Typology of land and forest fire in South Sumatra, Indonesia Based on Assessment of MODIS Data

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Abstract. In 2015, Sumatera and Kalimantan, in particular, has undergone dramatic fires. The fires were particularly bad in 2015 because of a prolonged dry season caused by the El Nino weather pattern and creating a lot of greenhouse gas emissions. Between about July and December, more than a million hectares of forest were burned. South Sumatra is one of the provinces with the highest of hotspots number and of fire area on this period. The aim of the study was to find burned area that caused by fire activity in 2015 and to identify a typology of land and forest fire the South Sumatera. In our study showed that between July and December 2015 the estimated burned area during El Nino in South Sumatra was 422,718 ha, of which 163,143 ha in mineral soil and 260,575 ha in peat soil. The majority of burned area occurred outside concession and inside concession with following typology: the fire activity in the HTI on non-forested land (26%), in the HTI on forested land (24%), in oil palm on non-forested land (17%), and in oil palm on forested land (2%).

1. Introduction
Land and forest fires have become an increasing problem in Indonesia in the past decades and occurred almost every year with varying intensity and burned area. These fires have many adverse environmental, social and economic effects. They affect global carbon dynamics and the haze from peat fires in this region has serious negative impacts on the ecosystem, economy and human health. The intensity of land and forest fires tends to rise in El Niño years. In 1997–98, fires associated with an exceptional drought caused by El Niño/Southern Oscillation (ENSO) devastated large areas of Indonesian tropical rain forests [1]. Indeed, several authors have reported strong correlations between large scale fire activity in Indonesia and El Niño, in particular for fire episodes in 1982–83, 1997–1998, 2002 and 2006 [1-4]. The last drought in 2015 associated with ENSO creating conditions that affected extensive fires in Indonesia’s tropical forests and peatland. The fire last year was one of the worst after the 1997-1998 event, where between June and October 2015, an estimated 2.6 million hectares burned [5]. These fires were equivalent to four times the island of Bali [6].

In 2015, Sumatera and Kalimantan have undergone the most extensive fires. The fires were particularly bad in 2015 because of a prolonged dry season caused by the El Nino weather pattern and creating a lot of greenhouse gas emissions. According to Ministry of Environment and Forestry,
Indonesian National Institute of Aeronautics and Space, Global Fire Emission Database, and former REDD+ Agency, which have been using different types of data source of fires activity and different technique, the estimated emissions from land and forest fires Indonesia ranged from 0.8 to 1.9 Gt CO2-e [7]. The Indonesian Government estimated that between February and October, fires affected more than 2.6 million hectares [5,7], which spread-out all over Indonesia with mostly concentrated in the two provinces: South Sumatra and Central Kalimantan, where peatlands may have accounted for more than 600 thousand hectares [7]. The South Sumatra is one of the provinces with the highest of burned area on this period.

The aim of the study was to map burned area that caused by fire activity in 2015 and to identify a typology of land and forest fire the South Sumatera. The results of this study are expected to evaluate the characteristics of fires that occur in South Sumatra Province and eventually to be used for fire prevention and mitigation.

2. Material and Method

2.1. Study Area

The study was conducted in the South Sumatra Province (Figure 1) by observation fire activity from July to December 2015. The Ministry of Environment and Forestry estimated that during drought session of July and October 2015, Sumatra Selatan was one of provinces with the most extensive forest and land fire, in addition to Central Kalimantan, of which the fires mostly may have occurred in mineral soil [7]. Administratively, South Sumatra Province consists of 13 Districts and 14 Municipal Government, with Palembang as its capital. The District of OganKomeringIlim is the largest area and followed by Musi Banyuasin. Rubber and Oil palm is the main commodity of agriculture sector, while forest plantation estate in forestry sectors [8].

![Figure 1. Map of study area](image-url)
2.2. Data
Data on fire activity was derived from Moderate Resolution Imaging Spectroradiometer (MODIS) covering the period July – December 2015. To understand the typology of fire in South Sumatera, we studied the relationship between burned area and several biophysical data. These were concession map (2011), forest area map (2010) and land cover map (2015) produced by Ministry of Forestry as well as peat soil map sourced from Ministry of Agriculture (2014).

2.3. Method
Fire activity on the ground was not collected due to the large surface areas to be surveyed. Identification of fire activity relies only from satellite data. Using satellite data of MODIS (Terra and Aqua), the identification of fire activity was performed by using hotspot detection and detection of burnt area.

Hotspots detected by both MODIS (Terra and Aqua) sensors were used to identify fire activity. For the purpose of this study, the hotspot number for South Sumatra was computed for each month between July and December 2015. A simple method developed by REDD+ Agency was used to identify fire activity. The burned area was estimated using MODIS hotspot data with confidence level $\geq 80\%$, which overlaid with a $1 \times 1$ km grid map. Grids without hotspots were considered as areas that were not burned and excluded in the estimation of burned area. Each grid pixel with at least one hotspot is considered to be burned with the burned area of 75 ha (75% of the grid area). This rule applies for each grid regardless of the number of the hotspots within a particular grid [9].

Since the burned area have different thematic areas and therefore different typology of fire, we also computed the typology of fire identified in South Sumatra province by overlaying the estimated burned area by the concession map, forest area map, land cover map, and peat soil map.

3. Results and Discussions
The temporal analysis of the hotspot number detected in South Sumatra province (Figure 2) shows interesting features: the fire activity season occurred in 2015 with peaks between June and December and there was fire activity in rainy season namely in February. The fires activity was particularly worst from September through November 2015 because of a prolonged dry season caused by the El Nino weather pattern. The highest hotspot number occurred in September, while the lowest hotspot number in December. The decreasing of fire activity in South Sumatra after November 2015 may due to success of firefighting by the government, private and community as well as a lot of rain fell in some area [6, 10].

![Number of hotspots detected in South Sumatra in 2015](image-url)

**Figure 2.** Number of hotspots detected in South Sumatra in 2015
Between July and December 2015, an estimated 422,718 ha burned, where 163,143 ha occurred in mineral soil and 260,575 in peat soil. The peatland area covers 14% of total area and mostly located in eastern part of South Sumatra. The rainfall influences the moisture content of the peat soil. Along with increasing rainfall, peatlands store large amount of water so that the peat water content increases and it is difficult to burn. When the rainfall decreases, the peat moisture content is to be on the wane and peat is to be dry. In the seasons with lower rainfall, water level drops to a critical threshold that causes the peat is highly flammable [11]. The dry peat with very low moisture in the last extreme drought season will become a fuel that is very combustible. This is also confirmed by [12] that the dried peat soil cannot absorb any water when it was watered and it is inflammable.

Spatially, the fire activity is occurred and correlated in a certain land cover and land use since land cover and land use changes are driven by fire. However changes in land cover and land use will ultimately have an impact on fire regimes through changes in the ignition frequency, fuel load, and land management. The overall impact of land cover land use change on fires often is specific to location, ecosystems, land use, and climate that underlie a particular place [13]. Based on land cover, the fire activity is mostly occurred in forested land (36%), grassland (36%), cropland (18%), and other land (10%) as depicted in Table 1. The grassland is a result of land use changes from one dominant vegetation type to grassland, and it may change the ignition or land management. The study result in South Sumatra showed that the grassland burn more frequently than active cropland. The grassland is an area that is prone to burning because it provides abundant fuel and flammable. Likewise the grassland fire may larger than other in agricultural lands, since the fire still used as mechanism for opening area suitable for agriculture [13-15].

| Land Use Category | Area (ha) | Percentage (%) |
|-------------------|-----------|----------------|
| Forestland        | 152,221   | 36             |
| Cropland          | 77,858    | 18             |
| Grassland         | 165,232   | 36             |
| Otherland         | 27,407    | 10             |
| Total area burnt  | 422,718   | 100            |

Area burnt by land use type during drought session in 2015 is presented in Table 2. More than 165 thousand hectares of grassland and 152 thousand of forestland in this period was burnt due to fire exposure (Figure 3). The area burnt of forest plantation was larger than other forest cover, followed by secondary swamp forest as the second largest area burnt, where the fire in peatlands may be larger than in mineral soil.

Data analysis by overlapping burned area with licensed/ land concession reveals the burned area occurred in palm oil plantation (19%) was less than in industrial forest plantation (50%) as presented in Figure 4. In addition, there was burned area occurred outside the licensed/ concession (31%). Based on licensed/ land concession, fires in the HTI (forest plantation) occurred in non-forested land was 26% and inlands that are still covered by forest (forested land) 24%, while fires in the oil palm occurred in non-forested land was 17%, and in forested land 2%. This data indicated that some of licensed and concession for the palm oil plantation and the HTI was not yet planted. Fires in this region may be suspected since some the community/farmers or companies open the land for cropland using slash and burn technique that is still widely used in the study area.
Table 2. Area burnt by land use category during the 2015 drought session

| Land use category | Land use type         | Area (ha) | Percentage (%) |
|-------------------|-----------------------|-----------|----------------|
| Grassland         | Grass                 | 13,079    | 3.09%          |
|                   | Shrub                 | 41,098    | 9.72%          |
|                   | Swamp Shrub           | 111,055   | 26.27%         |
| Otherland         | Bare land             | 26,820    | 6.34%          |
|                   | Mining                | 587       | 0.14%          |
| Foresland         | Primary dryland forest| 10,958    | 2.59%          |
|                   | Secondary dryland forest| 4,979    | 1.18%          |
|                   | Primary mangrove forest| 317       | 0.07%          |
|                   | Secondary mangrove forest| 267       | 0.06%          |
|                   | Secondary swamp forest| 24,856    | 5.88%          |
|                   | Forest plantation     | 110,844   | 26.22%         |
| Cropland          | Plantation            | 22,976    | 5.44%          |
|                   | Dryland agriculture   | 14,906    | 3.53%          |
|                   | Mix dryland agriculture| 37,801    | 8.94%          |
|                   | Paddy field           | 2,141     | 0.51%          |
|                   | Transmigration        | 34        | 0.01%          |
|                   |                       | 422,718   | 100.00%        |

Figure 3. Distribution of estimated area burnt by land cover type of South Sumatera
4. Conclusion
In our study showed that between July and December 2015 the estimated burned area during El Nino in South Sumatra was 422,718 ha, of which 163,143 ha in mineral soil and 260,575 ha in peat soil. The grassland fire was larger than other land use category as the grassland is prone to burning because of abundant fuel and flammable.

The majority of burned area occurred outside licensed/concession (31%) and followed in concession with following typology: the fire activity in the HTI on non-forested land (26%), in the HTI on forested land (24%), in oil palm on non-forested land (17%), and in oil palm on forested land (2%).

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