MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT **MINISTRY OF EDUCATION AND TRAINING**

VIETNAM NATIONAL UNIVERSITY OF FORESTRY

LE NGOC HOAN

RESEARCH ON EFFECTIVE APPLICATION OF GEOSPATIAL TECHNOLOGY (RS, GIS, AND GPS) TO DETECT FOREST FIRE IN VIETNAM

SUMMARY OF DOCTORAL THESIS IN FORESTRY

HA NOI - 2018

The thesis is completed in:

Vietnam National University of forestry
Xuan Mai - Chuong My - Ha Noi

Supervisor: Assoc. Prof. Dr. Tran Quang Bao

Reviewer 1: ....

Reviewer 2:..

Reviewer 3: ....

The thesis is defended at the Defending Board in primary level at Vietnam National University of forestry in …………

Further more information about the research can be find at …

…………………………………………………………………..

INTRODUCTION

1. The necessary of research

Forest fire is the disaster that is not only damaging human life, property, disrupting the landscape but also has negatively impact on national security and defense and especially reducing biodiversity. In another side, forest fire has a negative influence on local weather, global warming, and the extinction of valuable species in long term. Forest fires are often occurred on large scale in mountainous area, sothat they are difficult to detect by using traditional methods. In many cases, when forest fires happen in the amount of time and spread over a large area were detected. In Vietnam, forest fires are considered as a frequent disaster.

Nowadays, geospatial technology is one of the most exciting technologies in the world. In forestry, geospatial technology has been widely applied, such as area calculation, identify spatial distribution of forest, forecasting and warning of forest fire, monitoring of forest resources. So the application of geospatial technology on forest fire detection is very necessary. It provides an effectively method to help forest manager to have the appropriate forest fire prevention and control solution. Then the research on “the Effective application of Geospatial technology (RS, GIS, and GPS) to detect forest fire in Vietnam” were conducted.

2. Research objectives

2.1. General objective: *Apply geospatial technology effectively to enhance the quality of forest resources management, especially in detection and management of forest fire in Vietnam*.

2.2. Specific objectives: (1) To emprove the quality of forest fire detection in Vietnam by applying forest fire detection algorithm from MODIS satetlite images combining with data from "National Forest Inventory" program; (2) To develop the forest fire detection model from ground-based monitoring equipments for early detecting forest fires and minimizing the damage caused by fire; (3) To propose the technical solutions for detecting forest fires automatically from satellite images and ground-based monitoring equipments.

3. Research object and research scope

3.1. Research object

(1) Satellite images are capable of detecting fires; (2) Forest fires have occurred over a 5-year period; (3) The latest forest status according to national forest inventory data; (4) Algorithm for extracting hotpots from satellite images and analyzing frame from surveillance equipment to detect forest fires;

3.2. Research scope

(1) Spatial: *(i)*Satellite images on a national scale. (ii) Hotspot in Lai Chau, Hai Duong, Kon Tum and Kien Giang rpr extracting process. (iii) Verification of the possibility of hotspot in forest fire in the past at the Lao Cai, Hoa Binh, Ha Tinh and Da Nang. (iv) Comparison between the hotspots and occurred forest fires in Lao Cai, Hoa Binh, Ha Tinh and Da Nang for verification; Burning the sample plot to verify the ground-based monitoring equipment in U Minh Thuong National park, Ba Vi National park, Hanoi Forest Protection Management Board and Vietnam National University of Forestry.

(2) Temporal: (i) MODIS images from 2010 to 2015. (ii) Forest fire data in period of 2010 – 2015.

(3) Contents: (i) Select algorimth. (ii) Testing and verification, (ii) to propose technical solution to detect forest fires in Vietnam.

(4) Data: (i) Data of practical forest fires: second data of 100 forest fires in the past of Forest Protection Department at Lao Cai, Hoa Binh, Ha Tinh and Da Nang.

- Satellite images was dowloaded from NASA website (https://ladsweb.modaps.eosdis.nasa.gov);

- Algorithm and method of detecting forest fires were referenced from the published research and scientific papers.

4. New contributions of the research

4.1. Research methodology: the research is the comprehensive study of the application of geospatial technology in the detection of forest fires by selection, algorithm application, testing, data transmitting and improvement of alarm methods.

4.2. About theoretical and academic aspects: *(i)* applying geospatial technology to collect a large amount of image data on a large scale and multi-temporal to study about detection of forest fires in forest resource management in Vietnam. (ii) Develop an automatically video analysis algorithm, extracting forest fires from ground-based monitoring devices to establish an effective fire detection system automatically in Vietnam.

4.2. About practical aspect: *(i)* Determine the ability to automatically detect forest fires from MODIS images. (ii) Develop a ground-based monitoring device that automatically detects fires for areas at high risk of forest fire. (iii) Propose advanced solutions to automatically early detect forest fires, then contributing to improving the quality of forest fire prevention and control activities in Vietnam.

Chapter 1
LITERATURE REVIEW

The contents of published researches and papers are related to (1) Geospatial technology (RS, GIS, and GPS). (2) Overview of forest fires forecast. (3) Overview of forest fire prevention and control. (4) Overview of forest fire detection methods. (5) Overview of forest fire detection model.

The basis for forest fire forecasting is the close linkage between weather conditions, especially rainfall, humidity with material moisture and potential for forest fires MiBbach,1972; Belop, 1982; Chandler, 1983). In addition, based on the material moisture, water content in the soil, wind speed, number of days without rain and evaporation, etc.

Researches on fire detection methods from satellite images have been studied in many countries, but there are some limitation.

Researches on ground monitoring device show that the variation of the optical system works on different algorithms all of which share the same principle of smoke detection and fire. Wireless sensor technology typically uses a large number of small sensors which are set up at high density, which can observe and collect physical information around and convert it into electrical signals then send them to further locations to analysis in different applications.

From the overview content, this research are conducted to (1) Select satellite images data, algorithm for extracting hotspot by *Louis Giglio* et al developed in 2003, algorithm for detecting smoke and fire to test forest fire detection in Vietnam. (2) Analyze the relationship between some parameters and occurred forest fire in Vietnam, then proposing the algorithm or detecting forest fires that suitable for conditions of Vietnam. (3) Use geospatial analytical technology that is integrated remote sensing, GIS and automatically filter out hotspot within forest area to provide forest managers the credible informations. (5) Study on establishing forest fire monitoring and detection devices based on ground. (5) Propose the establishment of an automated information system for forest management by telephone, emails, messages and websites.

Chapter 2
CONTENTS AND METHODOLOGY

2.1. Research contents

2.1.1. Research on the possibility of detecting forest fires from satelite images: *(1) Selecting satellite imagery suitable for research; (2) Application of algorithm to extract hotspot from satellite images*; (3) *Analyzing the relationship between the brightness threshold and the confidence level of hotspot; (4) Testing the ability to detect forest fires from satellite images; (5) Analyzing and identifying the brightness threshold and the deviation ΔT of hotspots of forest fires in Vietnam; (6) Eliminating the fires located in the non-forest area.*

2.1.2. Research on the possibility of detecting forest fires from ground-based monitoring devices: (1) Application fire detection algorithm for video frame; (2) Application fire detection algorithm for camera IP; (3) Testing the forest fire detection model based on ground monitoring; (4) Influence the height and distance of the ground monitoring device to the fire.

2.1.3. Propose technical solutions for detecting forest fires from satellite imagery and ground monitoring device

2.2. Research methodology

2.2.1. Theoretical method

<u>Theoretical point:</u>

(1) Remote sensing technology, in particular infrared remote sensing (especially mid-infrared and thermal-infrared), allows detection of fires and hotspot that are closely related to fires.

(2) Combination of remote sensing and information technology provide early detection and monitoring of fire exactly, which can effectively support forest fire prevention.

Approach point:

(1) Geospatial technology mainly is used throughout the research content.

(2) Information technology will be integrated to use in data processing and transmitting.

(3) Experimental model will be used to evaluate and test the accuracy of the results.

2.2.2. Particular method

2.2.2.1. Research methodology for detecting forest fire from satellite images

(1) Selecting suitable remote sensing images

In order to have a basis for the selection of remote sensing image for research purposes, the author analyzes the technical characteristics of remote-sensing imagery being widely used and having many applications on forest fire detection. The technical characteristics of the image analyzed include *spatial resolution, spectral resolution, coverage, etc.* In addition, the dissertation also analyzes *image availability, supply, price, level of application in the detection of forest fire.*

(2) Application of algorithm to extract hotspot from satellite images

Thesis applied algorithms of Louis Giglio et al. which were developed in 2003 based on the original algorithm of Kaufman in 1993 to extract hotspot from MODIS satellite. The algorithm uses brightness temperatures derived from the MODIS 4-and 11 µm channels, denoted by T_4 and T_{11} respectively. The MODIS instrument has two 4- Am channels, numbered 21 and 22, both of which are used by the detection algorithm. Channel 21 saturates at nearly 500 K; channel 22 saturates at 331 K. T_{11} is computed from the 11 µm channel (channel 31), which saturates at approximately 400 K for the Terra MODIS. The 12 µm channel (channel 32) is used for cloud masking; brightness temperatures for this channel are denoted by T_{12}.

(3) Analysis of the relationship between temperature T_4 channels with confidence level: The thesis use nonlinear regression to analysis relationship between temperature of T_4 channels and confidence level. In which, confidence is depend variable (Y) and the temperature is the independent variable (X)

(4) Testing detection rate of hotspot from MODIS image comparing with occurred fires: Applied ArcGIS 10.4.1 software to identify hotspots that have fire in the past.

(5) Proposed temperature threshold T_4 channel and ΔT value that suitable to detect forest fires in Vietnam: Based on outputs of algorithm, author aggregate 2 parameters including T_4 and ΔT and compare these between in occurred fire and hotspot to define threshold under Vietnamese conditions.

(6) Eliminate non-forest hotspots

Use ArcGIS software to determine the location of hotspots that within or outside the forest area.

2.2.2.2. Research methodology for detecting forest fire from ground-based monitoring device

(1) Algorithm for detecting forest fire from ground monitoring devices

In this research, the author did not build a new algorithm for image processing. A combination of algorithms that are being applied around the world are used to process a type of image data, to enhance confidence level of forest fire alarm information. In specific, the image obtained from the camera will be divided into 8 x 8 pixels. In the preprocessing stage, the DCT (Discrete Cosine Transform) inter-transformation is applied to all DCT blocks of 8 × 8 coefficients of each frame to get DCT blocks of 4 × 4 coefficients. Using the DC values of each DCT block of the 4 × 4 coefficients of several consecutive frames, motion and color properties of smoke are analyzed to get the smoke region candidates.

(2) Test the forest fire detection of ground monitoring devices

The research set up some “control burning point” in some areas to test algorithm and model as follows:

(i) U Minh Thuong National Park (Kien Giang)

(ii) Ba Vi National Park (Ha Noi)

(iii) Development Centre of Forestry in Ha Noi (Soc Son, Ha Noi)

(iv) Vietnam National University of Forestry

(3) Analyze the relationship and influent between height and distance of the monitoring device to the “control burring” area

Logistic regression is the appropriate tool in this case has form:

$$Ln(Y_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

In which Y_i is dependent variable that takes only values 1 or 0, X is independent variable, ε is the error (noise). The probability that Y = 1 with condition of $X_1 = X_o$. Then, $P(Y = 1/X_o) = p_i$ and $P(Y=0/X_o) = 1 - p_i$ respectively.

To check for the existence of parameters, the value of Sig will be compared to the significance level $\alpha = 0.05$. If Sig ≤ 0.05 the parameter exists, and otherwise Sig> 0.05 the parameter does not exist. In addition, Sig also shows the influence of independent variables on the dependent variable, the smaller the Sig the greater the degree of influence.

*** Coefficient of influence**

In this research, the direct influence of 2 factors including instance and height on fire detection were investigated to find out which factors had a more pronounced and significant. To do this task, the commands are used in SPSS.

Chapter 3
RESULTS AND DISCUSSIONS

3.1. Research on the detection of forest fires from satellite image

3.1.1. Selection of satellite image results

The thesis analyzed characteristics of 14 types of satellite images about spatial resolution, *spectral resolution, temporal resolution, coverage, image availability, supply, price, level of application in the detection of forest fire*. The thesis has identified the image used for detecting forest fires is MODIS image. Because MODIS images are free material; its temporal resolution is short (4 swaths per day); multi-spectral resolution including 2 channels 4 μm (channel 21 and 22) that are suitable for extracting hotspot; large coverage. Then MODIS is efficient to use for detecting forest fire in Vietnam.

3.1.2. Applied algorithm to extract hotspot results

3.1.2.1. The spatial distribution of hotspot

The total number of hotspot extracted from the MODIS satellite in the period of 2010-2015 is 123.558 hotspots and is distributed as following:

Table 3.1. The spatial distribution of hotspot

Region	Spatial distribution of hotspots					
	2010	2011	2012	2013	2014	2015
Red River Delta	199	278	228	211	196	303
Northeast	2123	801	1255	1254	1480	1700
Northwest	7548	2446	6230	3606	6314	4208
North Central Coast	2310	1627	1539	1793	2190	2744
South Central Coast	1771	1671	1783	2199	3105	3718
Central Highlands	7073	6962	6029	5214	5766	5502
Southeast	2041	1539	1177	1171	1419	1607
Southwest	2180	876	1436	1850	2056	2830

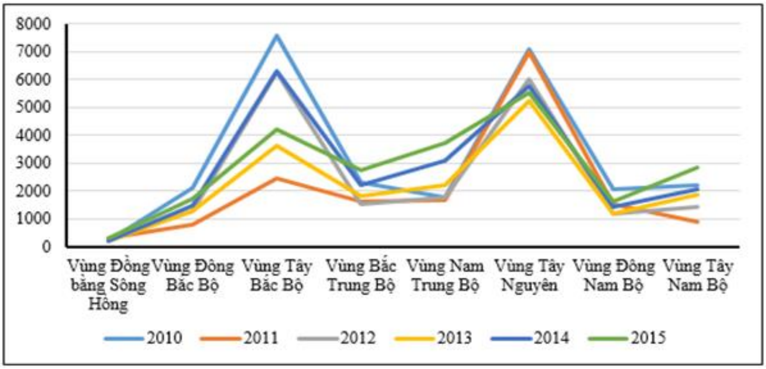


Figure 3.1. The diagram of spatial distribution of hotspots

The results show hotspot mainly located in some regions such as the Northwest region 6,519 hotspots; Central Highlands: 52,221 hotspots; Central Vietnam: 38,217 hotspots; and the regions of South West: 15,689 hotspots, the North East: 13,809 hotspots, the South East: 13,000 hotspots and the Red River Delta: 2,177 hotspots. In general, hotspots are located in the provinces that have large forest area.

3.1.2.2. The temporal distribution of hotspots results

According to data of hotspots from 2010 to 2015, this research has aggregated and determined the temporal distribution of hotspots by month. The results are illustrated as following:

Table 3.2. The temporal distribution of hotspots

No	Time	Hotspots	Note
1	January	13608	
2	February	29867	
3	March	55116	
4	April	35995	
5	May	15728	
6	June	8342	
7	July	4457	

8	August	4577	
9	September	3130	
10	October	2591	
11	November	2814	
12	December	5407	

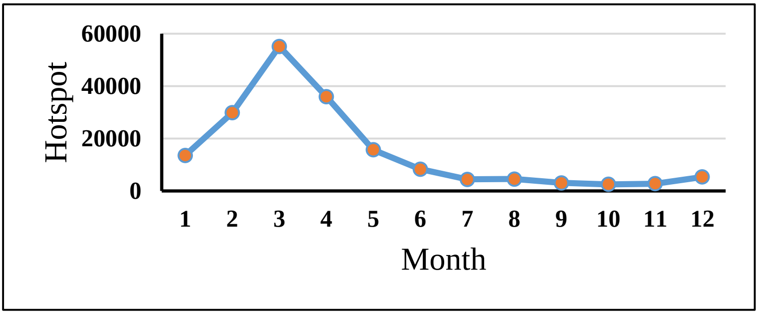


Figure 3.2. The diagram of temporal distribution of hotspots

According to table 3.2 and fig. 3,2, hotspots occurred mainly from November to June of the following month, even extended to July. It happened focus on period January to May, especially in the Northern provinces. Because dry season is long combination with solar energy, then surface temperature is increased leading to the emission of heat. However, depending on each regions, hotspots may occur differently about amount or time.

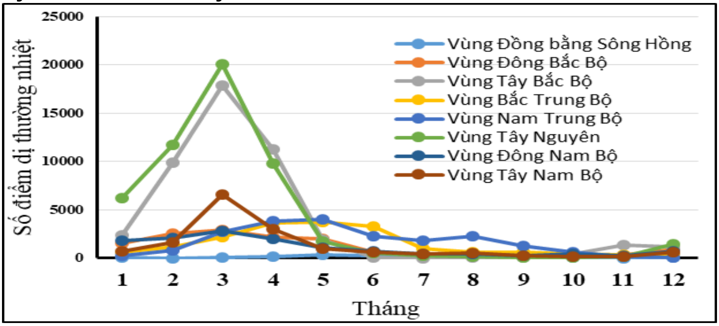
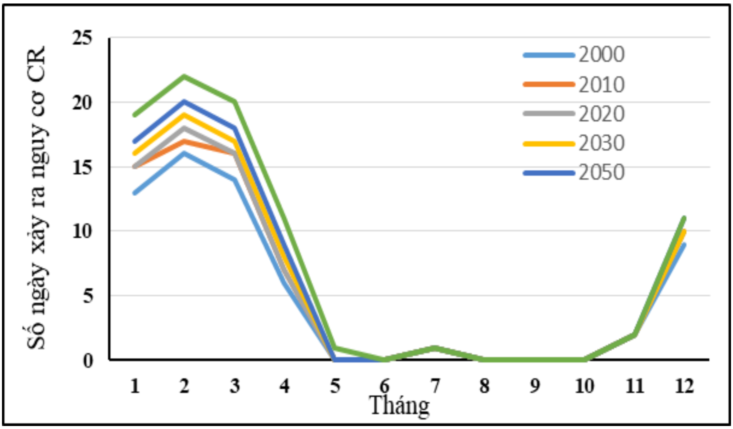


Figure 3.3. The diagram of spatial and temporal distribution of hotspot

The results show that three major areas of change are the Central Highlands, the Northwest and the South West; hotspots mainly occurred from February to April and reach a peak in March. However, the appearance frequency of hotspots in central region gradually increase from March to June and reach the highest pint in April and May. In period of August and September there are few areas of the country where have occurred hotspots.

In the other hand, the research “Method of forecasting the risk of forest fires under climatic conditions in Vietnam” of Vuong Van Quynh and Le Sy Doanh has concluded that the high risk of forest fire in Vietnam mainly focuses from November to April of the following year (Fig. 3.4).



Source: Doanh et al., 2014

Figure 3.4. Timeline of the risk of forest fire in Vietnam in different periods

The thesis shows results of spatial and temporal distribution of hotspots is relatively consistent with research of Vuong Van Quynh and Le Sy Doanh. It can be concluded that the algorithm of Louis Giglio et al. to extract fire in the form of images and lists of fire points for detection and warning of forest fires in Vietnam is absolutely appropriate and well-founded.

3.1.3. The relationship between brightness threshold and confidence level

The confidence level of forest fire detection provides the evident for manager to evaluate the quantity of particular pixel of fire. Confidence level (ranging from 0% to 100%) is divided into 3 levels (low, medium and high level) for all points.

The results showed that Quadratic and Cubic function are the most suitable to simulate the relationship between brightness and confidence level. Because they have largest R-square coefficient, the correlation is relatively closed. Therefore, it can be said that the effect of brightness on confidence level is relatively clear. When brightness changes, it will affect the possibility of hotspot, which means that when temperature high the confidence level is high.

3.1.4. Testing the detectable of forest fire from MODIS image results

3.1.4.1. Testing the ability of forest fire detection from MODIS image

To determine the ability of detecting hotspot from MODIS image compared with occurred forest fire, the research used data of 100 occurred forest fires in Lao Cai, Hoa Binh, Kom Tum and Da Nang that provided by Forest Protection Department. By using GIS technology to overlay and analyze data, the results showed:

Table 3.3. The results of occurred fires that contained hotspot.

No	**Region**	**Number of occurred fire**	**Number of occurred fire that contained hotspot**		**Number of occurred fire that not contained hotspot**	
			Point	Proportion (%)	Point	Proportion (%)
1	Hoa Binh	24	18	75.00	6	25.00
2	Ha Tinh	46	31	67.39	15	32.61
3	Da Nang	25	17	68.00	8	32.00
4	Lao Cai	5	5	100	0.0	0.0
	Total	**100**	**71**	**71.00**	**29**	**29.00**

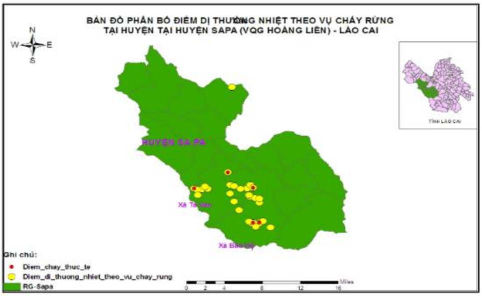


Fig. 3.5. Map of occurred fire that contained hotspot in Hoang Lien National Park, Lao Cai

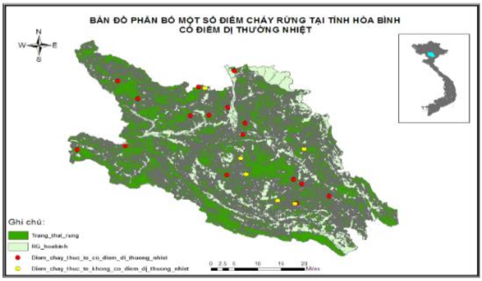


Fig. 3.6. Map of occurred fire that contained hotspot in Hoa Binh

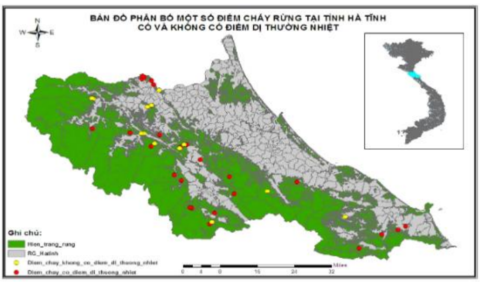


Fig. 3.7. Map of occurred fire that contained hotspot in Ha Tinh

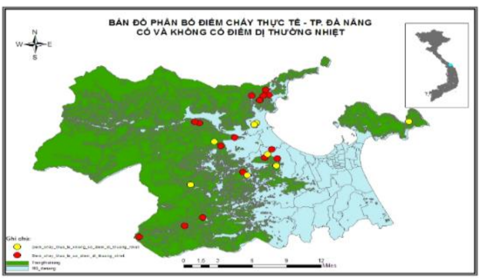


Fig. 3.8. Map of occurred fire that contained hotspot in Da Nang

In general, the results showed in 100 occurred fires in 4 provinces, there was 71 occurred fires that contained hotspot (accounting for 71%). This has proved that the ability to extract hotspot of the algorithm is relatively good, can be applied to detect forest fire in Vietnam.

The proportion of 29% occurred fires that not contained any hotspots could be due to a number of causes such as the confidence level of local reported about fires, path of satelite, fire area, etc.

3.1.4.2. Determining brightness threshold T_4 and ΔT value according to occurred fires

The results of analyzed 71 occurred fires show brightness threshold and they are equal or higher than 312k, and reach a highest point at 352k (table 3.4).

According to value of T_4 and ΔT above, it can be concluded that brightness threshold of fires or hotspot on Vietnam reaches from 310l and ΔT is 10k or higher due to input threshold of algorithm.

Table 3.4. Summary table of brightness threshold and ΔT value of occurred fires

Value	Region			
	Da Nang	Ha Tinh	Hoa Binh	Lao Cai
Brightness_T_4 (K)	315-337	313-352	314-335	312-349
Bright_T_{31} (K)	280-305	278-308	283-306	282-303
ΔT (K)	20-49	22-49	11-43	16-62

3.1.5. Eliminating hotspots are in non-forest area results

Algorithm extracted 123.558 hotspots which were overlaid with national forest inventory data by ArcGIS 10.4.1 and MapInfo 11. sortwares. The results show the proportion of 29.74% hotspots in a non-forest area. In addition, results also illustrate the distribution of hotspots on 4 provinces that have been showed some provinces with large forest area, the number of hotspots in non-forest area is low and vice versa. This result has important implications for improving the effectiveness of the fires prevention and control in Vietnam.

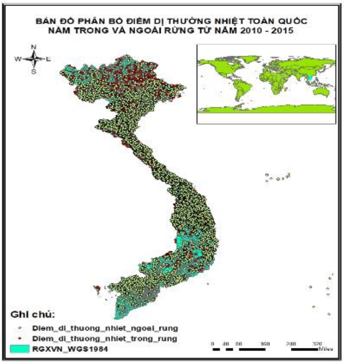


Figure 3.9. The distribution of hotspot in period of 2010-2015

3.1.6. Technical solutions for detecting forest fires from satellite imagery and ground monitoring device

3.1.6.1. Technical solutions for detecting forest fires

(1) Image acquisition: MODIS images are provided by NASA with 4 paths per day for Vietnam from TERRA and AQUA satellite.

(2) Data processing and hotspot determining: Using algorithm of Louis Giglio et al which developed in 2003 based on original algorithm of Kaufman in 1993.

(3) Removal of hotspot in non-forest area: Overlaid hotspot with forest inventory map by ArcGIS and MapInfo softwares.

3.1.6.2. Solution of fire alarm transmitting from the satellite image

Alarm information is provided in the following forms: (i) – send SMS messages to mobile phones, (ii) Email, (iii) Online website of fire surveillance.

3.1.6.3. System structure solution

(1) Server: Running Windows operating system, .NET Framework 4.0 or higher; Microsoft SQL Server 2008; Web uses IIS 7.0 or higher; ArcGIS Server 10.5 and devices have internet connection.

(2) Software extract hotspot and transmit fire information.

(3) Satellite image receiving station: from NASA Website or directly from the Forest Department.

(4) Receiving alarm devices: Phone, Tablet, computer, etc.

3.1.6.5. Advantages, disadvantages and application conditions

- *Advantages:* (i) large fires are often detected timely and bring certain effects in forest fire detection and control; (ii) Detecting abnormalities in temperature (hotspot) then alarm for stakeholders to active in establishing the effective forest fire prevention and control.

- *Disadvantages*: (i) cannot detect small fire area even occurred fires; (ii) Disturbed information from hotspots that are not fires (it takes time, workers, and materials when monitoring hotspot)

- *Application conditions*: forest fire detection and alarm transition system are applied for whole country that is installed at a fixed location.

3.2. The results of forest fire detection from ground monitoring devices

3.2.1. Testing algorithm with video frame results

The test results of 10 frames each time have low false alarm rate. Frame 01 has the highest false alarm rate of 3% and especially frame 6 has false rate false 0%, and remaining frames have a false alarm rate from 0.2 to 1%. The reason for false warning is due to in frames have many vehicles, and nest to camera has a large branch that are shaking by wind and dim background; in contrast, other frames are in static state, clear background. It means that with these conditions, the application of algorithms for forest fire detection is possible.

3.2.2. Testing algorithm with camera IP frame results

- *Smoke detection*

a b c

Figure 3.10. Smoke candidate region; (a, b) consecutive frames; (c) after processing

a b c

Source: Bao et al., 2017

Figure 3.11. (a)The development of fire; (b) consecutive frames; (c) after processing

From the algorithmic test results for the video frames and camera IP frames show:

- Discrete Cosine Transform algorithm, of each block size 8x8 if the inputs of smoke and fire process.

- Some characteristics of smoke, fire, move, color, and expansion properties are analyzed directly in the DCT domain to minimize the time and increase the accuracy of the results.

- JPEG image processing algorithms from digital cameras can be used to detect forest fires in Vietnam.

3.2.3. Testing model of forest fire detection from ground monitoring devices results

Research established some "control burning" plots in U Minh Thuong National Park, Ba Vi National Park, and Development Centre of Forestry in Ha Noi. The results of testing model are illustrated as following:

Table 3.5. Summary of testing model of forest fire detection from ground monitoring devices

No	Place	Control burning plot		
		Total	Detected	Not detected
1	U Minh Thuong National Park	18	14	4
2	Ba Vi National Park	4	3	1
3	Development Centre of Forestry in Ha Noi	10	10	0
	Total	32	28	5

The results show that 28 of 32 fires are detected and 5 fires are not detected.

In flat area condition, a device can observe the fire up to a maximum of 4 km from the system location, equivalent to a monitored area of 5,539 ha in flat terrain at U Minh Thuong National Park.

In complex area condition, a device can monitor the fire that far from station maximum 2.4 km approximately 1,808.64 ha.

On the other side, device cannot detect fire because it is obscured or its view coincides with the horizon. It can conclude that terrain conditions are one of the important factors in application of ground monitoring device to detect forest fire.

3.2.3.4. Analysis of the influence of height and distance of monitoring devices to fires.

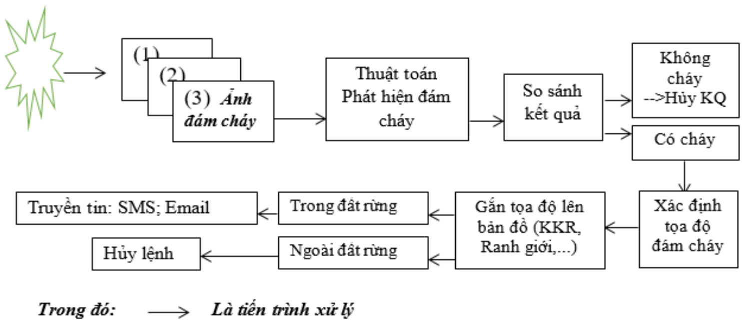
The form of logistic regression model is:

$$\text{Ln}(Phat\_hien) = 7.238 - 0.154 * Chieu\_cao - 1.339 * khoang\_cach$$

Because the parameters of height and distance are negative, it means that when the distance and height increase, the fire detection capacity will decrease. Moreover, the effect of distance is really evident on the ability to detect fire (Sig=0.017<0.05), while the effect of height is not really significant (Sig=0.217>0.05). These results also shows the influent of distance factor is more significant than height factor.

3.2.4. Technical solutions for forest fire detection from ground monitoring devices

3.2.4.1. Technical solutions for forest fire detection from ground monitoring devices



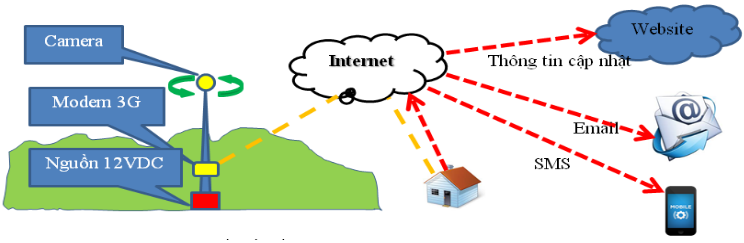
Source: Bao et al., 2017

Figure 3.12. The flow chart of detecting forest fire process based on ground monitoring devices

3.2.4.2. Solution for fire alarm transmission from ground monitoring devices

The manager receives and manage forest fire alarm from system as following: (1) Check the forest fire informations; (2) process these information.

3.2.4.3. Solution for forest fire detection system architecture



Source: Bao et al., 2017

Figure 3.13. The forest fire detection system architecture

3.5.2.5. Advantages, disadvantages and application conditions

- Advantages: (i) The ground monitoring system accurately detects active forest fires based on smoke's color (day time) or fire's color (night time); (ii) The forest fire monitoring and transmitting system based on ground monitoring devices can be used to detect small-scale fires, which can be integrated with MODIS satellite to increase accuracy.

- Disadvantages: This system cannot be applied for large area; it cannot detect forest fire in complicate terrain conditions.

- Application conditions: (i) In flat terrain, small angel of slope such as Southwest region; (ii) Early fire detection and alarm transmission based on ground monitoring devices are designed to observe critical areas, valuable forest areas, historic sites, cultural sites, protected areas, national parks that have high risk of fire.

CONCLUSION AND DISCUSSION

1.1. Forest fire detection and alarm transmission based on satellite image

1. The satellite image used for extracting hotspot and alarm transmitting is MODIS image; the temporal of this satellite image is 4 swaths per day (2 swaths in day time, and others in night time), multi-spectral resolution including 2 channels 4 µm (channel 21 and 22) that are efficient in detecting forest fire.

2. The algorithm used thermal infrared channels of the MODIS satellite image to detect hotspot; automatically processed bands 20, 22 and 31 combination with cloud mask to export fire data in form of image and lists of hotspot.

3. The test results of algorithm for extracting hotspot have confirmed the efficient of using this to detect forest fire due to spatial and temporal distribution in Vietnam.

4. Using MODIS image to detect forest fire in Vietnam accounted for 71% compared with occurred forest fires.

5. The brightness threshold (T_4) of forest fires or hotspot in Vietnam is 310K or higher and ΔT value is 10K or higher.

6. Applied National Forest Intervention data has eliminated 30% hotspots in non-forest area. This proportion can be increased more than 90% in provinces that have small forest area. This results brings benefit to managers of forest owners for determining the location of fires more accurately.

7. The model automatically receives MODIS images from NASA website or station of Forest Protection Department; Automatically process received images by closed cycle. The output is hotspots that are extracted and transmitted to managers by Email, SMS, etc.

In conclude, the detection of forest fires based on multi-temporal satellite image has significant benefits, which plays an integral part to set up an automatic model for forest fire detection and alarm transmission.

1.2. Forest fire detection and alarm transmission based on ground monitoring devices

1. Discrete Cosine Transform algorithm is the efficient tools to detect smoke and fire.

2. Test results confirmed:

- Monitoring capability of the devices by terrain: in flat conditions the proportion of detectable is higher than one in complicate conditions (high slope).

- Monitoring capability of the devices by view of equipment: When the monitor is set up in suitable location and the view is large enough, the accuracy of detection is high. By contrast, in cloudy conditions or the view of equipment is obscured, devices may not detect fire.

3. The forest fire monitoring and transmitting system based on ground monitoring devices can be used to detect small-scale fires, which can be integrated with MODIS satellite to increase accuracy; it is suitable for detecting in critical areas, valuable forest areas, historic sites, cultural sites, protected areas, national parks that have high risk of fire such as Southwest region (U Minh Thuong and U Minh Ha National park, etc). This device can be applied and transferred into practice in order to improve the efficiency of current forest protection and management.

4. The forest fire monitoring system consists of the following steps: (i) camera monitor forest area (the area depend on the location of camera); (ii) data processing software connects to

camera to receive captured images via the internet. Captured images from each camera will be analyzed to determine the location of fire. If a fire occurs, the system will perform sound and automatic send alarm email to predefined Email and SMS. (ii) After receiving the alarm information, manager re-check information and take appropriate plan.

2. Recommendations

In order to effectively apply remote sensing data for forest fire detection, the research propose some recommendation as follows:

1. Combining a number of remote sensing images such as AVHRR, ASTER, LANDSAT 8 to improve forest fire prevention and control in Vietnam.

2. Continuing to study and improve the forest fire detection system from MODIS satellite image and clarify the effect of rainfall and other meteorological parameters on the risk of forest fires, from which establish a forest fire prediction model in short and long term.

3. Continue to test the model of forest fire detection from ground monitoring devices at different heights, different distances and different terrains to confirm the forest fire detection capacity of the system.

4. For forest fire detection and alarm transmission system from satellite images, it need to develop and combine with the forest fire warning system of the Forest Protection Department to be used for forest fire prevention in Vietnam.

5. For forest fire detection and alarm transmission from ground monitoring devices, it need to continuous development, transfer and install in areas at high risk of forest fire (National Park, Protected area, etc) to replace tradition fire watch station.

PUBLICATIONS

1. Le Ngoc Hoan, Tran Quang Bao, Mai Ha An (2016), "Technical in early detection of fire by imaging analysis from IP camera", *Journal of Agriculture and Rural Development*, page 117-123.
2. Tran Quang Bao, Phung Nam Thang, Le Ngoc Hoan (2016), "Developing software for early detecting forest fire from MODIS satellite images", *Journal of Agriculture and Rural Development*, page 114-120.
3. Tran Quang Bao, Mai Ha An, Le Ngoc Hoan (2016), "Designing and Manufacturing Ground Station for Monitoring and Transmitting Forest Fire Information", *Journal of Forest Science and Technology*, page 52-58.
4. Tran Quang Bao, Nguyen Trong Cuong, Le Ngoc Hoan, Mai Ha An (2016), "Developing software to automatically detect forest fires from ground monitoring stations", *Journal of Forestry Science,* page 4538-4546.
5. Tran Quang Bao, Le Ngoc Hoan (2018), "Verification of forest fire detection from MODIS satellite images in Vietnam", *Journal of Agriculture and Rural Development* page 246-253.
6. Le Ngoc Hoan, Tran Quang Bao (2018), "Application of algorithm to extract hotspot from MODIS satellite images for forest fire detection in Vietnam", page 94-102.