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

Achmad Siddik Thoha[1]* and Alfan Gunawan Ahmad[1]
[1]*Faculty of Forestry, Universitas Sumatera Utara Medan, Indonesia*
*Corresponding author: siddikthoha@gmail.com

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

1.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).

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.

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 1.

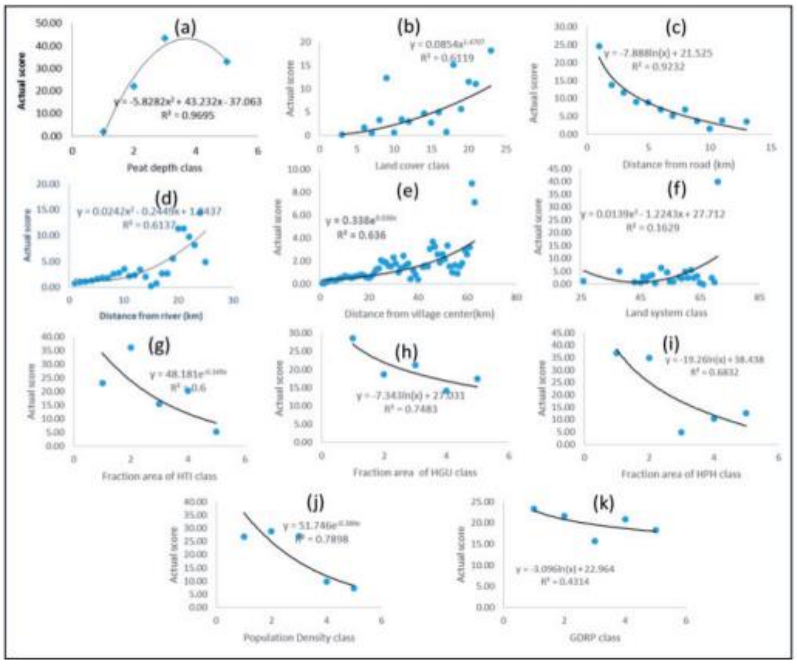

Figure 1. Relationship between actual score and peat depth class (a), land cover class (b), the distance from the road (c), the distance from the river (d), the distance from the center of the village (e), land systems (f), proportion area of HTI class by sub-district (g), proportion area of HGU class 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 R2 of 42.2 % with each variable weight shown in Table 1.

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

4. Conclusion

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.

Acknowledgement

This study was funded by BPPTN University of Sumatera Utara 2016 Agreement Number 6094/UN5.1/PPM/2016. Thanks are also forwarded to Natural Resources Conservation Agency (BBKSDA) of North Sumatera for the supports and assistances provided during the data collection process. Sincere appreciation is also extended to anonymous reviewers for correction and comments.

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.

Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, Balakrishnan K, Brunekreef B, Dandona L,Dandona R, FeiginV. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The Lancet 2017; 389(10082): 1907-1918.

Esclamado R, Cummings CW. Management of the impaired airway in adults. In: Cummings CW, Fredrickson JM, Harker LA, Krause CJ, Schuller DE, editors. Otolaryngology - head and neck surgery. 2nd ed. St. Louis, MO: Mosby Year Book; 1993. p. 2001-19.

Johnson RA, Wichern DW. Applied multivariate statistical analysis. 6th ed. New Jersey: Prentice-Hall; 2007.

Maier HR, Jain A, Dandy GC, Sudheer KP. Methods used for the development of neural networks for the prediction of water resource variables in river systems: Current status and future directions. Environmental Modelling and Software 2010; 25(8): 891-909.