Forest fire risk forecasting in the upper north region of Thailand

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Abstract: Forest fire often occurs in mountainous and agricultural areas as a result of a complex processes involving several factors in a particular location. landscape, local weather and human interventions are the most important factors which influence the occurrence of forest fire. Ten Provinces in the upper north region of Thailand are identified as highly susceptible areas to reoccurring hotspots and smoke plumes during January to May. Identification of hotspots will significantly aid in forecasting forest fire in these areas. Using this, forest fire risk assessment may then be undertaken which can be utilize to evaluate its impacts on the society and economy.

This research focused on enhancing the application of basic concepts of forest fire risk assessment. A case study was undertaken which entailed forecasting the risk areas of forest fire in 2015 as compared to other years. Two main methodological approaches were applied, spatial modelling for susceptibility assessment and forest fire impact determination. The research generated a risk forecasting model based on major physical-spatial factors in GIS environment. Analysis Hierarchy Process (AHP) was used to define ranges of risk conditions for 7 day forecast. The risk mapping in 2015 was validated by accumulated hotspots in the same year wherein 74 % of hotspots were located in high risk zones for forest fire. Moreover, the forest fire risk forecasting was deployed by local agencies for preparedness and prevention of wildfire incidents in 2016 and 2017. Result shows that burnt areas classified from LANDSAT-8 decreased from 28,803 km² in 2015 to 16,588 and 13,658 km² in 2016 and 2017, respectively. The cross matching results between risk maps and burnt areas show better correlation percentage at 52 % in 2016 and 60 % in 2017. Thus, forest fire risk forecasting can efficiently support forest fire management implemented by government agencies and local communities.

1. INTRODUCTION

Wildfires are complex events that occur as a result of natural processes and human factors (Vasilakos et al. 2009). Forest fire is one of the most important disturbance factors for natural ecosystem which causes serious damage to socio-economic and public property, and they will threaten human' lives if they spread to residential area (Wenliang et al. 2010). In Thailand, forest fires and smoke plumes occur almost each year affecting people's health, property, the economy, society and environment. The crisis of the forest fire season annually occurs from January to April and its effect continuously felt until the end of (May). This is the state for the overall country, but more dominant on 9 provinces located at the northern part since 2014 till present. To address this issue, the government proposed a policy that would promote an integration among partner organizations to develop strategic plans during 2013-2023 for forest fire and smoke prevention. In accordance with the policy there would be guidelines for driving and integrating science and technology with the Ministry of Science and Technology. GISTDA as a specialized agency in aerospace and geospatial technology, utilized Geo-information technology from space technologies including satellites, Geographic Information (GIS) Base and Global Navigation Satellite System (GNSS) data to monitor and target hazard zones including undertaking of risk assessment. The cooperation of relevant agencies could be capable of providing devices that could assist in forest fire prevention by provincial center staffs. This could lead to consequently improve forest fires management and systematically reduce the effects of smoke.

Spatial data has been systematically developed, conforming to the rapid progress of the information technology aspects in both hardware and software. The geo-informatics technology consists of GIS, Remote Sensing (RS) and

Image Processing and GPS. The integration of Geographic Information Systems (GIS) has become increasingly important for realistic modeling of forest fire danger and behavior prediction (Lee, B.S. and Buckley, D.J.,1992). These components increase the performance for data collecting and analyzing. The processing results apply spatial data that is incorporated with modeling and simulations which develop decision support systems in planning and management of various aspects.

Geo-Informatics & Space Technology Development Agency's (GISTDA) forest fire risk assessment model was developed by using a GIS environment base on geo-information technology, satellite image processing and spatial modeling to adjust appropriate factors for analysis and defining of risk areas. The mathematical model can be interpreted into fire risk area maps with statistical data and analyzed together using Analysis Hierarchy Process (AHP). The expected result can be used for the decision making and management process by local staff in order to plan for, prevent and reduce the forest fires in prone areas.

2. OBJECTIVE

To develop a model of forest fire risk forecasting in the upper north region of Thailand for supporting forest fire management.

3. RELATED RESEARCH

A new approach for forest fire risk modeling using fuzzy AHP and GIS in Hyrcanian forests of Iran. A forest fire model was developed by Saeedeh Eskandari, 2017 to create risk map in a part of Hyrcanian forests of Iran. This model integrated fuzzy sets with analytic hierarchy process (AHP) in a decision-making algorithm. GIS tool was applied to model the fire risk with various factors in a specific area. The major factors including four criteria were topography, biology, climate, and human behavior and their 17 sub-criteria. Fuzzy AHP method was used for estimating the importance weight of the effective factors in the forest fire models. Validation results of the fire risk maps showed that 80% of the actual fires were located in the very high and high risk areas in a fire risk map. The acceptable accuracy of the risk map supports the development of a similar model and technique to monitor forest fires in Thailand.

Suchat Podchong, Ph.D. (2010), studied forest fire risk assessments in Thailand to define and confine the risk levels (low, medium and high) with the ENFA (Ecological Niche Factor Analysis) principle. This research used the Biomapper4 software and analyzed forest fire risk using statistic correlation between hotspot database (2007-2009) and local forest fire factors such as topology, fuel, population and climate. The study concluded that the risk level of forest fire with density distribution of hotspot per unit area varied according to risk level of wildfire. So the performance of the forest fire risk area map was reliable enough to compare with the amount of hotspots in the study area.

4. STUDY AREAS

The areas of interest for forest fire risk forecasting are located in 10 provinces. These comprise of Tak, Phrae, Lampang, Nan, Phayao, Chiang Rai, Chiang Mai, Lamphun, Mae Hong Son and Utaradit as shown in Figure1. Time duration of the study would be data from January to April between 2015 and 2017.

Figure 1. Study Area

5. METHOD AND DATA

Five important data that would need to be collected and analyzed from space-based sources are hotspot, burnt scars, land use/land cover, normalized difference water index (NDWI) and weather conditions as in the table 1.

Data	***Duration***	***Sources***
Hotspot	*2005 – 2017 (10 years)*	*NASA (Modis)*
Burnt scar	*2009 – 2017 (5 years)*	*LANDSAT-5, LANDSAT-8*
Land use/land cover	*2015 - 2016*	*LDD*
NDWI	*2015 - 2017 (7 Day)*	*Terra/Aqua (Modis)*
Weather	*2015 – 2017 (7 Day)*	*TMD*

Table 1. Table of Data Source

The hotspot data is to be gathered from (NASA, 2017) for the past 10 years to delineate hotspot frequency classes. The Landsat images would be classified using image processing to produce burning scar maps for the past five years, and the frequency of the burning area determined from this map. Digital land use data from 2015 - 2016 would be acquired from the Land Development Department (LDD) with land use or land cover types classified into 6 classes. These are to be used as indicators of potential surface fire behavior. The NDVI product from Terra MODIS and Aqua MODIS satellites would be considered as indicators of dry or wet conditions of the study area. The weather information of the northern part of Thailand during January to April would be collected from the Thai meteorological department (TMD.2002). In that time, the weather is assumed to be mild and dry for long periods, as an influence of the high air pressure. The precipitation, temperature and humidity are further assumed to affect the catalysts for the fire fuel and smoke wafting.

These important parameters would then be applied in a spatial model that is developed to integrate all data in raster data format to store attribute information of each factor. The Analysis Hierarchy Process (AHP) in multi-criteria decision making (Saaty, 1980) would be used since it has been stated to be a popular method. By assigning weights to the factors, they can be used to determine the best solution from several options and appropriate criteria for forest fire risk forecasting.

The fire risk forecasting in the northern part of Thailand would use the overlay technique with grid-based overlay analysis for GIS operations in the model builder tool. The spatial analysis also applied for accuracy assessment with overlay function. The efficiency of forecasting in this study relies on collecting datasets in a specific area to correlate them between physical spatial factors and local forest fire statistics. The accumulated hotspots for the last 10 years and in-situ data would be weighted by experts as listed in table 2 and the results of the overlay categorized into 3 levels (FSAC,2005):

1 = Low risk – No direct action required but consider improvements
2 = Medium risk – Action required unless good reason
3 = High Risk – immediate action required.

Factors		Score	Weight
Hotspot 10 years	none	0	5
	1 - 5 time	1	
	6 – 8 time	2	
	> 8 time	3	
Burnt Area 5 years	none	0	4
	1 - 2 time	1	
	3 – 4 time	2	
	> 4 time	3	

Factors		Score	Weight
Landuse	Water resource	0	4
	evergreen forest	1	
	urban	1	
	Agricultural perennial	2	
	Agricultural crops	4	
	deciduous forest	5	
NDWI	NDWI < -0.02	3	2
	NDWI- .002 – 0.2	2	
	NDWI > 0.20	1	
Weather	Precipitation 0 - 20 mm.	0	2
	Precipitation 21 - 50 mm.	1	
	Precipitation > 50 mm.	2	
	Humidity > 70 %	0	
	Humidity 60-70 %	1	
	Humidity 0-60 %	2	
	Temp 0- 24 ^{o}C	1	
	Temp 25- 34 ^{o}C	2	
	Temp > 35 ^{o}C	3	

Table 2. Table of Value and Weight Factor

The methodology of this study involves the use of both satellite image processing and GIS-based environment. These approaches would use mathematical operations within the spatial model to forecast the forest fire risk areas. A flowchart of the methodology of this study is shown Figure 2.

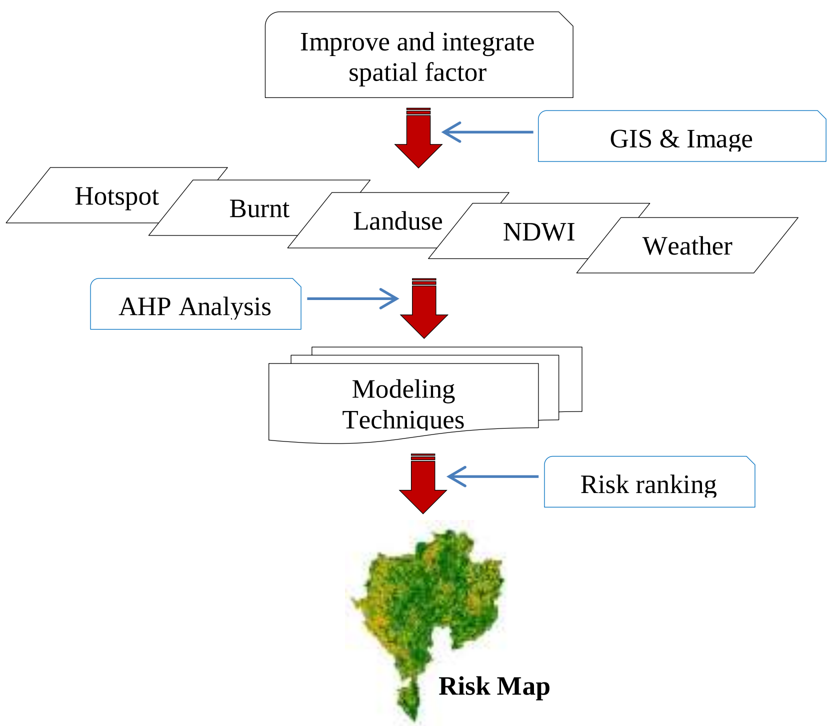

Figure 2. Methodology of this study

6. RESULT

Result shows that burnt areas classified from LANDSAT-8 decreased from 28,803 km² in 2015 to 16,588 and 13,658 km² in 2016 and 2017, respectively. The cross matching results between risk maps and burnt areas show better correlation percentage at 52 % in 2016 and 60 % in 2017.

Year	Ranking RISK	Area RISK	% RISK	BURNT	% Burnt	% Burnt in Risk
2015	Low	53,405	46	9,966	35	19
	Medium	18,406	16	4,683	16	25
	High	43,301	38	14,154	49	33
	Total	115,112	100	28,803	100	25
2016	Low	50,778	44	4,333	26	9
	Medium	22,616	20	3,676	22	16
	High	41,718	36	8,578	52	21
	Total	115,112	100	16,588	100	14
2017	Low	45,117	39	1,794	13	4
	Medium	16,815	15	3,694	27	22
	High	53,180	46	8,170	60	15
	Total	115,112	100	13,658	100	12

Table 3. Percentage Burnt area in Risk area * km^2

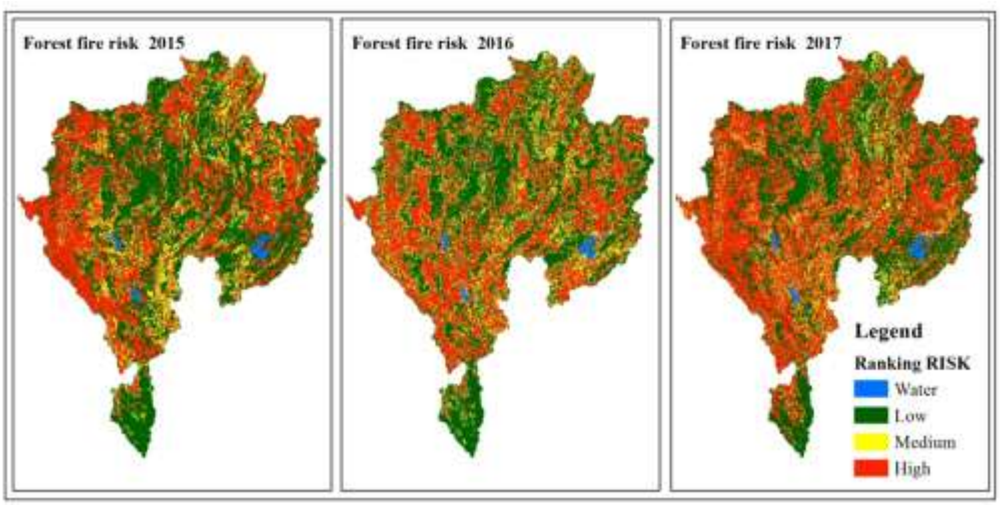

Figure 3. Forest fire risk map in 2015 2016 and 2017

This research was performed to the risk mapping in 2015 was validated by accumulated hotspots in the same year wherein 74 % of hotspots were located in high risk zones for forest fire. Moreover, the forest fire risk forecasting was deployed by local agencies for preparedness and prevention of wildfire incidents in 2016 and 2017.

Year	Ranking RISK	Area RISK	% RISK	Hotspot	% Hotspot
2015	Low	53,405	46	1,455	14
	Medium	18,406	16	1,311	12
	High	43,301	38	7,866	74
	Total	**115,112**	**100**	**10,652**	**100**

Table 4. Validation by accumulated hotspots in forest fire risk forecasting area

7. CONCLUSION

The spatial model with multi-criteria decision making is an effective approach for forest fire forecasting. So the practical model continually develops and improves processing and parameters for the forest fire risk assessment. In the future, an existing fuel quantity and forest fuel accumulation for the last 5 years will be considered as additional factors in this model. The forest fire risk maps are useful in delineating vulnerability of the areas to fire and helpful in locating and creating fire lines and locating forest fire watchers. Moreover these maps have come handy in to monitoring, prevention and reduction the severity of wildfires based on intensity and priority.

8. REFERENCE

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