IMPROVEMENT OF LAND AND FOREST FIRE HAZARD MAPPING METHOD FOR SUMATERA AND KALIMANTAN BASED ON REMOTE SENSING DATA

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Abstract

Improvement of land and forest fire hazard mapping method for sumatera and kalimantan based on remote sensing data. Fire hazard prediction model has been developed using spatial and satellite data for Sumatra and Kalimantan since these areas are very prone to land and forest fires. The model could predict fire hazard for several months ahead based on predicted rainfall and predicted vegetation indices. The previous method used four parameters as inputs, which were rainfall, vegetation index, land cover, and land type. The objectives of this research are to improve the method of fire hazard determination using spatial and satellite data and to compare the results of previous and last methods for Sumatra and Kalimantan. An improved method has been developed by using topographic map as additional input of the method. Improvement has been also made by using raster format data instead of vector format data as used in previous method of overlaying by geographic information system software. The results show that the use of raster data format could produce more detailed land/forest fire hazard maps for Sumatra and Kalimantan compared with the use of vector data. Further more, the use of slope parameter based on topographic map derived from SRTM data could generate better fire hazard maps in terms of vulnerability indication and spatial information.

Keywords: fire hazard, raster data, vector data, slope

1. INTRODUCTION

Since 1980s land and forest fires in Indonesia have been attracted world attention particularly in Southeast Asia. In most occurrences, the fires set by the ranchers and subsistence farmers often get out of hand or uncontrolled, inadvertently burning forests, pastures, and plantations. Each year, fires in Sumatra and Kalimantan burn a large area of shrubs, logged forests, croplands, and plantations. Wetlands and peat lands would cause the fires spread out fast and produce a large number of smoke and haze. The haze will increase air pollution even become transboundary haze over the Southeast Asia and has various impacts (Murdiyarso, 1998; Murdiyarso and Lebel, 1998; Suyanto et al., 2001, 2003).

According to Saharjo (2000) the sources of land and forest fires come from illegal shifting cultivation, forest concession, plantation, logging, and spreading. Tacconi (2003) suggests that land cover and its changes are major influencing factors on fires in Indonesia. Based on fires in 1997/1998 it has been calculated that the largest amount of burned areas in Indonesia consists of crop land and followed by brackish forest, peat forest, lowland forest, shrubs, grassland, forest plantations and plantations. Furthermore the results of Murdiyarso et al. (2002) reveal that forest fire risks are related to accessibility and vegetation type or fuel type. Highest fire frequency (as indicated by cumulative hotspot frequency) is usually found at the areas having high accessibility by secondary roads. Various studies on fires are therefore becoming higher interests of many scientists in Indonesia as well as in other countries.

Research on land and forest fire hazard has been done by modeling the impact of climate anomaly on fire hazard prediction for Sumatra and
Kalimantan (Adiningsih et al., 2003, 2004). The results show that four factors i.e. rainfall, vegetation index, land cover, and land type, could be used for fire hazard mapping. Fire hazards could also be predicted for several months ahead based on predicted rainfall and predicted vegetation index. However, the results still need improvement since spatial accuracy of resulted maps was less than expected. The objectives of this research are to improve the method of fire hazard determination using spatial and satellite data and to compare the results of previous and last methods for Sumatra and Kalimantan.

2. MATERIAL AND METHOD

Data Collection

Data used in this research consist of monthly rainfall, monthly vegetation index (NDVI), land cover map, land type map, and topographic map. Monthly rainfall data were collected from 21 stations in Sumatra and 10 stations in Kalimantan. Monthly NDVI and hotspot locations are derived from NOAA-AVHRR data. Land cover maps are derived from Landsat imageries of 2002, while land type from soil map is obtained from existing maps published by Soil Research Center. Hotspot location and number of all provinces in Sumatra for the period of 1996-2002 are derived from NOAA-AVHRR satellite data. Field data include land use condition, vegetation and fuel conditions in Riau and South Sumatra.

This research used a set of PC with Sea Scan software and ErMapper to process NOAA-AVHRR data, ArcView for geographical information processing and mapping, and statistical software for statistical processing and analyses. For field survey we used GPS (Global Positioning Satellite) to determine geographical location and camera for documentation.

Data Processing and Analysis

Monthly vegetation index or NDVI are obtained from daily AVHRR data by maximizing the values of one month data to minimize the effect of cloud cover. In the previous study, maps of NDVI are generated by extracting the values of selected pixels and then making contour of NDVI to generate map in vector format. Similar technique is also applied on rainfall data. Some improvements have been made in this study. Firstly, original format of raster NDVI data are used. Secondly, rainfall contour map is converted into raster format data as well as land cover map and land type map. The two are aimed to enhance spatial resolution of generated maps. Thirdly, parameter of slope is also as additional parameter of the model since a few works have suggested the effect of topography on the spread of fires. To ensure digital image processing for all parameters having different spatial resolution, pixels of rainfall, land cover, land type, and slope layers are re-sampled into NOAA AVHRR pixel size.

Land and forest fire hazard is determined using a set of criteria and scores of five parameters as shown in Table 1. The parameters are rainfall, NDVI, land cover, land type, and slope. The first four parameters are used for method 1 which is similar to previous study and the fifth parameter (slope) is used as additional parameter of method 2. Calculation of parameter score is as follows:

Parameter score = weight * score

Since there have been several previous works on forest fire factors, scoring method was based on previous related works. Total score was obtained by summing all parameter scores. Forest fire risk classification could be established by dividing total score range into 5 intervals or classes which describe fuel availability and flammability. The five classes of forest fire risks are very low, low, moderate, high, and very high fire hazard. The weight of each parameter in the two methods is presented in Table 2.

Data processing is established for generating actual hazard and predicted hazard. The predicted hazard uses predicted rainfall and NDVI values as prediction model has been obtained in the previous study. Since our previous study has analyzed several months of fire hazard maps for normal and anomalous years, in this study we analyze hazard maps of June 2002, 2003, and 2004 as case study.

3. RESULT AND DISCUSSION

The results of fire hazard mapping for all methods both for Sumatra and Kalimantan are shown in Figure 1, 2, and 3. From Figure 1 we might see that improvement in spatial data format, i.e. from
vector to raster formats, could provide better spatial resolution of fire hazard information. From Figure 1 we might also see that the patterns of fire hazard for all classes from method 2a are more detailed than from method 1, both for Sumatra and Kalimantan. This is due to the use of original resolution of satellite data. However, fire hazard level of method 2a seems to be lower than of method 1. As the hazard level of method 1 tends to be overestimated, the hazard level of method 2a tends to be appropriate or at least not too much underestimated. As an example, the eastern coast of Riau in Sumatra indicates high fire hazard although only few hotspots are found at the area. Similar condition is found in western part of Kalimantan. Meanwhile the hazard level of method 2a seems to coincide with hotspot occurrence, meaning that the method is relatively appropriate to provide information on potential fire occurrence. In other words the use of raster data format could produce more detailed land/forest fire hazard maps for Sumatra and Kalimantan compared with the use of vector data. However the accuracy still needs to be proven by verification and validation.

From Figure 2 we can see that fire hazard level in Sumatra generated from method 1b (without slope parameter) tends to be a little bit higher than the one generated from method 2a and 2b (with slope parameter). As the location of hotspots coincide with indicated moderate fire hazard level of method 1b rather than of method 2a and 2b, this result indicate that method 1b is relatively more accurate than method 2a and 2b. Similar situation is also found in Kalimantan as shown in Figure 3. However since the number of hotspots is only a few during June 2004, the result does not prove any indication of accuracy. It is a must that the result needs a statistical test. Besides, the weight factor still needs to be validated and improved for method 2b.

Based on those results we might summarize that the use of slope parameter based on topographic map derived from SRTM data could generate better fire hazard maps in terms of vulnerability indication and spatial information. Nevertheless the spatial accuracy has not been sufficient as the vulnerability depicted from the maps tends to be lower than resulted by the previous study. However improved method needs to be verified and validated in order to obtain proper constants of all parameters.

**Table 1. Improved score and criteria for forest fire hazard**

<table>
<thead>
<tr>
<th>Score</th>
<th>Monthly NDVI</th>
<th>Monthly Rainfall (mm)</th>
<th>Land use Type</th>
<th>Land type</th>
<th>Slope (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt; 0.55</td>
<td>&gt; 250</td>
<td>Settlement</td>
<td>Mineral Soils</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>2</td>
<td>0.46 - 0.55</td>
<td>200 - 250</td>
<td>Paddy Field</td>
<td>-</td>
<td>20-40%</td>
</tr>
<tr>
<td>3</td>
<td>0.36 - 0.45</td>
<td>151 - 200</td>
<td>Cropland</td>
<td>-</td>
<td>40-60%</td>
</tr>
<tr>
<td>4</td>
<td>0.26 - 0.35</td>
<td>101 - 150</td>
<td>Plantation</td>
<td>-</td>
<td>60-80%</td>
</tr>
<tr>
<td>5</td>
<td>0.16 - 0.25</td>
<td>51 - 100</td>
<td>Forest</td>
<td>-</td>
<td>80-100%</td>
</tr>
<tr>
<td>6</td>
<td>0.06 - 0.15</td>
<td>0 - 50</td>
<td>Swamp, Bush</td>
<td>Peat soils</td>
<td>&gt;100%</td>
</tr>
</tbody>
</table>

Note: (*) Slope parameter is used as additional parameter of method 2a and 2b.

**Table 2. Weighing method for fire hazard parameters.**

<table>
<thead>
<tr>
<th>Method</th>
<th>Monthly NDVI</th>
<th>Monthly Rainfall (mm)</th>
<th>Land Cover Type</th>
<th>Land type</th>
<th>Slope</th>
<th>Data Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>0.35</td>
<td>0.35</td>
<td>0.15</td>
<td>0.15</td>
<td>Not used</td>
<td>Vector</td>
</tr>
<tr>
<td>1b</td>
<td>0.35</td>
<td>0.35</td>
<td>0.15</td>
<td>0.15</td>
<td>Not used</td>
<td>Raster</td>
</tr>
<tr>
<td>2a</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>Raster</td>
</tr>
<tr>
<td>2b</td>
<td>0.30</td>
<td>0.25</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>Raster</td>
</tr>
</tbody>
</table>
Figure 1. Comparison between fire hazard maps generated from method 1a and method 1b for Sumatra and Kalimantan.
Figure 2. Fire hazard maps of Sumatra of June 2004 based on method 1b, method 2a, and method 2b.

Figure 3. Fire hazard maps of Kalimantan based on method 1b, method 2a and method 2b.
4. CONCLUSION

This study has revealed an improved method of land/forest fire hazard mapping and the result has shown better spatial resolution of generated maps than in the previous study. The use of raster data format could produce more detailed land/forest fire hazard maps for Sumatra and Kalimantan compared with the use of vector data. Further more, the use of slope parameter based on topographic map derived from SRTM data could generate better fire hazard maps in terms of vulnerability indication and spatial information. Nevertheless the spatial accuracy has not been sufficient as the vulnerability depicted from the maps tends to be lower than resulted by the previous study. However improved method needs to be verified and validated in order to obtain proper constants of all parameters.

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REFERENCES


