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Modeling of Forest and Land Fires Vulnerability Level in North Sumatera Province, Indonesia

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Abstract

The assessment of vulnerability level can help the policy makers to develop strategy and actions for managing fire risk and also to develop spatial plan that can lowering the fire risk. The purposes of this research were to determine the variables that affect the level of vulnerability of forest and land fires, to determine the level of fire vulnerability of spatial models and to determine the areal distribution of forest and land fires in North Sumatera Province. Composite Mapping Analysis was used to develop spatial model of forest and land fires vulnerability level. The study found that the most important role factors of forest and land fires vulnerability model is land cover which have almost 38% of weight from nine variables. The study also found that shrubs and grassland are land cover type that almost became the initial source of fire in North Sumatera Province. Padang Lawas District and Labuhan Batu Selatan District have the most extent area of very high vulnerability level. This study provided suggestions to North Sumatera Province stakeholders to enhance intentions to improve land productivity, to improve land rehabilitation and to extent land clearing without burning.

Keywords: Composite mapping analysis; Forest and land fires; North Sumatera Province Indonesia; Vulnerability level

Introduction

Forest and land fires occur almost every year in Indonesia and its impact is detrimental to human life and the environment. Over the years 1997/1998, when El Nino hit areas of Indonesia, forest and land fires emissions have contributed the equivalent of 13-40% of global carbon emissions (Page *et al.,* 2002). Social and economic activities were disrupted by the haze generated from forest and land fires (Harrison *et al.,* 2009, Langner and Siegert 2009). In fact, according to the study by Tacconi (2007), forest and land fires in 1997/1998 has resulted from the haze across the country, respiratory illnesses of millions of people and economic losses of trillions rupiah. In 2015, the big forest and land fires reoccurred that burned 2.7 million hectares with economic losses reaching 221 trillion (Kompas.com, 2015).

The strategic effort that is very important in the control of forest and land fires is prevention. Prevention, fire suppression and post-fire action are aspects that will support the success of forest and land fire control. One of the attempts to do fire prevention is through early warning systems. The early warning system is a term commonly used in disaster risk management. According to UNISDR (2009), the early warning system is a series of capacity required to produce and disseminate warning information that is meaningful in time to allow those individuals, communities and organizations threatened danger to prepare and take the appropriate action and within a reasonable time to reduce the possibility of damage or loss. One of the instruments of early warning systems in forest and land fires control is by using a map of the vulnerability of land and forest fires. In the map the vulnerability of forest and land fires, there is important information about the extent and magnitude of the regions corresponding risks assessment. A fire vulnerability map is also a tool that can help monitoring the condition of the area and community activities in vulnerable areas. Determination of a fire-prone area is very important for the implementation of more precise early warning systems. In addition, map the vulnerability of forest and land fires could be used as an instrument to predict the key factors that caused the fire in the particular area.

Determination of the area of forest and land fires is also the policy of the government to control forest and land fires. The policy related to forest and land fires which is on Forestry Minister (Minister) No. 12 The year 2009 on Forest Fire Control. Regulation No. 12 2009 was elaborated on the scope of control of forest fires include prevention, extinction and post-fire program. The vulnerability of forest and fires can be made using modeling of the relationship between forest and land fires with the factors that influence it. Due to these factors largely referenced spatial, then the model can be approached and developed in a geographic information system.The related research for determination of the level of vulnerability to fire spatially also demonstrated by several studies. Soewarso (2003), which made the prediction model of prevention of peat fires in South Sumatra found that the distance from the river and agriculture land played a significant role in the level of vulnerability to peat fires. Likewise, studies Jaya *et al.* (2008) who found that the factor of human activities such as roads, rivers and settlements are dominant factors in deciding the fire vulnerability level.

Forest and land fires in the province of North Sumatra is currently quite got attention in local, national or international. In 2016, forest and land fires in North Sumatra have damaged land and forest area of more than 5000 hectares. The purpose of this research is to determine the variables influencing the level of vulnerability to forest and land fires, determining the spatial model vulnerability of forest and land fires and determining the areal distribution of forest and land fires in the North Sumatera Province.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted in North Sumatera Province. The study was conducted over six months in June - November 2016. The field survey to verify the vulnerability maps of fire and to conduct interviews with people were located in some districts namely Simalungun, Karo, Toba Samosir, Humbang Hasundutan, Asahan, Tanjung Balai, North Labuhan Batu and North Padang Lawas District.

2.2 Data collection

The data that were used in this study was a map of hotspots in 2002, 2006, 2009 and 2015 from the MODIS (Moderate-resolution Imaging Spectroradiometer) as well as several other spatial data, namely administrative map, land cover map, land system map, road network map, river network map, location of the village map, population density map, peat depth map, forest and oil palm plantation concession company map. Field data collection tools included GPS, camera and voice recorder. Data analysis tools that was used were Minitab, Excel and ArcGIS, 10.x

Hotspot data sourced from satellite Terra/ Aqua MODIS sensor (Moderate-resolution Imaging Spectroradiometer) from 2002 to 2015 was obtained from the Fire Information for Resource Management System (FIRMS), which can be accessed for free at the link https://earthdata.nasa.gov/data /near-real-time-data/firms/active-fire-data. To determine survey sites for field verification based on inputs from Manggala Agni Natural Resources Conservation Agency of North Sumatra and the results of analysis of the hotspots density. Field verification was done by collecting point coordinates, land cover observations and community activities observation at locations with a high density of hotspot from spatial analysis.

2.3 Data Analysis

The method of determining the vulnerability level of forest and land fires used Composite Mapping Analysis (CMA) with a modification of that developed by Jaya *et al* (2008) and Samsuri *et al* (2010). CMA method according to Hepner (1999) are the main techniques used to the communities vulnerability model. This method involves combining separate spatial data layer to produce a meaningful relationship on the spatial relationships between these data (Boonyanuphap, 2001). Boonyanuphap (2005) also uses the CMA method in determining the spatial model of the deforestation-prone area. Eleven variables used in determining the vulnerability of forest and land fires in North Sumatera province i.e. peat depth (x1), land cover (x2), distance from road (x3), distance from river (x4), distance from village center (x5), land systems (x6), area fraction of forest plantation concession (percentage area per sub-district) (x7), area fraction of oil palm concession (x8), area fraction of timber concession (x9), population density (x10) and Gross Regional Domestic Product (x11)

2.3.1 Data Preparation

Data preparation to analyze the vulnerability of forest fire including: (i) processing hotspot data by extracting hotspot data at El Nino years (2002, 2006, 2009) and the value of confidence above 50, (ii) creating distance map (buffering) data of the road network, river network and the distribution of villages, (iv) creating a map of area fraction (percentage area per sub district) of the forest plantation, oil palm and timber concession per sub-district, (v) creating a map of population density (vi) creating a map of land values based on the value of GRDP (Gross Regional Domestic Products) and (vii) creating a hotspot density map in calculate density method with a resolution 1000 m and radius 15 km.

Each of these variables that was used in the creating models was divided into several classes and determined the distribution of hotspots per class. Distribution of the number of hotspots per variable class was created by summarize of join spatial between variables and hotspot map on the Geographic Information System (GIS). Summarize process between the variables of land cover and hot spots obtained from join spatial between hotspot in 2002, 2006, 2009 and 2015 with land cover 2003, 2006, 2009 and 2015.

2.3.2 Scoring Classes of Each Variables

Developing actual score, estimated score and rescaled score for each variable are determined by the density of hotspots per class in each variable determinant of vulnerability fire. Hotspots that are used to build a score is a hotspot with confidence criteria above 50%. According to Giglio *et al* (2003), the Confidence Level is used to determine classes of low confidence (> 30%), nominal-confidence (30% -80%) or high-confidence (> 80%) in all the pixels on fire. The confidence value of a hotspot is quite varied in different parts of the world. In Kapuas District of Central Kalimantan Province Indonesia, hotspot with a confidence value above 50% adequately describe their forest and land fires in the field (Thoha *et al.,* 2014)

The actual score is the ratio between the number of the actual hotspot to hotspot expectations, while estimated scores are calculated using trend line models derived for each variable. Scores classes in the variables obtained from the formula 1 and 2.

$$E_i = [\frac{T \text{ x } F}{100}] \qquad (1)$$

$$X_i = [\frac{o_i}{e_i}] \times \frac{100}{\Sigma(\frac{o_i}{e_i})} \qquad (2)$$

Where:

Xi = Actual score in variable (sub-factor)

Oi = Average of hotspot in variable class

Ei = Expected hotspot

T = Total of hotspot

F = Percentage of area per variable class

Based on the trend line, the relationship between the actual score of each class variable with the class code obtained estimated score by non-linear regression equation which has a coefficient of determination that is relatively higher. To get the same standard score among all the factors that will be used in developing the model, then the score is recalculated to get rescaled score. Rescaled score is obtained of formula of Jaya *et al.* (2008) as shown by equation 3 with a minimum of 10 and a maximum of 100.

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

Where:

Score R_{out} = Rescaled score
Score E_{input} = Estimated score input
Score E_{min} = Minimum estimated score
Score E_{max} = Maximum estimated score
Score R_{max} = Maximum rescaled score
Score R_{min} = Minimum rescaled score

2.3.3 Determining Weight Variable

Determining the weight of each spatial variable conducted using Composite Mapping Analysis/CMA (Jaya *et al,* 2008). In this case, the relationship between the number of hotspots per km^2 (hotspot density) with variables score of construct the vulnerability of forest and land fire were analyzed to get the weight of the variables. The variables that were significant (p value < 0.05) compared with the other variables that are selected and used to construct a linear regression model with variable density of hotspots as predictors. The weight of each variable is the proportion of each coefficient (α) of the linear regression of the total of all the regression coefficient.

2.3.4 Creating the Vulnerability Equation Fires and Visualization Models

Rescaled score of each factor was used to calculate a composite score of several factors. A stepwise regression model was used to determine the composite score that stated the relationship between the number of hotspots per km^2 (hotspot density) with a score of constituent factors. Hotspot density is obtained from the spatial analysis through Kernell Density methods with a radius 15 km. The data that is used to create the equation from the relationship between composite score equation and the density of hotspots are taken throughout the province of North Sumatra Province. The composite score is determined by weight derived from each coefficient of the factors of the composite constituent. Based on the scores and weights of each variable, arranged a mathematical equation as follows (Equation 4):

$$y = w_1x_1 + w_2x_2 ... + w_ix_i \quad (4)$$

where

y = Composite score model
Wi = Variable weight …-i
xi = Variable rescaled score …-i

The Map of forest and land fires vulnerability was made based on visualization of spatial models with equation 4. The distribution of the value of the mathematical model is converted to spatial models through raster calculation and reclassify process. Composite score of the spatial model process is classified by the method of natural break in GIS software which was divided into five classes.

2.3.5 Determining Distribution of Forest and Land Fires Vulnerable Area

The determination of the fire extent based on the spatial analysis results by overlaying fire vulnerability level maps of the dominant variable (the highest weight) of the model and the results of the ground check. Fire-prone areas is determined by geoprocessing process and overlaying the level of vulnerability of forest and land fire maps by the administrative boundaries so that is obtained the distribution of the very low - very high vulnerable level. Flowchart of

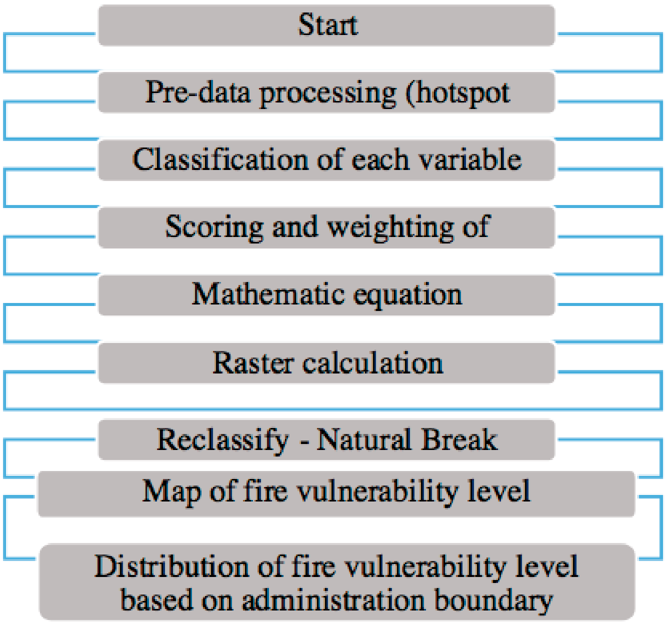

Figure 1. Flowchart of fire vulnerability establishment

determining the level of vulnerability of forest and land fires in the North Sumatra province are presented at Figure 1.

3. RESULTS AND DISCUSSION

3.1 Relationship between fire activity and variables effected of forest and land fires

The scores that were calculated in each variable class produced a pattern that described the relationship between fire activity and variables contributing to forest and land fires in North Sumatera Province. The relationships between the actual score with variables classification code are given in Figure 2a- Figure 2k.

The relationship between actual score and peat depth followed a polynomial pattern with coefficient determination (R^2) of 71.2%, that is the deeper the peatland, the bigger would be the estimated score (Figure 2a). Such pattern indicated that lands with low vegetation density would attain higher scores (Figure 2b). Figure 2c indicated that the closer the forest or land to the road, the greater was the estimated score. Figure 2d showed that the closer the distance to the river, the bigger is the estimated score. The relationship between distances from village center with fire activity showed that the farther the distance was from the village center, the lower was the probability of fire activity (Figure 2e). Estimated scores from regression equation between actual score and land system followed a polynomial pattern with coefficient determination (R^2) of 16.29 %, indicating that the higher the peat characteristics of a land, the higher was the prediction score (Figure 2f).

The relationship between actual score and fraction area of forest plantation concession (HTI) followed an exponential pattern with coefficient determination (R^2) of 60 %, that is, the higher of fraction area (percentage area per sub-district), the lower would be the estimated score (Figure 2g). Similarly, estimated scores from regression equation between actual score and area fraction area of oil palm concession (HGU) followed an exponential pattern with coefficient determination (R^2) of 74.8 %, indicating that the higher the area proportion of HGU per sub-district, the lower was the prediction score (Figure 2h). Estimated scores from the regression equation between the fraction area of logging concession (HPH) per sub-district and actual score followed a logarithmic pattern with coefficient determination (R^2) of 68.3% (Figure 2i). Estimated scores from regression equation between actual score and population density followed an exponential pattern with coefficient determination (R^2) of 78,98%, indicating that the higher population density, the lower was then estimated score (fire activity) (Figure 2j). The last model is the relationship between Gross Regional Domestic Product (GRPP) and actual score. Estimated scores from regression equation between actual score and GRDP followed a logarithmic pattern with coefficient determination (R^2) of 43.2%, indicating that the higher population density, the lower was then fire activity (Figure 2k).

The relationship between fire activity and variables that contributing to forest and land fires showed that deep peatland are still available in the large area and easily accessible, thus increased the intensity of land clearing in this area. According to land cover factor, shrubs and grassland generally area unmanaged land. In unmanaged land, outsiders could easily perform burning activities both intentionally and unintentionally without being monitored. Examples of intentional burning activity on the unmanaged land area to open the way for hunting and to transport timber, to take fresh water fish and to hunt of animal, to flare of smoking activity as well as to cook food and water (Akbar, 2011). A study by Prasetyo *et al.* (2016) in Jambi Province also found fire occurrence generally on bush or unmanaged land for land clearing activities. Boer *et al.* (2007) noted that in a significant portion, fires in Central Kalimantan occurred close to the road network, which could be used to predict the causes of fires.(Figure 2c). Figure 2d showed that the closer the distance to the river, the bigger is the estimated score. According to Hecker (2005) and Hoojier *et al.* (2008), river and canal network area provided access for allowing human activities. The construction of the canals has increased the drying up of the peatland and turning it into a fire-prone area. Soewarso (2003) also notes similar situation in the peat swamp forest of Sugihan River, where areas close to rivers and canals showed higher chances of fire occurrence. Land allocated for transmigration and cultivation areas could also drove an area to be prone to fire. Similar situation was also observed by Stolle *et al.* (2003) who found that the fires in Jambi Province were caused by human related factors such as the existence of village in transmigration projects and land allocation for special uses.

Land allocated for transmigration and cultivation areas could also drove an area to be prone to fire. Similar situation was also observed by Stolle *et al.* (2003) who found that the fires in Jambi Province were caused by human-related factors such as the existence of settlements and population density in transmigration projects and land allocation for special uses. A similar to the relationship between actual score and peat depth, estimated scores from regression equation between actual score and land system also followed an exponential pattern with coefficient determination (R^2) of 86.0 %, indicating that the higher the peat characteristics of a land, the higher was the prediction score (Fig 2f). Based on the relationship between concession area and fire activity (Figure 2g-2i), there were indicating that lower covering by vegetation tend increase fire activity. Gaveau (2013) also confirmed their study that most burning occurred on the low vegetation cover area.

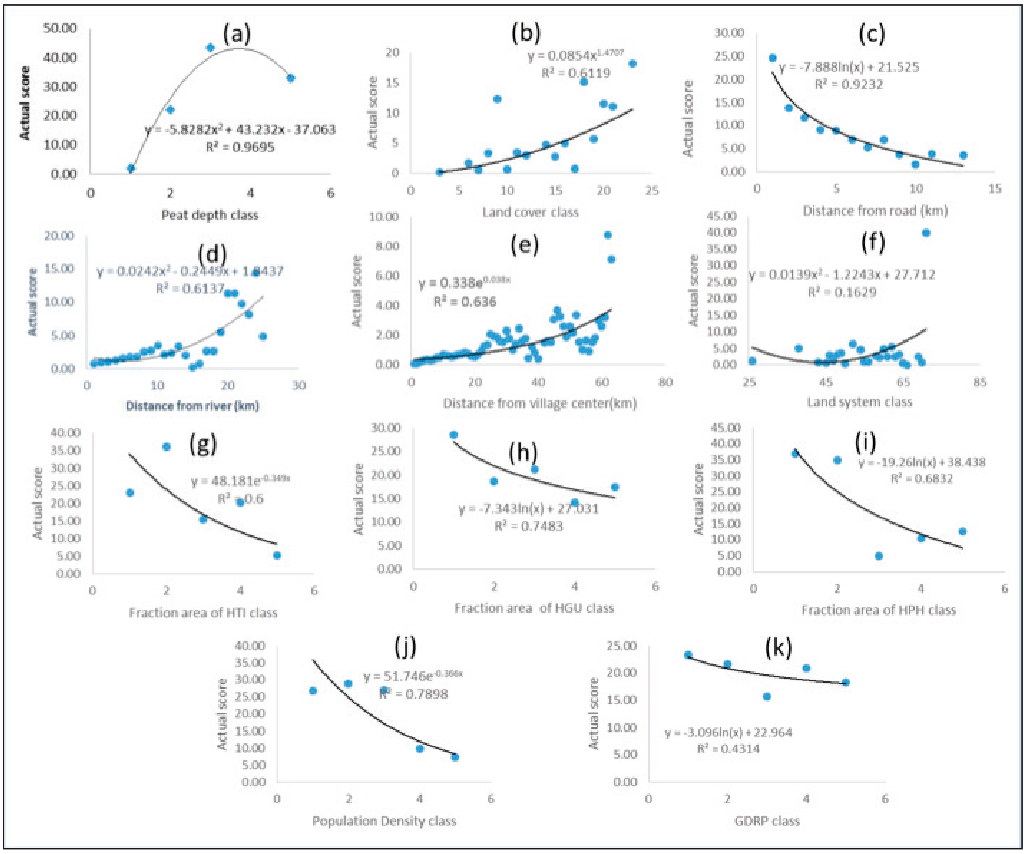

Figure 2. Relationship between actual score and peat depth class (a), land cover class (b), the distance from the road (c), the distance from the river (d), the distance from the center of the village (e), land systems (f), proportion area of HTI class by sub-district (g), proportion area of HGU class by sub-district (h), proportion area of HPH class by sub-district (i), population density class (j), GDRP class

3.2 Spatial Model of Forest and Land Fires Vulnerability Level

Analysis of stepwise regression of eleven variables as stated in Table 2, have yielded two non-significant variables ($\alpha > 0.1$), i.e., peat depth (x1) and GDRP (X11) with R2 of 40 %. Consequently, the composite score model (vulnerability score) to develop forest and land fires vulnerability score used the three significant variables namely land cover (x2), distance from road (x3), distance from river (x4), distance from village center (x5), land system (x6), area proportion of HTI (x7), area proportion of HGU (x8), area proportion of HTI (x9) and population density (x10), to estimate the hotspots density. Linear regression analysis of these nine variables resulted in R^2 of 42.2 % with each variable weight shown in Table 1.

According to the variables weights in Table 3, a model equation for forest and land fires vulnerability score in North Sumatera Province was formulated as follows:

$$y = 0.371x2 + 0.125x3 + 0.102x4 + 0.145x5 + 0.020x6 + 0.057x7 + 0.127x8 + 0.032x9 + 0.020x10$$

where,

y = Composite score
X2 is rescaled score of land cover
X3 is rescaled score of distance from road
X4 is rescaled score of distance from river
X5 is rescaled score of distance from village center
X6 is rescaled score of land system
X7 is rescaled score of area proportion of HTI per district
X8 is rescaled score of area proportion of HGU per district
X9 is rescaled score of area proportion of HPH per district
X10 is rescaled score of population density score

Table 1. Coefficient score and weight of composite score of forest and land fires vulnerability level in North Sumatera Province (Source: Authors)

Variable	Coefficient	Weight
Land cover	0.000356	0.371
Distance from road	0.000119	0.125
Distance from river	0.000098	0.102
Distance from village center	0.000139	0.145
Land system	0.000019	0.020
Area proportion of HTI per district	0.000055	0.057
Area proportion of HGU per district	0.000122	0.127
Area proportion of HPH per district	0.000031	0.032
Population density	0.000019	0.020

Based on the mathematical equation above, the weights related to human activity and biophysical variables could be calculated. In North Sumatera Province, human-related variables (distance from road, distance from river, distance from village center, area proportion of HTI, area proportion of HGU, area proportion of HPH and population density) had a weight of 60.9% while the biophysical variables (land cover and land system) had a weight of 39.1%. According to the model with nine variables, in predicting fire activity, land cover played the most important role in forest and land fires, with the weighted value of almost 38%. This indicated that land cover that low vegetation density such as shrubs land and grassland were fire-prone areas in North Sumatera Province, hence it should become the main focus in controlling forest and land fires. In addition, distance from road, distance of village center and HGU were also important variables in the prevention of forest and land fires.

Vulnerability maps obtained from thecharacteristics of a vulnerable area burned by the fire trigger major factor. In North Sumatra fires generally occur on land cover of shrubs, grasslands, away from the village center and the lands that will be built into plantations. Shrubs and grassland often became the source of the fire could spread to another land cover. Fire by human activity is generally followed by the emergence of new plantations well managed by the company and the community.

Human activity factors have a role in determining the level of vulnerability of forest and land fires in North Sumatra province which contributed more than 60%. Land cover and distance from the village center to contribute almost 52% in determining the level of vulnerability. According to the model with nine variables, in predicting fire activity, land cover played the most important role in forest and land fires, with the weighted value of almost 38%. This indicated that land cover that low vegetation density such as shrubs land and grassland were fire-prone areas in North Sumatera Province, hence it should become the main focus in controlling forest and land fires. In addition, distance from road, distance of village center and HGU were also important variables in the prevention of forest and land fires. Thoha *et al.* (2014) have found that shrubland and grassland in unmanaged lands were the fire-prone areas.

Land cover determines the level of vulnerability of the aspects of ease of fuel burned. Generally, forest and land fires occur on land cover of shrub, shrub swamps and grassland. Shrubs and grass very flammable in long dry condition because the condition of low water levels and types of thin fuel is flammable. The distance from the village is a variable associated with social and economic aspects related to accessing, monitoring and managing the land. Forest and land fires in North Sumatra, mostly occur in the area with low monitored and unmanaged land. These lands are not maintained either because of bad management or abandoned land is generally far from the center of the village or commune relatively more vulnerable to fire. Grassland and gardens are unmanaged lands that was found in Padang Lawas and North Padang Lawas District. The expanse of grasslands was partially included native vegetation region of North Padang Lawas almost always burnt each year which then spread to agricultural lands which unmanaged surrounding forest.

3.3 Distribution of Forest and Land Fire Vulnerability Level in North Sumatera

Based on area calculations, it is found that the majority of North Sumatra province covered by the areas where the vulnerability level in low, approximately 45.92% of the total area (for 5 classes). As for the fire-prone areas (high degree of vulnerability – very high) covering an area of about nearly 800 thousand hectares of 11:45% of the total area of the North Sumatra Province. Distribution area and obtained from the model presented in Figure 3. The area of the fire vulnerability by grade and a composite score of each class of vulnerability of forest and land fires are presented in Table 2.

The overlapped results of the vulnerability maps of forest and land fires with district boundary map generate vulnerability level distribution per district/city as shown in Figure 4. The area district that has the largest area of very high level are Padang Lawas, North Padang Lawas, South Labuhan Batu and Labuhan Batu District. These districts region close to the Riau Province, one of the most prone areas of forest and land fire in Indonesia.

Padang Lawas District according to the interview with the Natural Resources Conservation Agency of North Sumatra is the most fire-prone district in North Sumatra Province. In early November 2016, there has been 30 times the incidence of destructive fires and plantations, plantations, secondary forests and primary forests. Fire events with large areas in Padang Lawas also reported by antarasumut.com (2016) in which an area of over 150 hectares of forest were burned during 2016. In addition, other areas were also very fired prone was North Padang Lawas Regency. The results of a field survey found the found location of the fire that burned the community garden and reeds in several villages in the District of Batang Onang in August to October 2016.

Table 2. Distribution of Class Wide of Forest and Land Fire Vulnerability in North Sumatera

Vulnerability level	Composit Score Model	Area (ha)	Percentage
Very low	19.068 – 30.757	1358548	19.58%
Low	30.758 – 39.456	3185815	45.92%
Medium	39.457 – 50.874	1599489	23.05%
High	50.875 – 62.563	591646	8.53%
Very High	62.564 – 88.389	202486	2.92%

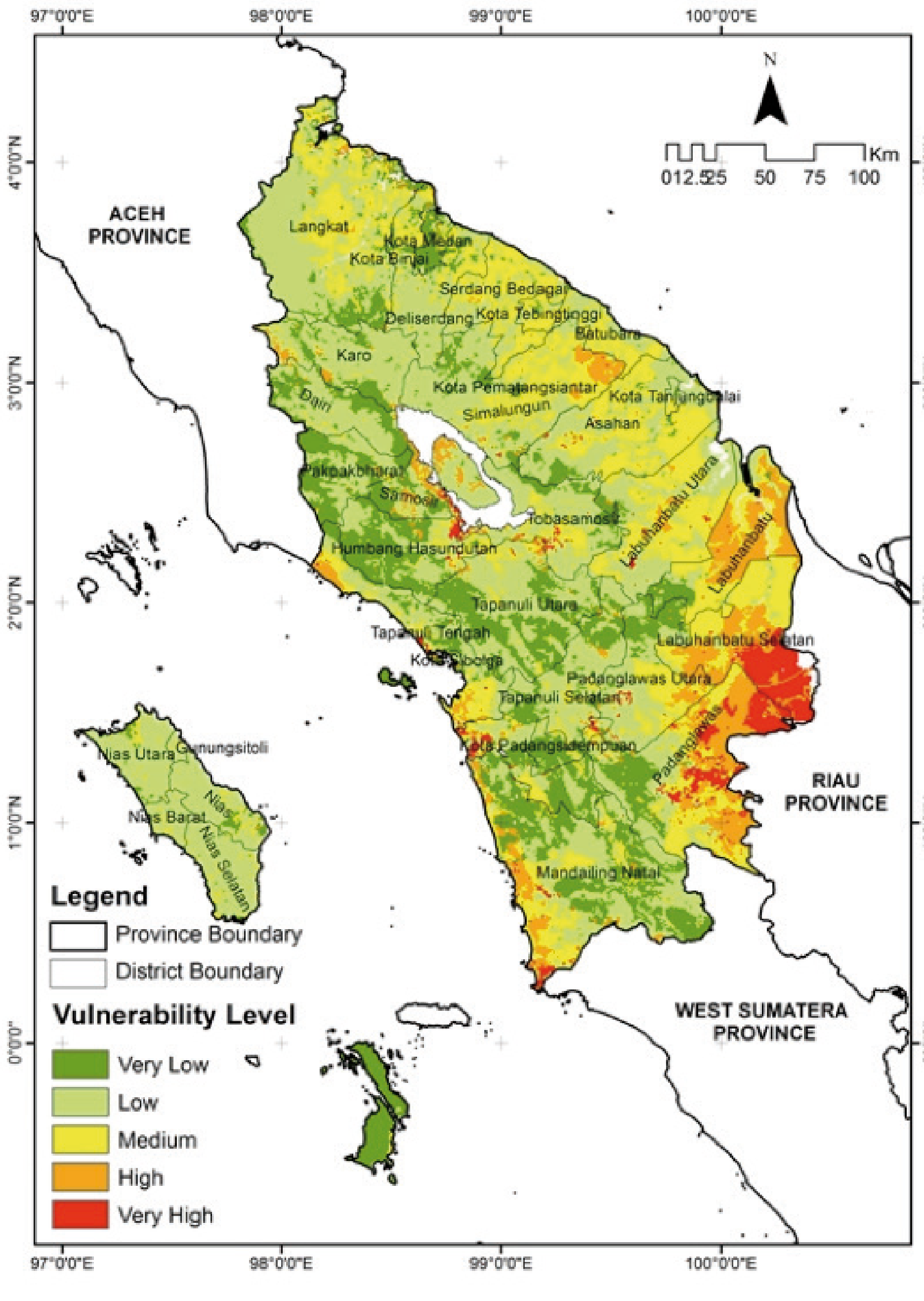

Figure 3. Forest and land fires Vulnerability Map in the North Sumatra Province

Implementation of the vulnerability map of forest and land fires in forest and land fires management in North Sumatra Province can apply to some aspect. First, to understand the relationship between the various factors that affect the vulnerability of the fire so that it can be used to determine the characteristics of fires in more detail. Second, to understand the key factors that trigger fire which can be very useful in determining the priority program to decrease forest and land fires occurrence. Third, it can determine the fire-prone areas in anticipation of future fire risk. Fourth, it can determine the priority areas to prevent forest and land fires so as to assist in formulating strategies and better prevention action.

4. Conclussion

Land cover played the most important role in the modelling of forest and land vulnerability level, with the weighted value of almost 38% from nine variables. The nine variables were used to develop the model of $y = 0.371x2 + 0.125x3 + 0.102x4 + 0.145x5 + 0.020x6 + 0.057x7 + 0.127x8 + 0.032x9 + 0.020x10$ where the coefficient determination was 42.4% and could be used to predict hotspots density per km2. Human activity factors have the role in determining the level of vulnerability of forest and land fires in North Sumatra province which contributed more than 60% of the spatial model. The study found that shrubs and grassland are land cover type that almost became the initial source of fire in North Sumatera Province. Padang Lawas District and Labuhan Batu Selatan District have the most extent area of very high vulnerability level.

This study provided suggestions to the North Sumatera Province stakeholders to enhance intentions to improve land productivity, to protect peatland conservation area and to manage water in peatland. The study concluded on the importance to develop time-series forest and land fires vulnerability map and to include the capacity response from community variables in the model.

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REFERENCES

Akbar A, Sumardi, Hadi R, Purwanto and Sabarudin MS. Study of fire sources and community respond for peat swamp forest fire control in Mawas area Central Kalimantan. Jurnal Penelitian Hutan Tanaman 2011; (5): 287-300

Boer R, Kolopaking L, Bagja B, and Dasanto BD. Early Warning Systems in Indonesia for flood, forest fire, volcano eruption and tsunami. Final Report to GTZ, Jakarta. 2007.

Boonyanuphap J., Gunarwan Suratmo F, Jaya INS., and Amhar F.. GIS-based method in developing wildfire risk model (case study in Sasamba, East Kalimantan, Indonesia). Tropical Forest Management Journal. 2001; 7 (2): 33-45

Boonyanuphap J. Spatial model for determining risk area of deforestation. Suranaree Journal of Science and Technology 2005; 12 (2) :145-159

Gaveau, DLA, Salim, MA, Hergoualc'h, K, Locatelli, B, Sloan, S, Wooster, M, Marlier, ME, Molidena, E, Yaen, H, DeFries, R, Verchot, L, Murdiyarso, D. Nasi, R, Holmgren, P, Sheil, D. Major atmospheric emissions from peat fires in Southeast Asia during non-drought years: evidence from the 2013 Sumatran fires. Scientific Reports. 2014; 4; 6112; DOI:10.1038/srep06112

Giglio L, Descloitres J, Justice CO, Kaufman YJ. An Enhanced Contextual Fire Detection Algorithm for MODIS. Remote Sensing of Environment 2003; 87:. 273-282.

Harrison M.E, S.E. Page, and S.H. Limin. The global impact of Indonesian forest fires. Biologist 2009; 56 (3); 156-163.

Hecker JH.. Promoting Environmental Security and Poverty Alleviation in the Peat Swamps of Central Kalimantan, Indonesia Commissioned by the Institute for Environmental Security, The Netherlands. 2005. http://www.envirosecurity.org/espa/PDF/IES_ESA_CS_Kalimantan_Case_Study.pdf

Hepner, FG. Geographic Information systems development. The Southwest Center for Environmental Research and Policy (SCERP), Department of Geography, University of Utah, Final Report. 1999. www.scerp.org/ scerp/projects/HW93_21.html..

Hooijer A, Van der Vat M, Prinsen G, Vernimmen R, Brinkman JJ, Zijl F. Hydrology of the EMRP Area – Water Management Implications for the Peatlands. Technical Report Number 2, Master Plan for the Rehabilitation and Revitalization of the Ex-Mega Rice Project Area in Central Kalimantan. Euroconsult Mott MacDonald and Deltares and Delft Hydraulics. 2008.

Jaya INS., Purnama ES, Arianti I, Boonyanuphap J. Forest fire risk assessment model and post-fire evaluation using remote sensing and GIS: A case study in Riau, West Kalimantan and East Kalimantan Provinces, Indonesia. Paper presented at The Forest Restoration and Rehabilitation Training Course and Workshop in the Viiki Tropical Resources Institute (VITRI) of the University of Helsinki, Finland, 13~19 May 2007, Helsinki (FIN). http://nasional.kompas.com/read/2015/12/18/17001251/BNPB.Skala.Bencana.2015.Lebih.Kecil.Dibanding. 2014.

Langner A, Siegert F. Spatiotemporal fire occurrence in Borneo over a period of 10 years. Global Change Biology 2009; 15: 48-62.

Page, SE, Siegert J, Rieley JO, Boehm HV, Jayak A, Limin SH. The amount of carbon released from peat and forest fires in Indonesia during 1997, Nature 2002; 420: 61-65.

Prasetyo LB, Dharmawan AH, Fredian TN, Ramdhoni S. Historical forest fire occurrence analysis in Jambi Province during the period of 2000 – 2015: its distribution & land cover trajectories. Procedia Environmental Sciences 2016; 33 450 – 459

Samsuri, Jaya INS, Syaufina L. Spatial Model of Land and Forest Fire Risk Index, Case Study in Central Kalimantan Province. FORESTA Indonesian Journal of Forestry 2010; I(1) 2012: 12-18

Soewarso. Establishment of peat swamp forest fire prevention using prediction model. 2003. [Dissertation]. Graduate School of Bogor Agricultural University. Bogor [Indonesian].

Stolle F, Chomitz KM, Lambin EF, Tomich TP. Land use and vegetation fires in Jambi Province, Sumatra, Indonesia. Forest Ecology and Management 2003; 179 : 277-292

Thoha AS, Saharjo BH, Boer R, Ardiansyah M. Spatiotemporal distribution of peatland fires in Kapuas District, Central Kalimantan Province, Indonesia. Agriculture, Forestry and Fisheries 2014; 3 (3): 163-170. http://www.antarasumut.com/berita/161672/foto

United Nation International Strategy for Disaster Reduction [UNISDR]. Terminology on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland. 2009. http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf.

Tacconi L, Moore PF, Kaimowitz D. Fires in tropical forests: what is really the problem? Lessons from Indonesia. Mitigation and Adaptation Strategies for Global Change. 2007; 12: 55-66.