini Lebih Parah *Liputan 6*
[2]  Lestari A, Rumantir G and Tapper N 2016 *Proc. A Spatio-Temporal Analysis on The Forest Fire Occurrence in Central Kalimantan, Indonesia* (Chiayi: Pacific Asia Conference Information Systems)
[3]  Sitanggang I S, *et al.* 2015 *Proc. Spatio-temporal Data Mining on Hotspot Data as Indicator for Forest and Peatland Fires in Riau Province* (Bandung: PPM IPB 2015)
[4]  Firdaus, *et al.* 2017 Spatio-temporal Analysis of South Sumatera Hotspot Distribution *Conf. on International Conference on Electrical Engineering and Computer Science (ICECOS)*
[5]  Eko M, Gandasasmita K and Djajakirana G 2013 *Globe* **15** 178-184
[6]  Stockwell C E, *et al.* 2016 *Atm. Chem. and Phys.* **16** 11711-32
[7]  Fitria W and Pratama M S 2013 *Jurnal Meteorologi dan Geofisika* **14** 65-74
[8]  Sakya A E 2015 El Nino Menguat, Kemarau diperkirakan Hingga November *CNN Indonesia*
[9]  Supari F T, Salimun E, Aldrian E, Sopaheluwakan A and Juneng L 2018 *Clim. Dyn.* **51** 2559-80
[10] Ikhwan M 2017 *Jurnal Kehutanan* **11** 57-66
[11] Tjahjono J A E 2007 *Proc. Inventarisasi Endapan Gambut Daerah Barambai Dan Sekitarnya Kab. Barito Kuala, Prov. Kalimantan Selatan* (Bandung: Pusat Sumber Daya Geologi)
[12] Prayoto, Ishihara M I, Firdaus R, and Nakagoshi N 2017 *J. of Envir. Prot.* **8** 1312-32
[13] Widyati E 2011 *Tekno Hutan Tanaman* **4** 57-68
[14] Taufiq M, Siswoyo H and Anggara W W S 2013 *Jurnal Teknik Pengairan* **4** 47-52
[15] Marlier M E, DeFries R, Kim P, Koplitz S, Jacob D, Mickley L and Myers S 2015 *Envir. R. Letr.* **10** 1-9
[16] Wicaksono P E 2015 Petani Sawit Harus Ganti Cara Pembukaan Lahan *Liputan 6*
[17] Republik Indonesia 2014 *Undang-Undang Nomor 39 Tahun 2014 Tentang Perkebunan.* (Jakarta: Sekretariat Negara)
[18] Wahyuni S 2019 Pembangunan Sekat Kanal Jadi Alternatif Pilihan Antisipasi *Tribun Pontianak*
[19] Republik Indonesia 2009 *Undang-Undang Nomor 32 Tahun 2009 Tentang Perlindungan dan Pengelolaan Lingkungan Hidup* (Jakarta: Sekretariat Negara)
[20] Loren A, Ruslan M, Yusran F H and Rianawati F 2015 *EnviroScienteae* **11** 1-9
[21] Rusilowati A, Supriyadi, Binadja A and Mulyani S E S 2012 *Jurnal Pendidikan Fisika Indonesia* **8** 51-60