GIS Application in Mapping of Forest and Land Fires and Mitigation in Banjarbaru City, South Kalimantan

Fikhriyah Khairunnisa & Indah Ratna Rosalena

1Department of Geography, Faculty of Mathematic and Natural Sciences
University of Indonesia

E-mail: fikhriyah.khairunnisa@ui.ac.id

Abstract. Forest and land fires is an important issue to be concerned due to its impact to the environment, especially in Banjarbaru City, South Kalimantan. Since the city is used as government area and mostly located in peatland, the prevention is needed to overcome the fires disaster. It can be done by using Geographic Information System (GIS). This study aims to mapping and analyzing the susceptible area of forest and land fires and its mitigation to overcome it. The level of susceptible of forest and land fires is the possibility of fires disaster which is done by GIS to define the priority area of mitigation. The modelling processed to obtained the susceptible area of forest and land fires by using GIS application. Geographic Information System (GIS) applied by using in ArcMap 10.2 facilitates the coating process between fires-causing factors. Physical environmental factors and human activities are two main factors of forest and land fires disaster. Factors used in modelling are land type, altitude and landuse. Each of them has score and percentage due to its risk to the fires disaster. From the modelling of fires-causing factors in Arc. Map 10.2 has been generated the susceptible area of forest and land fires. There are five level of susceptible area, such as not susceptible, low, moderate, high, and very high. Banjarbaru has five district, namely Lianganggang, Landasanulun, Banjarbaru Utara, Banjarbaru Selatan, and Cempaka. The very high area is around 15% area of Banjarbaru City and located in north and west area of Lianganggang district, north area of Landasanulun District and in the west of Banjarbaru Utara district. The high area has about 32% area of Banjarbaru City which is located in south Lianganggang district, southwest and east of Landasanulun district, in the center and west area of Cempaka district and also in north and east part of Banjarbaru Utara. The moderate level of forest and land fires disaster has about 17% area of this city that located in the middle of Lianganggang, southeast of Landasanulun, and south and west part of Cempaka district. And the low level has 32% area of the city and mostly located in cempaka, Banjarbaru utara dan Banjarbaru Selatan district. The last, not susceptible area is only about 0,13% in Cempaka district. The mitigation mostly located in Landasanulun dan Lianganggang district by making canals and boreholes. Local people are also encouraged to do quick response action by giving them water machine to extinguish the fires if it suddenly happened around them while waiting the helicopter from BNPB coming to help. Banjarbaru City, South Kalimantan Selatan is susceptible enough of forest and land fires disaster, especially in the west of Banjarbaru city. The susceptible area of forest and land fires is useful to assist in monitoring and determining priority areas in fires disaster mitigation. Besides, it useful to improve the level of local people awareness to not do something at risk of causing fires.

1. Introduction
Forest and land fires in Indonesia have become an international concern especially since forest fires that occurred in the 80s [1]. The causes of forest and land fires are more caused by human activities than natural processes [2]. In the annual report of WorldLife Fund, a non-governmental organization (NGO) that focuses on environmental issues states that Kalimantan Forests are believed to be shrinking by 75 percent by 2020 if the rate of deforestation is not stopped. Of the approximately 74 million hectares of forests owned by Kalimantan, only 71% were left in 2005. While the number in 2015 shrank to 55%. If
the rate of deforestation does not change, Kalimantan is believed to be losing 6 million hectares of forest by 2020, meaning that only less than one third of the forest area is left [6].

The city of Banjarbaru is a city that part of its territory stands on peat land [8]. Forest and land fires have become not only in Indonesia but also in the Southeast Asian region which affects various aspects of life such as disturbances in daily life, transportation barriers, environmental damage, poverty, economy and health problems [9]. Forest and land fires can be a particular threat to this city because of course there are activity centers, such as government offices, transportation facilities in the form of airports, and markets as a place of trading activity.

According to Minister of Environment Regulation No.10 of 2010 concerning the Mechanism of Pollution Prevention and / or Environmental Damage Related to Forest and / or Land Fires (State Secretariat, 2010 in eco mapilata 2013), it was explained that prevention of forest and land fires can be done by providing data and information include location/area of fire and areas prone to forest and land fires. Location / area of ex-fire can be identified using remote sensing technology [7].

From this study, researchers utilize spatial data by processing using applications based on Geographic Information System (GIS), namely ArcMap 10.4 to obtain areas that are susceptible to fires, especially on peatlands. Thus, land fires disasters can be monitored in real-time combined with field surveys. In addition, the ability of GIS can also be maximized as information on how to handle forest and land fires, which during this time the action was only carried out at the time of the fires, but there was no pre and post-event prevention. As a result, the impact will be greater due to the absence of prevention. In this study the author aims to map susceptible area to forest fires and analyze their distribution. The problems studied were hotspot distribution, forest fires hazard mapping and mitigation carried out in dealing with cases of forest fires.

2. Study Area and Data

2.1. Study Area

![Figure 1. Study Area](image_url)
Banjarbaru City is located between 3º25’40” to 3º28’37” South Latitude and 114º41’22” to 114º54’25” East Longitude. The city of Banjarbaru is at an altitude of 0–500 m above sea level, with a height of 0–7 m (33.49%), 7–25 m (48.46%), 25–100 m (15.15%), 100–250 m (2.55%) and 250-500 m (0.35%). The area of Banjarbaru City is 371.38 km² divided into 5 (five) Subdistricts and 20 (twenty) Kelurahan, with boundaries where the north is bordered by Martapura District, Banjar Regency, bordering on the south by Tanah Laut Regency, on the west bordering Gambut Subdistrict, Banjar Regency, and to the east bordering Karang Intan District, Banjar Regency [10].

Banjarbaru, South Kalimantan has a protected forest area of 900 hectares, in the Sub-district of Liang/Ulin and grounding [1]. At 2015 when disaster struck the smog in South Kalimantan, Banjarbaru contributed to the scale of forest fires and the breadth of reach 500 hectares more. The incidence of forest fires have caused an impact in various aspects of both ecological, social, economic, and political [8].

2.2. **Data Selection**
The data required in the processing of this technical module based on updates to the forest and land fires susceptible map in South Sumatra Province the year 2015 of the Biodiversity and Climate Change Project (BIOCLIME), including:
   a. Data Administration of Banjarbaru (Geospatial Information Agency).
   b. Land cover Data for the year 2007 (from Geospatial Information Agency).
   c. Elevation Data/DEM SRTM DATA.
   d. Map of soil types (from the Ministry of Environment and Forestry).
   e. Hotspots in 2017 (from NOAA Satellite).

3. **Metodology**

3.1 **Workflow**
Figure 2. Workflow of the research

The research is to determine the level of fire susceptibility in the city of Banjarbaru using three variables: elevation, land use, and soil type. Data on soil types is indicated by the distribution of peat soil. Elevation variables were obtained from Digital Elevation Model (DEM) SRTM data which processed using ArcMap 10.4 to be able to display the required classification of elevation in the form of elevation of under 25 meters and above 25 meters. In addition, to requiring data relating to research variables, it is also needed data in the form of administrative shapefile of Banjarbaru City. This shapefile in spatial data processing serves to show the boundaries of the study area and for cropping data based on the study area. The modelling process is performed with GIS software. At this stage data processing is still done in ArcMap 10.4. The overlay type used is Intersect. Then, we do weighted overlay process to giving score of each variable. The processing result show the mapping of forest and land fire susceptibility. After the map is obtained, it is tested with groundchecking and interviews to find out how conditions are in the field.

3.2 Data Processing

Based on the 2015 technical module for updating the hazard map for forest and land fires in South Sumatra Province from the Biodiversity and Climate Change Project (BIOCLIME), the matrix for susceptible forest fire areas is determined below:
Table 1. The matrix of susceptible area of fires.

| Factors          | Percentage | Classification       | Score |
|------------------|------------|----------------------|-------|
| Landuse          | 40%        | Forest of industry plants | 5     |
|                  |            | Plantation           | 3     |
|                  |            | Settlements          | 2     |
|                  |            | Dry land agriculture | 3     |
|                  |            | Rice fields          | 2     |
|                  |            | Temporary land farming | 2    |
| Moor/fields      |            |                      | 3     |
| Type of soil     | 30%        | Peat                 | 5     |
|                  |            | Non-peat             | 1     |
| Elevation        | 30%        | 0-25 meters          | 5     |
|                  |            | 25-500 meters        | 1     |
|                  |            | >500 meters          | 1     |

\[
\text{The Susceptible Area} = 0.4 \times \text{landuse} + 0.3 \times \text{elevation} + 0.3 \times \text{soil type}
\]  

(1)

The results of the spatial analysis of the susceptibility map, based on the technical module for updating forest and land fire hazard maps in South Sumatra Province in 2015 from the Biodiversity and Climate Change Project (BIOCLIME) will be classified into 5 classes, based on the above formula, namely:

Table 2. Classification of susceptibility class scores.

| Class of susceptibility | Score |
|-------------------------|-------|
| Not susceptible area    | 0-0.9 |
| Low                     | 1-1.9 |
| Moderate                | 2-2.9 |
| High                    | 3-3.9 |
| Very high               | 4-4.9 |
4. Results and Discussion

4.1 Elevation in Banjarbaru City

The elevation used as a climate factor to define the susceptible area of forest and land fires. Elevation affected to the land temperature, precipitation and sunlight intensity. The higher elevation makes the temperature lower, the precipitation higher, and sunlight intensity lower. The lower elevation makes the temperature higher, the precipitation lower, and sunlight intensity higher which can drive to forest and land fires disaster happened.

The elevation data obtained from SRTM, and processed by GIS application. Elevation divided into 2 classification, under 25 meters and above 25 meters. The area that has elevation under 25 meters is very susceptible to forest and land fires, and vice versa. As it impact to the disaster, elevation contributes 30% to forest and land fires.

Figure 3 Elevation in Banjarbaru City, South Kalimantan.

Banjarbaru city mostly located at low elevation, especially in the west area of Banjarbaru city. In Lianganggang district, all of the area has elevation 0-25 meters. In Landasanulin district, the elevation under 25 meters is on the west, south and north of the district, meanwhile on the east area of Landasanulin has elevation above 25 meters. In Banjarbaru Selatan district, most of the area is above 25 meter. So does Banjarbaru Utara district, only the west and east area that has elevation under 25 meters. And in Cempaka district from the east to southeast area and the northwest area are above 25 meters, the west to southwest and the center area are under 25 meters. Based on the elevation, the west area of Banjarbaru city is more susceptible to forest and land fires.

4.2 Type of Soil in Banjarbaru City

Type of soil is the second variable as physical environmental factor that contributes 30% to forest and land fires. The data of type soil obtained from Ministry of Environment and Forestry. The composition
of type of soil map classified according to analysis needs by distinguishing between mineral soil types and peat. The peat map component is the key information in developing a fires map because peat becomes a material that is flammable in the dry season. Peat soil is irreversible drying and when long dry season, it will be difficult to tie the water back so it is susceptible to burning. Peat soil has highest score, meanwhile non-peat soil has the lowest score to forest and land fires mapping.

Figure 4. Type of soil in Banjarbaru City, South Kalimantan.

In Banjarbaru City, the peatland is mostly located in Lianganggang district and Landasanulin, and also the west area of Banjarbaru Utara District. Non Peat soil type located on west to east area of Lianganggang district, most of the area in Landasanulin district from west to east and the southeast area of the district, most of the Banjarbaru Utara district, except the western part of the district, all of Banjarbaru Selatan district, and also all of Cempaka district. From the type of soil which classified into peat soil and non-peat soil, Lianganggang and Landasanulin district are more susceptible than other district in Banjarbaru city.

4.3 Landuse in Banjarbaru City

Human factor in the field was represented spatially by land use. Land use greatly affect forest and land fires. Some land coverings are included in the fires-susceptible ecosystem, which is an open area with covered shrubs, litter and twigs both on land and in peat swamps, plantations, especially in peat swamps, agriculture, especially in peat swamps, and good secondary forests on land and in peat swamps. Land use data obtained from the Geospatial Information Agency was then processed to determine the distribution of land use in the study area by using Arc. GIS 10.2.

The weighting of landuse is carried out based on the sensitivity of the type of vegetation concerned to the occurrence of fires. A weight value to a very sensitive type of vegetation, which is very flammable is higher than the landuse that difficult to burn.
Figure 5. Landuse in Banjarbaru City, South Kalimantan.

Landuse in Banjarbaru city dominated by dry land agriculture. Every district has area of dry land agriculture. This landuse has area 14703.9 hectare in Banjarbaru city. The second largest landuse is rice field. It has area about 6602.95 hectare mostly located in Landasanulin and Lianganggang district. Then, landuse of dry land farming mixed with shrubs has 3372.38 hectare area that located in Cempaka district and North and South Banjarbaru district. Mining area mostly located in Cempaka and Landasanulin district has area 2530.04 hectare. Settlement located near boundary of North and South Banjarbaru district, Lianganggang and also Landasanulin district. It has area 1062.05 hectare. Another landuse in Banjarbaru city has area under 1000 hectare. Due to its impact to forest and land fires and reflected as human factor, landuse contributes 40% to the disaster of forest and land fires.

4.4 Susceptible Area of Forest and Land Fires in Banjarbaru City

Forest and land fires have various impacts on human life. Syumanda (2003) stated that the impacts of forest fires are (1) social, cultural and economic impacts, (2) impacts on ecology and environmental damage, (3) impacts on relations between countries and (4) impacts on transportation and tourism. Forest fires often cause smoke disasters that can disrupt the activities and health of the surrounding community. From this study, researchers utilized spatial data by processing using GIS applications to obtain areas that are susceptible to forest fires.

From the results of the overlay of the three variables, types of soil, altitude, and land use are found to be susceptible to forest fires. Susceptible areas of forest fires are divided into 5 classes of non-susceptible area, low, moderate, high, and very high.
Figure 6. Susceptible area of forest and land fires in Banjarbaru City, South Kalimantan.

From processing result, the map of susceptible area of forest and land fires showing that the most susceptible area in Banjarbaru city is in Lianganggang district. It has large area of high and very high of susceptible. The second susceptible district is in Landasanulin district. And low susceptible of forest and land fires are Cempaka, North and South Banjarbaru district. The very high area is around 15% area of Banjarbaru City and located in north and west area of Lianganggang district, north area of Landasanulin District and in the west of Banjarbaru Utara district. The high area has about 32% area of Banjarbaru City which is located in South Lianganggang district, southwest and east of Landasanulin district, in the center and west area of Cempaka district and also in north and east part of Banjarbaru Utara. The moderate level of forest and land fires disaster has about 17% area of this city that located in the middle of Lianganggang, southeast of Landasanulin, and south and west part of Cempaka district. And the low level has 32% area of the city and mostly located in cempaka, Banjarbaru utara dan Banjarbaru Selatan district. The last, not susceptible area is only about 0,13% in Cempaka district.

Table 3. Area of susceptibility of forest and land fires in Banjarbaru City.

| District         | Not Susceptible | Low   | Moderate | High     | Very High | Area   |
|------------------|-----------------|-------|----------|----------|-----------|--------|
| Lianganggang     | 0,00            | 0,00  | 1,632,76 | 3,027,80 | 3,550,56  | 8211,12|
| Landasanulin     | 0,00            | 599,18| 1,456,18 | 3,885,71 | 1,303,23  | 7244,30|
| Banjarbaru Utara | 0,00            | 1,270,60| 335,75 | 795,22   | 356,94    | 2758,51|
| Banjarbaru Selatan | 0,00     | 1,332,28| 34,32  | 135,21   | 0,00      | 1501,81|
| Cempaka          | 42,56           | 8,130,15| 2,098,16| 2,768,25 | 0,00      | 13039,12|
| Total            | 42,56           | 11332,21| 5557,17| 10612,19 | 5210,73   | 32754,86|

Lianganggang district is the most susceptible area of all the district in Banjarbaru. The very high area is about 3550,56 Ha, which more than one third of the total district area. The high susceptible is 3207,80 Ha which also more than one third of the district area (table 3). Lianganggang are located in elevation...
under 25 meters, more than half of the area is peat land, and the majority of landuse are rice field, swamp shrub, and dry agriculture. In Landasanulin district the area of each level of susceptibility are shown in table 3, where the high susceptible area is dominate in Lianganggang. In Lianganggang has similar landuse with Lianganggang and more than half area is under 25 meters and also have peatland in the north area which make the north area is very high susceptible and also located in southwest. While, Cempaka, Banjarbaru Utara and Banjarbaru Selatan are dominating with low susceptible.

4.5 Point of Interest in Banjarbaru City

![Point of Interest in Banjarbaru](image)

Figure 7. Point of Interest in Banjarbaru

As a government area, Banjarbaru city has several important Point of Interest such as Airport, Goverment buildings, University, and markets. For that reason, Banjarbaru is prioritize to restoration programs. The result show that important point such as university and airport are located in high susceptible area. Meanwhile, markets and goverment area are in moderate and low susceptible area.

4.6 Hotspot Distribution in Banjarbaru City
In the context of forest fires, GIS has been used to make efforts to predict forest fires by estimating flammable areas through fires-susceptible maps combined with the distribution of hotspots. Hotspot data is obtained from NOAA satellites. With the distribution of hotspots, it will strengthen the results of mapping susceptibility of fires areas in addition to the influence of the 3 previous physical factors, namely the type of land, height and land use. Hotspot points are abundant on peat soils and on bush land use, dry land farming and fields so that it has high potential to become a hotspot for fires.

The distribution of hotspot in 2017 in Banjarbaru city mostly located in South Lianganggang and Landasanulin district. The highest amount of hotspot is in high susceptible area. It has 36 hotspot. The second one is in moderate area in Landasanulin district has about 18 hotspot. Hotspot trigger the forest and land fire, but from the field study, the society said the human activity also cause the forest and land fire, such as improper burning of land and throwing cigarette butts carelessly which can also trigger the forest and land fire. The very high area has only 2 hotspot but the area is located in swamp shrub, peatland and the elevation is under 25 meters. Then, the result show that the location is very high susceptible eventhough there is only 2 hotspot.

Table 4. Hotspots distribution in Banjarbaru City in each level of susceptibility

| Susceptibility Level | Amount of Hotspot |
|----------------------|-------------------|
| Not Susceptible      | 0                 |
| Low                  | 3                 |
| Moderate             | 18                |
| High                 | 36                |
| Very High            | 2                 |
After knowing hotspot distribution that can trigger to forest and land fires, we must take action quickly when a fire suddenly appears. Based on the results of the field survey, residents living in the area admitted that fires occur frequently each year. So that they are equipped with individual water machines at each house to take quick action in handling fires that can suddenly appear around their homes. Given that the area is peat and dry land farming. They said that during the dry season the area was very susceptible to fires, even fires could appear suddenly from the middle of fields or bushes and grazed until they grew bigger. To handle this, the water machine is used to prevent the fires from getting bigger while waiting for the fires extinguisher to help from the helicopter sent by the BNPB of Banjarbaru city.

4.7 Mitigation in Banjarbaru City

Forest and land fires mapping can be used as a reference to determine disaster mitigation measures to minimize the impact of the disaster. From the results of field observations and surveys, forest fires disaster mitigation carried out is as follows:

4.7.1 Making Channels

Figure 8a and 8b. Channels for mitigation

Banjarbaru City is a priority for peatland restoration programs in South Kalimantan because airports are in the city so that they are severely affected by fires on peatlands. The peat restoration program that has been implemented anticipates forest and land fires in Banjarbaru, one of which is the construction of canals around the peat area. The canalization system to prevent the area from burning and also serves as a water source that can be used to water hotspots in the surrounding area.

4.7.2 Drilling Wells

Another forest fires disaster mitigation program is the construction of boreholes. Drilling wells are made up of 50 bore wells in Banjarbaru City. Drilling wells will be very useful during the dry season because the area of peatland will experience drought and flammability, wetting can be through water sources (Head of Peat Restoration Agency, Nazir Foead in Banjarbaru, 2017).
5. Conclusion

From the research, GIS helps to mapping the susceptible area of forest and land fires in Banjarbaru City. As a result, banjarbaru Selatan is susceptible enough of forest and land fires disaster, especially in the west of Banjarbaru city. The distribution of hotspot drive to the forest and land fires. The susceptible area of forest and land fires is useful to assist in monitoring and determining priority areas in fires disaster mitigation by making canals and drilling wells. It also helps to show the center of human activity places in each level of susceptibility. So, it useful to improve the level of local people awareness to not do something at risk of causing fires.

6. References

[1] Akbar, Acep dan Faidil, Sukhyar. 2007. Kebakaran Hutan dan Lahan Rawa Gambut: Penyebab Faktor Pendukung Dan Alternatif Pengelolaannya. *Balai Penelitian Kehutanan Banjarbaru*.

[2] Latifah, R. Pamungkas, A. 2013. Identifikasi Faktor-Faktor Kerentanan Terhadap Bencana Kebakaran Hutan dan Lahan di Kecamatan Liang Anggang Kota Banjarbaru. *Jurnal Teknik Pomits Vol. 2, No. 2, (2013)*

[3] Nugroho, Dudy dkk. 2015. Modul Pemutakhiran Peta Rawan Kebakaran Hutan dan Lahan di Provinsi Sumatera Selatan Tahun 2015. *Biodiversity and Climate Change Project (BIOCLIME)*.

[4] Rizal, Yose. 2017. Banjarbaru Jadi Prioritas Restorasi Gambut. Kalsel Antaranews (accessed from https://kalsel.antaranews.com/berita/43891/banjarbaru-jadi-prioritas-restorasi-gambut accessed on March 28th 2018)

[5] Solichin, L. Tarigan, P. Kimman, B. Firman, dan R. Bagyono. 2007. *Pemetaan Daerah Rawan Kebakaran*.

[6] Syaraffudin. 2017. *Berkah dan Bencana Lahan Gambut Banjarbaru*. Kalsel: ProKalsel. (http://kalsel.prokal.co/read/news/12048-berkah-dan-bencanalalahangambutbanjarbaru.html accessed on February 15th 2018).

[7] Syaufina L. 2008. Kebakaran Hutan dan Lahan di Indonesia: Perilaku Api, Penyebab, dan Dampak Kebakaran. Malang: Bayu Media.

[8] Humas dan Protokol Banjarbaru. 2018. Geografis. https://www.humas.banjarbarukota.go.id/tentang-banjarbaru/geografis/ accessed on November 29th 2018.

Acknowledgments

The paper helped by our lecturer. We also thank to government people, because of the informations that they gave help us to make the paper done. The society is also so friendly to give information for us. We hope the paper will usefull for them.