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# Climate Changes Projection for Land and Forest Fire Risk Assessment in West Kalimantan

S D Jadmiko<sup>1\*</sup>, D Murdiyarso<sup>2,3</sup> and A Faqih<sup>1,3</sup>

<sup>1</sup> Center for Climate Risk and Opportunity Management in Southeast Asia and Pacific (CCROM-SEAP), Bogor Agricultural University, Bogor-Indonesia.

<sup>2</sup> Center for International Forestry Research (CIFOR), Bogor-Indonesia.

<sup>3</sup> Department of Geophysics and Meteorology, Bogor Agricultural University, Bogor-Indonesia.

E-mail: [djsyamsoe@gmail.com](mailto:djsyamsoe@gmail.com)

**Abstract.** Risk analysis is a method used to determine the probability of disaster in the current and future. This research analyse of fire risk in West Kalimantan by using extreme climate and vulnerability analysis. Extreme climate was calculated based on the extreme dry rainfall from regional climate model RegCM4.4 outputs. Vulnerability analysis was conducted by using a composite mapping analysis used hotspot data and eleven indicators of vulnerability. We found that very high level of extreme dry rainfall located in the southern region and the western coast area of West Kalimantan. This condition was influenced by environment factors such as topography and land use. Extreme dry rainfall also associated with the pattern of annual rainfall in West Kalimantan which ranges between 1753-4861 mm. Modelling of the vulnerability of land and forest fires in West Kalimantan showed that the land use has impact 24% on the vulnerability model. The results of the vulnerability model analysis shows that the plantations areas and secondary swamp forests are highly vulnerable, particularly on the peat area with depth about 50-200 cm. The analysis of land and forest fires risk found that the vulnerable areas have high risk which is largely unmanaged plantation areas and peatlands.

## 1. Introduction

Forest and land fires have become the annual disaster phenomena in Indonesia, especially in Sumatra and Kalimantan. In the last two decades, the massive event of land and forest fires occurred during the El-Niño year at 1982/83, 1987, 1991, 1994 and 1997/98 [1]. El-Niño affects the drought and this condition cause the flammable areas [2-3]. The fires of 1997/1998 had become the largest land and forest fire event in Indonesia and caused large losses [4]. The main impact of forest and land fires is the haze, which is not only impacted of human health, but also socio-economic activities. Forest and land fire also caused land degradation and changes of forest function [5]

Forest and land fire is influenced by climates, fuels, ignition agents and human activities [6]. However, climates and human activities have become the dominant factor in Indonesia [5]. Climate (especially rainfall) will be affected the land drought. Strongly drought relates to fires event in Indonesia. For example, forest and land fire in 1997/1998 in Indonesia caused drought due to El-Niño events [7].

Climate change has impacts on rainfall changes which is can be changes the pattern of future droughts and the fires risk. Risk is a tools to assess the probability impact of disaster likes fires [8]. The level of risk can be determined by a probability of disaster (e.g. extremes climate) and that impact.



The impact caused by a disaster is determined by the level of vulnerability. Therefore, the risk can be calculated based on the relationship between probabilities of the hazard event and the level of vulnerability (risk = hazard x vulnerability) [9]. The concept of risk is widely used to assess in the current condition and the future due to climate changes. Understanding of fires risk would be minimize the potential impact of land and forest fires.

The objective of this research is to analyse the forest and land fires risk in West Kalimantan Province by using extreme climate and vulnerability analysis. Extreme climate was calculated based on the extreme dry rainfall with threshold value using 5<sup>th</sup> and 10<sup>th</sup> percentile. The extreme climate analysis, historical climate data information and projections were obtained through dynamical downscaling by using regional climate model RegCM4.4. Vulnerability analysis was conducted by using a composite mapping analysis used hotspot data and eleven indicators of vulnerability.

## 2. Fire Risk Analysis

Assessment of fire risk based on a matrix of risk that combines vulnerability analysis and the extreme dry rainfall (Table 1).

**Table 1.** Matrix of Fire Risk with five level (Very Low; VL, Low; L, Medium; M, High; H, Very High; VH). Category of monthly extreme dry rainfall: (1) 0-40 mm, (2) 41-80 mm, (3) 81-120 mm, (4) 121-160 mm dan (5) 161-200 mm.

| Vulnerability<br>Level | Category of Extreme Dry Rainfall |    |   |    |    |
|------------------------|----------------------------------|----|---|----|----|
|                        | 5                                | 4  | 3 | 2  | 1  |
| VL                     | VL                               | VL | L | L  | M  |
| L                      | VL                               | L  | L | M  | H  |
| M                      | L                                | L  | M | H  | H  |
| H                      | L                                | M  | H | H  | VH |
| VH                     | M                                | H  | H | VH | VH |

The vulnerability level could be calculated based on statistical approach of scores and weights of vulnerability indicators. We used the composite mapping analysis (CMA) to calculate of scores and weight of the level of vulnerability. This method was widely used in spatial analysis, not only in determining fires vulnerability but also can be used in other spatial vulnerability [10-11]. Scores for each indicator was calculated by using formula:

$$X_i = \left[ \frac{O_i}{E_i} \right] \times \frac{100}{\sum_{i=1}^n \frac{O_i}{E_i}} \quad (1)$$

$$E_i = \left[ \frac{T \times F}{100} \right] \quad (2)$$

With the Xi as Actual score for each indicator, Oi as number of hotspots at each classes of indicator (observed hotspot), Ei as expected hotspot for each indicator, T as total of number of hotspot for each indicator, F as percentage of areas (Ha) for each classes of indicator and i as classes of indicator. The rescaling scores was created with scale about 10-100 following the formula:

$$Score R_{out} = \left[ \left( \frac{Score E_{input} - Score E_{min}}{Score E_{max} - Score E_{min}} \right) \times (Score R_{max} - Score R_{min}) \right] + Score R_{min} \quad (3)$$

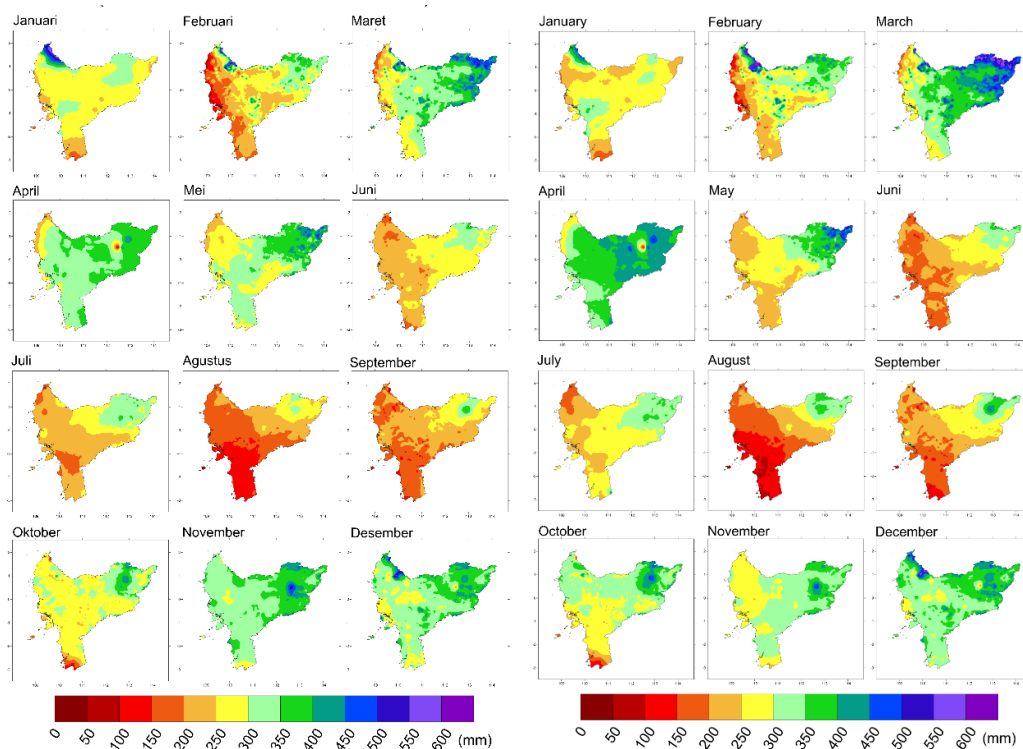
With the Score  $R_{out}$  as rescaling score, Score  $E_{input}$  as estimate score input, Score  $E_{min}$  as minimum estimated scores, Score  $E_{max}$  as maximum estimated scores, Score  $R_{max}$  as maximum of rescaling scores (100) and Score  $R_{min}$  as minimum of rescaling scores (10). The level of vulnerability used in this analysis included 5 levels (very low, low, medium, high and very high).

Analysis of extreme climate is more emphasized on rainfall due to its significant impacts on drought condition. There are several ways to define the climate extremes. Chu et al. [12] suggested three common approaches in defining extreme based on, i.e. i) actual rainfall values, ii) data probability distributions exceeding 95<sup>th</sup> or 99<sup>th</sup> percentile and less than 10<sup>th</sup> or 5<sup>th</sup> percentile, and iii) return periods of maximum annual rainfall. In this study, we used the probability analysis for analyzing the extreme dry rainfall with threshold 10<sup>th</sup> and 5<sup>th</sup> percentile. Extreme dry rainfall calculated for dry season at June-July-August (JJA).

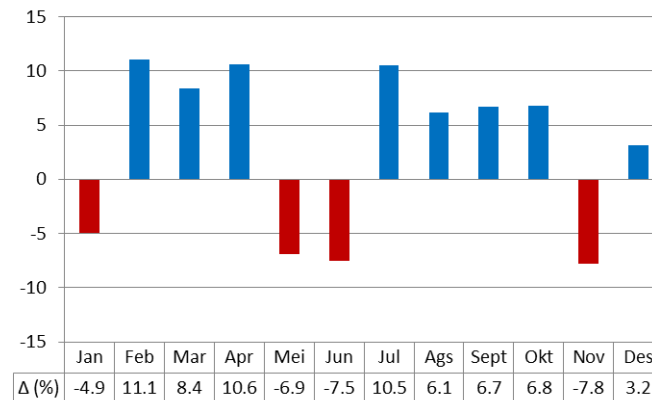
The climate data for calculated the extreme dry rainfall generated by the dynamical downscaling analysis using model RegCM4.4. Simulations of RegCM4.4 conducted to obtain the climate information with high resolution. The outputs of simulations validated by using observations data in West Kalimantan. Simulation model RegCM4.4 intended to projection of climate in the future based on RCP-4.5 climate scenarios [13]. Projections of climate made for the 2016-2040 with the baseline year at the 1981-2005.

### 3. Result

West Kalimantan has equatorial pattern of rainfall with two peaks of rainfall in April and October. The high rainfall in occurred in the eastern part e.g. at Lake Sentarum National Park, while in the western part generally have lower rainfall. The pattern of projected rainfall distribution generally does not significantly changes compared to the baseline period (Figure 1).

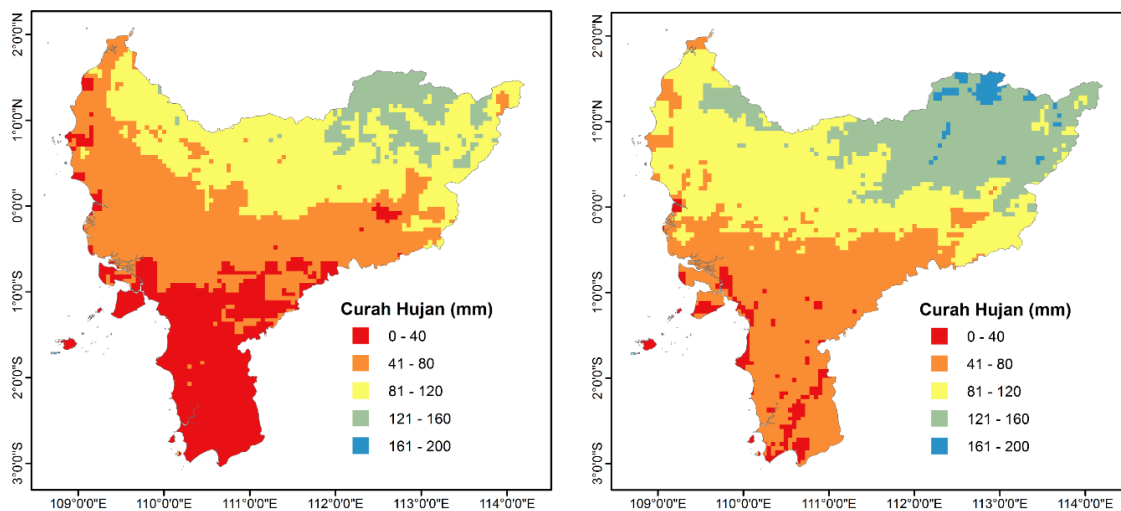


**Figure 1.** Comparison of spatial pattern of monthly rainfall for baseline (left) and projection (right).



**Figure 2.** Projected monthly rainfall changes (%) at 2016-2040 relative to 981-2005 for West Kalimantan.

The results of the rainfall changes analysis indicate decreased in January, May, June and November and increased in other months. The highest decrease rainfall occurs in November, which reached 7.8% compared with the baseline period, while the highest increase occurred in February, which reached 11.1% (Figure 2). Based on the pattern of these changes, the changes of rainfall (both increases and decreases) can occur in wet or dry season. The condition is certainly interesting to see how the impact of this change on extreme climate in the future.



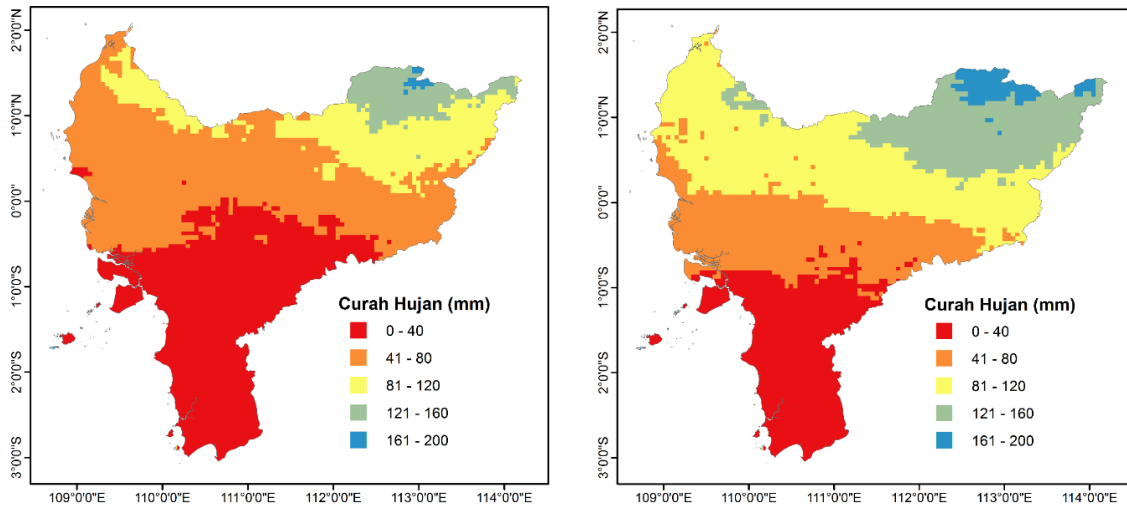
**Figure 3.** Pattern of baseline extreme dry rainfall at June-July-August (JJA) based on threshold by 5<sup>th</sup> percentile (left) and 10<sup>th</sup> percentile (right). The very extreme dry conditions generally occur in the southern part of West Kalimantan.

Analysis of extreme dry rainfall shows that areas of dry conditions due to low rainfall in the baseline period occurred in southern and western parts. Northern area has a lower levels of dry extreme rainfall than in other regions. The dry season (JJA) rainfall at the northern part generally above 100 mm. The pattern of extreme dry condition above happen to the threshold with 5<sup>th</sup> and 10<sup>th</sup> percentile (Figure 3).

Projected of extreme dry rainfall projection shows that an increase in the area of extreme drought. With the 5<sup>th</sup> percentile, the very extreme dry rainfall areas becomes more widespread until the middle part of West Kalimantan. Similarly, in the 10<sup>th</sup> percentile value where most of the southern part of

West Kalimantan become too extreme dry in June-July-August (JJA). The increase in the global area dry extreme potential to cause an increased risk of forest fires and land in the future. The pattern of projected extreme dry rainfall shows changes of future rainfall in dry season period at June-July-August (JJA).

The pattern of extreme dry rainfall as above when linked with land-use, areas of natural forest has lower level extreme dry rainfall than other region with agricultural area, plantation areas and peat areas which is located along the western coastline from southern part to middle areas of West Kalimantan.



**Figure 4.** Pattern of projected extreme dry rainfall at June-July-August (JJA) based on threshold by 5<sup>th</sup> percentile (left) and 10<sup>th</sup> percentile (right). The very extreme dry conditions generally occur in the southern part of West Kalimantan.

Modelling of the vulnerability shows the land use has impact 24% on the vulnerability model. Plantation areas and scrub swamp areas are the region of frequent forest and land fires. However, based on eleven indicators, biophysical factors (as deep of the peat, land cover and land systems indicator) provides 49.85% compared to the 16% of the effect of human activity factor (the distance from the road, distance from the river and the distance from the center of the village / town) and a socio-economic factor (population density, the GDP, HTI, HGU and HPH) amounted to 34 %. The results of the vulnerability model analysis shows that plantations areas and secondary swamp forests are highly vulnerable, particularly on the peat area with depth about 50-200 cm. The equation for vulnerability model of forest and land fire shows at Equation 4.

$$VM = 0.0758 PEA + 0.2409 LUS + 0.0193 STR + 0.0116 RVR + 0.1291 VLG + 0.1818 LSY + 0.0481 HTI + 0.1291 HGU + 0.0873 HPH + 0.0297 POP + 0.0474 PDRB \quad (4)$$

- VM = Vulnerability model for land and forest fire in West Kalimantan
- PEA = Peat depth
- LUS = Land-use
- STR = Distance from street
- RVR = Distance from river
- VLG = Distance from village
- LSY = Land system
- HTI = Percentage of area of HTI (Hutan Tanaman Industri/Industrial forest)
- HGU = Percentage of area of HGU (Hak Guna Usaha)
- HPH = Percentage of area of HPH (Hak Pengusahaan Hutan)

POP = Population density

PDRB = Produk Domestik Regional Bruto (Gross Regional Domestic Bruto)

Spatial planning needs to consider the condition of land use in view of the condition that affects the vulnerability of land and forest fires. Changes in land-use will affect the vulnerability of forest and land fires. If the type of land-use changes with the area which has a strong correlation with the presence of hotspots, then most likely will increase the level of vulnerability. Conversely, when the land-use be returned in their original function, the vulnerability of land and forest fires will likely decrease.

Figure 5 shows the pattern of vulnerability map of forest and land fires for West Kalimantan. Most areas of West Kalimantan has a low level of vulnerable which is about 43% of the total area, while the regions with high and very high level of vulnerable approximately 13% of the area of West Kalimantan. Areas with high level of vulnerability occurs in the western region as Kubu Raya and Mempawah district as well as the southern part at the Ketapang district.

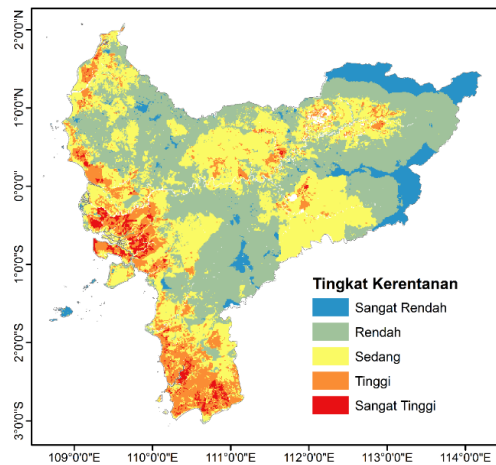


Figure 5. Vulnerability map for fire in West Kalimantan.

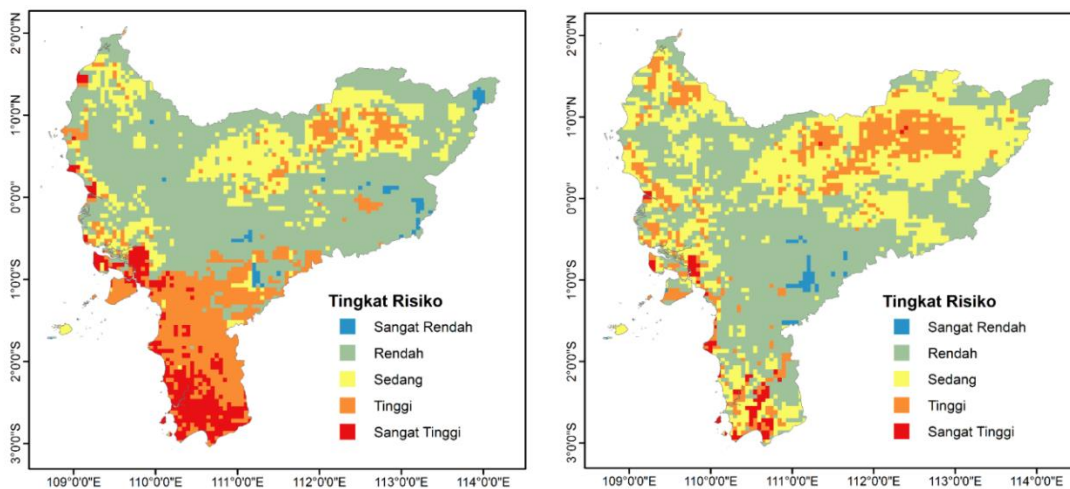
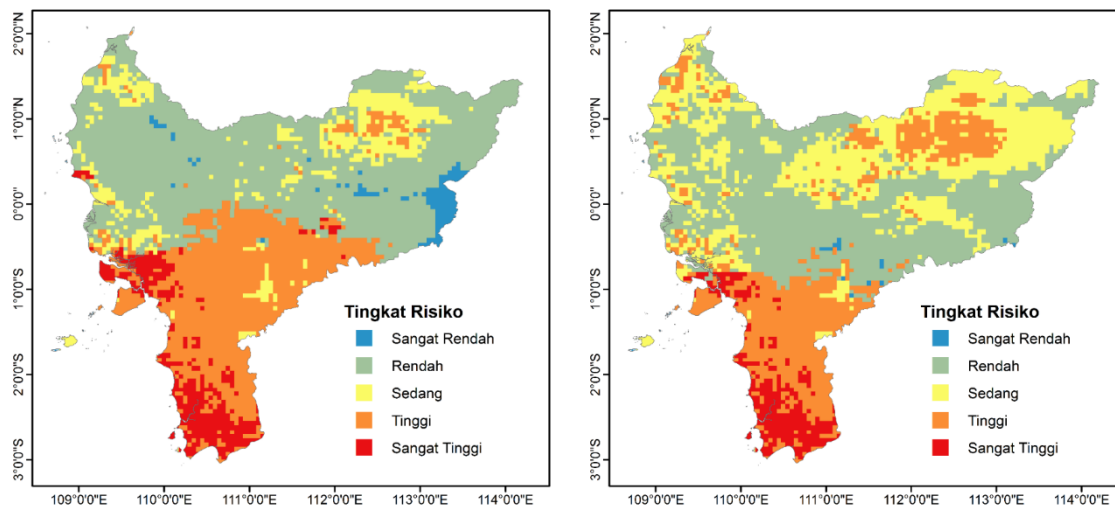


Figure 6. Pattern of baseline fire risk based on threshold by 5<sup>th</sup> percentile (left) and 10<sup>th</sup> percentile (right). The areas with very high level of risk generally occur in the southern part of West Kalimantan.



**Figure 7.** Pattern of projected of fire risk based on threshold by 5<sup>th</sup> percentile (left) and 10<sup>th</sup> percentile (right). The areas with very high level of risk generally occur in the southern part of West Kalimantan.

The very high level of fires risk occur in the southern part and the western part of West Kalimantan with land-use as peat areas and shrub swamps. In an area of natural forest, the level of fires risk has low level. The extreme dry rainfall value by 5<sup>th</sup> percentile indicates a higher risk than the 10<sup>th</sup> percentile. Projected of fires risk showed an increased risk in the southern part of West Kalimantan and decreased of fires risk in the northern part and eastern part. With 5<sup>th</sup> percentile a decrease in the fires risk in the northern region, while with 10<sup>th</sup> percentile can be clearly seen that the southern part has increased of fires risk in the future (Figure 7).

The very high level of fires risk generally located at secondary swamp forest land and shrub swamp in the southern part of West Kalimantan. These region also the location of peatlands, which has a depth about 50-200 cm. Areas with high level of vulnerability generally located on plantation areas and peat swamp forests rounded the Danau Sentarum National Park (DSNP). Normally, the DSNP region is a protected national park. However, there is a tendency in the communities around these location will conduct fishing activities during the dry season. These activities allegedly affect the fires risk where they will do the expansion of fishing regions in a way that could be caused forest and land fires [14].

#### 4. Conclusion

The rainfall pattern in West Kalimantan is equatorial pattern with high rainfall locate in the northern and eastern part, while low rainfall in the southern and western part. Projected rainfall in 2016-2040 relative to the 1981-2005 indicate that an increase rainfall in the rainy season and decrease during the dry season. Projected of the extreme dry rainfall will increased and over most of West Kalimantan areas.

Vulnerability models of fire showed that some indicators such as land cover, distance from the center of government / village and land systems have a strong influence at the number of hotspot. Areas with the peat and agricultural areas has a propensity of a higher level of vulnerability compared to other land-use. Areas with high and very high level of vulnerability generally located on the southern and western parts of West Kalimantan province, while the level of vulnerability of low and very low generally in northern and eastern part.

The risk of forest and land fires for baseline condition have the same pattern with the patterns of vulnerability. In the projection period, the risk of forest and land fires increased with the wider region. The trend of decreased rainfall during the dry season in the future will contributed to the increased of risk level of forest and land fires.



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