FOREST FIRE RISK MAPPING BY USING SATELLITE IMAGERY AND GIS FOR QUANG NINH PROVINCE, VIETNAM

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ABSTRACT: Forest Fire in Vietnam, in particularly, in the province of Quang Ninh, which is located in the northern part of the country, is considered to be disaster that damage the environment. In order to understand the forest fire occurrence and prevent the damage that causes by this disaster, the authors have developed the forest fire risk map of the study area by using the high-resolution satellite imagery with the MODIS Fire Product (MOD14), GIS data, fire occurrence information that collected by the provincial forest protection department and during the field visit. The risk zones were defined using the weight overlay analysis, and then the forest fire risk index were generated for reclassifying and validation, prior to generate forest fire risk zone map.

1. INTRODUCTION

Vietnam, the tropical country with very high density of population, there are about 9 millions ethnic minorities living closed in mountainous area. They base on the forest to earn living with very backward tradition of cultivation. The forest is contained of very valuable natural resources, which role is important for human living. People harvest many different kinds of forest products from nature. The forest is watershed of many big rivers, which contain high potential of hydro-electronic. Beside, it also contains of water resources for agriculture, industry and using of local people.

The forest in Vietnam cover about 11,785,000ha of land, in which the nature forest is 9,865,000 ha and plantation forest is 1,930,000ha. The area of forest and plant vegetation with high risk of burning are about 6 millions ha, belong to 46 provinces. It is included pine, casuarinas, pomu, eucalyptus, bamboo forest and savana. However, when the severe weather conditions occure in dry season, most of forest types is easy to catch fire.

2. OBJECTIVES

The objectives of the study are the following:

a. To investigate the forest fire occurrence in the study area using remote sensing, GIS data and ground truth information.

b. To compare the hotspot from ground truth survey and MODIS Fire Product for validation
c. To generate forest fire risk zone map
d. To find the relationship of forest fire occurrence with the social aspect in term of human activities for better understanding and decision making.

3. STUDY AREA

The study area for this study is Quang Ninh province with the coordinates of 21.66ºN, 106.43ºE for left top corner and 20.72ºN, 108.09ºE for right bottom corner. Quang Ninh province has an area of more than 5,900 km^2 with the approximated population of 1,000,000. As it is located in the North-East of Vietnam and close to the Eastern Sea, Quang Ninh is affected by hot and humid tropical monsoon: the rainy season from May to September and the dry season from October to April; Annual average precipitation is 1995 mm; Average temperature is 22.90ºC; Maximum temperature is 40.50ºC; Annual average humidity is 82 %.

Quang Ninh has 392,000 ha of forests which occupies about 66 % of the total province's area. At present, the forest acreage is 153,000ha, natural forests occupies about 82 %. The area of forest and plant vegetation with high risk of burning is belong to almost of district in Quang Ninh. It include pine, bamboo forest, shrub, etc. Therefore, when severe weather conditions occurre in dry season, many forests types are easy to catch fire. According to the statistical information from the Vietnam Forest Protection Department, it shows that each year hundreds of hectares has been destroyed. In 2005, there are 45 cases related to forest fire which caused damage about 152 ha. In 2006, 35 cases were reported, which caused damage for more than 360 ha.

Currently, Quang Ninh becomes the centre for the implementation of the master plan in the development of the national economy. The province has high tourism potential, in particularly, the well-known Ha Long Bay. Based on this reason, it is obviously that the natural enviromental need to be protected. Therefore, forest fire risk zone mapping as one of the urgent task for the protection of the environment is necessary.

4. DATA COLLECTION

There are many causative factors of forest fire in Vietnam. The list below shows the data that were collected for this study:

4.1 Digital Elevation Model

In this study, we used the SRTM of 90m resolution, which was collected from the website of Global Landcover Faculty at the University of Maryland.

4.2 Slope and Aspect Map

The slope and aspect maps were generated from the SRTM of 90m resolution.

4.3 Road Map

Road map was extracted from topographic map of year 2002 with the scale of 1:100,000. This map was obtained from the Ministry of Natural Resource and Environment (MONRE).

4.4 Settlement Points

The settlement points were extracted from the topographic map of year 2000 for the scale of 1:100,000. This topographic map was obtained from MONRE.

4.5 Forest Map

The forest map that used to this study was done for the year of 2005, with the scale of 1:1000,000 and it was collected from Forest Protection Department, Ministry of Agriculture and Rural Development (MARD).

4.6 Forest Fire Inventory

Forest Fire Inventory is very important data, which will be used for validation the result of the study and evaluation the weight of each input component. Three sources of forest fire points were collected:

a. MODIS Fire Product (MOD14) of 1-km resolution was collected from MODIS Fire Information System, Geoinformatics Center, AIT.
b. 20 forest fire points for the years 2006-2007 were obtained from the field survey records done by the Provincial Forest Protection Department of Quang Ninh.
c. 10 forest fire points were collected through a survey carried out using hand held GPS instruments during the field visit in December 2007. Accordingly, burning points theme were created. However, it should be noted that most of the area are high mountainous, which is difficult to access, therefore, surveying for all of the burning points in the study area is limited.

Based on the information obtained from the field survey, we can understand the major causes of forest fire, which mostly are related to the human activities around the burning points. The activities can be listed as below:

a. Burning in the cultivation land of ethnic minorities; straw and grass burning in rice field near the forest boundary and sometimes the fire could not be controlled and then spread to forest.
b. The illegal activities related to the exploration of forest products such as timber, wood and others also are the causes of fire. In some forest plantation area, people deliberated to burn the forest first and then cut for commercial purpose.
c. In some cases, people deliberated to burn the forest to harm other for during the dispute for land possession.
d. In addition, we also have two scenes of ALOS/AVNIR-2 which were acquired on Jan 29, 2007 and Landsat ETM+, which was acquired in year 2000. The ALOS/AVNIR-2 has good quality of high spatial resolution, unfortunately, the available image does not cover the whole study area, due to this reason, the available ALOS data was not used in this study, only the Landsat ETM+ was applied as a reference for landcover and for field survey.

5. METHODOLOGY

The Forest fire risk of the study area was chosen to be assessed by a probabilistic approach which is called Weighted Overlay Analysis (WOA). This methodology requires identification of the causal factors of forest fire and the input of the same as thematic maps. The methodology used for this study has three main ideas as the following:

5.1. Comparison of the Ground Truth with the MODIS Detected Hotspots

During the data analysis, the comparision of ground truth with the MODIS detected hotspot was conducted, and only 10 points that matched with MODIS product, which the reason can be explained as below:

a. The provincial department collected the burning area using simple way without GPS
b. For some burning locations could be taken by mistake due to lack of GPS.
c. For some burning area which has small size, MODIS may not be able to detect.
d. Finally,we decided to use 10 points collected from field survey, which are realiable since it was recorded by GPS and investigated carefully. For the other 3 points, it was obtained from the Provincial department and it matched with MODIS Fire Product. Therefore, these points were finalized to use for validating and allocating the input components of model.

5.2. Allocation of the Ground Truth and MODIS Detected Hotspots to Physical and Social Parameters in the Study Area

In this study, 13 forest fire points were overlayed to forest map, settlements, roads, slope and aspect to find the relationship between forest fire points and the input components. These informations will be used to determinate the risk factors in the next step.

5.3. Determination of Risk Factors and Weight

In order to determine the risk factors and weight, we have considered two information sources:

a. The correlation between hotspot and input components.
b. The knowledge and experiences of the forestry experts at the forest management in Quang Ninh who has good understanding for all of the factors that cause the forest fire together with the background related to forestry.

Then, the factors were analysed in the following order based on the priority of importance: Forest, Settlements, Roads, Slope and Aspect. The first classes represent higher risk places and the last one represents low risk places.

a. Forest types were reclassified according to the burning possibility (easy or difficult to catch fire). For example: Grass, shrub or pine are very dry, which are considered to be the most flamable.

b. Distance from Settlements and Roads were evaluated to have the second highest weight. The risk factor decreases farther from these places. It means that a zone near to these places were evaluated to have a higher rate.

c. Slope and Aspect are also important to determine risk area. From the analysis, many points are located on slope were found over 35 degrees. Within this slope, fire can move fastly to close area and burn everything on the moving way because soil on this slope is very thin and moisture is not high. In addition, Vietnam has two main monsoon season: Southwest in summer and Northeast in winter. Hence, Southwest aspect and Northeast aspect has high possibility for fire ocurrence and easy to increase burn area.

d. Water body or rocky mountain area do not effect to the forest fire risk, therefore, there is no weight to determine fire rating class.

5.4. Data Processing and Weighted Overlay Analysis

Thematics map were processed in ENVI and ArcGIS software. In this step, all data and maps were converted and registered to the WGS84-UTM projection. In order to integrate the statistics and to enable the analysing process basing on different targets, it is necessary to standardize the data: Grouping all the collected statistics into groups of the same ones so as they can overlay and analyse. In this study, the vector format is used to analyse. Therefore, it is necessary to convert the data from vector to raster format and to classify raster based on unique standard. We aim to keep the same pixel size of the raster after conversion. For the data like forest map, buffering settlement points, buffering roads network, the conversion process from vector to raster is done by the software ArcMap with the support of Spatial Analyst.

To be able to integrate the information using the above formular with raster, we can use the tools in the softwares GIS such as: “Map Calculation” or “Weighted Overlay”(WO). To facilitate the calculating process, the said tools which are available in ArcGIS were used. The cell values in all the file raster need to be in the integer and have the same value of “scale value” which range from 1 to 5 before Weighted Overlay. The tool used for classifying are Reclassify tools in Spatial Analyst.

The raster data of the study area were classified into five values and each data raster file is evaluated by one of the weight. The cell values of the output are calculated using the following equation:

$$SI_{Map} = [(F_R \times 0.4) + (S_R \times 0.2) + (R_R \times 0.2) + (S_R \times 0.1) + (A_R \times 0.1)] \quad (1)$$

in which, SI_{Map} is Susceptibility Index Map, F_R is Rated Forest, S_R is Rated Settlement, R_R is Rated Road, S_R is Rated Slope and A_R is Rated Aspect. The output risk map will include 5 risk categories.Very high risk is the area in which the land cover type is plantation, shrub, grassland; near the settlements and road; slope is more than 35 degrees on the southwest. High risk is the area in which the land cover is plantation; that is 1,000-2,000m far from the settlements and less than 200m from roads; slope is between 25-35 degrees on the southwest or northeast. Medium risk is the area in which the forest type is secondary forest, mixture of wood tree and bamboo; that is 2,000-3,000m far from the settlements and 200-400m from roads; slope is between 10-25 degrees on the southwest or northeast. Finally, Low and very low risk is the area in that forest type is rich forest, poor forest or mangrove; that is more than 3000m far from the settlements and more than 400m from roads; slope is between 0-10 degrees on the Southeast or Northwest.

6. RESULTS AND DISCUSSION

Each factor was fixed with a scale value and after that we used Weight Overlay function to build up it. In order to generate the final output fire risk map which is shown in Figure 1, we have classified the forest fire risk into 5 levels from Very low risk to Very high risk. 13 points from 30 forest fire points from the ground truth and FPD which has exactly position were added on the final and all thematic maps for validation and comparison. The corresponding statistical summary of this study area was calculated. It was found that there are 8 hotspots (61,53%), 3 points (23.07%) fall into Very high risk, High risk and 2 points (15.40%) fall into Medium risk zone, the error here is due to the statistical updating on the fire causing factors: the forest status, the newly constructed road or the new residental area near to the forest, in particularly one factor

which is unable to be controlled is the public awareness, uncontrolled forest burn and destroy for cultivation or dispute on land possesion, internal conflict between civil and forest management as well.

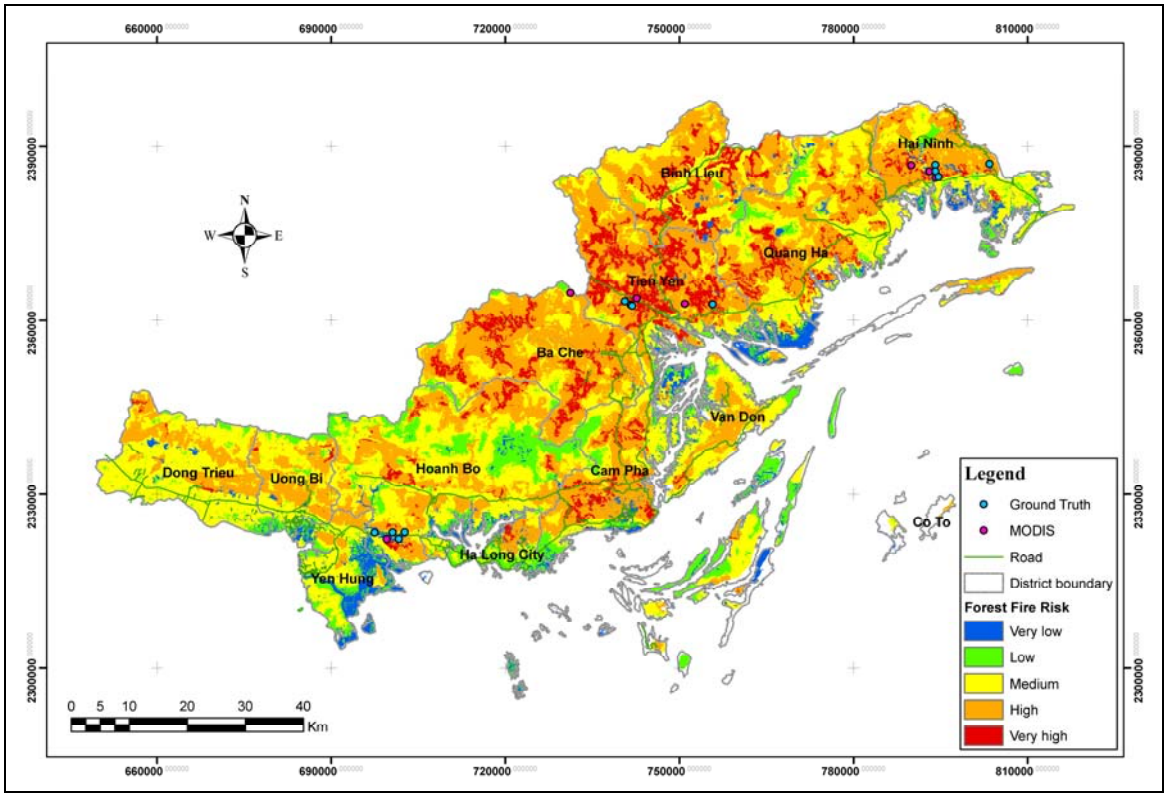

Figure 1: Forest Fire Risk Zone Mapping

The classification for the weight evaluation for each factor is highly affected to the accuracy level of the output result. Thus, to evaluate the fire causing factors, it is necessary to collect the knowledge of the experts on forestry as well as the relevant field such as hydrometeorology, social statistics, etc.

7. CONCLUSIONS AND RECOMMENDATIONS

a. The forest fire occurrence in the study area were investigated using RS&GIS with ground truth information (Objective 1).

b. During the data analysis, the data from both sources (MOD14 vs. ground truth) were compared (Objective 2).

c. Based on the information from the above two sections, the forest fire risk zone mapping has been generated by probabilistic method using Weighted Overlay Analysis as a tool (Objective 3).

d. In addition to the obtained forest fire risk map, burning points locations are logically distributed, which can be seen in the result that most of hotspots are located in the high and very high risk zones.

e. During the field survey, the relationship of the forest fire occurrence with the human activities in the study area were identified (Objective 4).