APPLICATION OF GEOINFORMATICS TECHNOLOGY FOR DETECTING ACTIVE FOREST FIRES IN VIETNAM

Tran Quang Bao[1], Le Ngoc Hoan[1]
[1]*Vietnam National University of Vietnam*

SUMMARY
This paper presents the results of applying geoinformatics technology in early detection of forest fires in Vietnam. Two methods were used to detect forest fires, including (1) Using ground monitoring equipment: applying algorithms to detect smoke and fire from the series of "forest fire" recorded by IP Camera, characteristics of smoke, such as color, movement and expandable properties used in fire detection; accuracy of algorithm for fire detection with video frames is 97% and with image frames from digital cameras is 100%; Ground monitoring equipment can detect 84.38% of testing fires, and indicated the cause of the fire not being detected. (2) Using MODIS satellite image: Applying algorithm developed by Louis Giglio (2003) to extract thermal anomaly from MODIS satellite image; The accuracy of using MODIS satellite image to detect forest fire from is 71% with the brightness level is from 310 degrees K and the deviation value (ΔT) is 10 degrees K or more; the accuracy of forest fire detection increases by applying GIS tools and national forest inventory data to eliminate thermal anomalies outside the area of forest land. The study has proposed models to detect forest fires and transmit forest fires information from ground monitoring equipment, and from MODIS satellite images, the models can be applied for forest fire monitoring and management in Vietnam.
Keywords: Forest fire detection, Geoinformatics, MODIS, smoke and fire detection.

1. INTRODUCTION

In Vietnam, forest fires are a frequent disaster. In many cases, a forest fire can be detected when it has occurred for a long time and spread over a large area, inadequate information may lead to low firefighting effectiveness, causing much damage, especially for special-use forests with a lot of tourists, flammable areas in the dry season (Tran Quang Bao et al., 2017). In recent years, an average of 650 fires occurred annually, an average of 4,340 ha of forest loss, of which planted forests are about 3,200 ha, and natural forests are about 1,140 ha. In 2002, forest fires in U Minh Thuong and U Minh Ha destroyed 5500 ha of cajuput forest, of which 60% were primary Melaleuca forest. In early 2010, forest fires in Hoang Lien, Lao Cai National Park, damaged more than 700 hectares of forest. Forest fires have caused substantial economic, social, and environmental losses and are difficult to calculate (Le Sy Doanh et al., 2017).

The main causes of frequent and widespread fires are long-term drought, careless use of fire in the forest, lack of modern equipment for fire prevention and fighting. Currently, many fire detection and monitoring systems are in use in the world, including observation towers, satellite image surveillance systems, optical camera sensor detection, and monitoring systems, or combination detection technologies (Ahmad, 2014). Today, geoinformatics technology is one of the world's most exciting technologies. In the forestry sector, this technology has been widely applied to determine the spatial distribution of forest types, forecasting and warning of forest fires, and monitoring forest resources (Ahmad, 2014; Le Ngoc Hoan, 2018).

Therefore, the study of the application of geoinformatics technology to detect forest fires is now essential. It will provide forest managers have appropriate forest fire prevention and fighting solutions. The objectives of the study are: (1) proposing a model for detecting forest fires from ground monitoring equipment; (2) proposing a model for remote sensing application in forest fire detection in Vietnam.

2. RESEARCH METHODOLOGY

2.1. Detecting forest fires from ground monitoring equipment

2.1.1. Algorithm for detecting forest fires

The image collected from the camera was divided into blocks of 8 x 8 pixels of each frame. After division, bi-dimensional DCT (*Discrete Cosine Transform)* was applied to non-overlapped blocks of 8 × 8 pixels of each frame. In the preprocessing stage, the DCT inter-transformation was applied to all DCT blocks of 8 × 8 coefficients of each frame to get DCT blocks of 4 × 4 coefficients. Using the DC (Discrete Cosine) value of DCT blocks to classify potentially smoke or fire blocks and remove non-suspicious blocks (Leonardo Millan-Garcia et al., 2012; Le Ngoc Hoan et al., 2016). Algorithm application results with real images are described in Fig. 01. To test the accuracy of the algorithm in detecting forest fires, the study used 06 video frames taken by the camera during the day and night.

A. Daylight Images

Image without fire   Image with fire   Image of detecting fire

B. Night Images

Image without fire   Image with fire   Image of detecting fire

Figure 1. Detecting potential forest fire by applying the algorithm

2.1.2. Testing the accuracy

To assess the accuracy of detecting forest fires from ground monitoring equipment, the research team conducted control burnings at:

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

(ii) Ba Vi National Park, Ba Vi, Hanoi;

(iii) Hanoi Protection and Special Use Forest Management Board, Soc Son, Hanoi.

2.1.3. Effect of height and distance

Logistic regression was developed to determine the relationship between the height and distance of the monitoring device and the ability to detect fire (Nguyen Hai Tuat et al., 2006):

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

In which, Y_i is dependent variable taking only two values 0 and 1, X_i are independent variables, ε is errors. The probability for Y = 1 under the condition $X_1 = X_o$, written as P (Y = 1/Xo) = pi and similar to P (Y = 0/Xo) = 1 - pi.

To check the existence of the parameters, the Sig. value was used to compare with the significance level of $\alpha = 0.05$. If Sig ≤ 0.05, the parameter then existed, and vice versa. In addition, Sig. value also indicated the degree of influence of the independent variables on the dependent variable, the smaller the Sig., the higher the influence level.

2.2. Detecting forest fires from satellite images

2.2.1. Selecting remote sensing images

The satellite imagery selected for forest fire detection was analyzed based on image characteristics and actual usability. (1) Characteristics of image: spatial resolution, spectral resolution, image swaths, and temporal resolution (2) Practical usability: image availability, price, level of application in detecting forest fire.

2.2.2. Algorithm to extract anomalous thermal spots from satellite images

Using the algorithms by Louis Giglio et al., developed in 2003 based on the original algorithm of Kaufman in 1993 to extract anomalous thermal spots from MODIS satellite images. The algorithm uses brightness temperatures derived from the MODIS 4µm and 11 µm channels, denoted by T_4 and T_{11}, respectively. The MODIS satellite has two 4 µm 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. The 12- µm channel (channel 32) is used for cloud masking; brightness temperatures for this channel are denoted by T_{12} (Louis Giglio et al., 2003; Le Ngoc Hoan et al., 2018).

2.2.3. The brightness threshold (T4) and ΔT values for Vietnam.

Based on the results of verifying hotspots detected by MODIS images in the past that have occurred forest fires, compared threshold values of T4 and ΔT in actual fires with the values of the algorithm to determine threshold values appropriated for Vietnamese conditions.

2.2.4. Eliminate hotspots distributed outside the forest

Applying GIS technology was used to determine the distribution of hotspots detected by MODIS image, then it overlaid the hotspot map on the forest status map to eliminate hotspots distributed outside the forest area.

3. RESULTS AND DISCUSSIONS

3.1. Detecting forest fires from ground monitoring equipment

3.1.1. Testing algorithm with video frames

Testing algorithms with six video frames (10 times/each video frame) has a relatively low false alarm rate, ranging from 0 - 3%. Test results show:

- Discrete Cosine Transform (DCT) algorithm of each 8 × 8 block was an input data for detecting smoke and fire from forest fires.

- The characteristics of smoke, fire, motion, color, and expansion were analyzed directly in the DCT, to minimize the time and increase the accuracy of the calculation results.

- The JPEG image processing algorithm taken from digital cameras was applied well for detecting forest fires in Vietnam (Figure 2 and Figure 3).

a b c

Figure 2. Day-time smoke test block; (a, b) consecutive frames; (c) Image after processing

a b c

Figure 3. Night-colored fire test blocks; (a, b) consecutive frames; (c) Image after processing

3.1.2. Testing forest fires detected by ground monitoring equipment

The results in table 1 show that there were 27 forest fires detected (84.38%) and 05 undetectable fires (15.63%) in a total of 32 tested fires. The device can detect fire at a maximum distance of 4 km in flat terrain and 2 km in complex terrain, equivalent to a forest area of 5539 ha and 1808.64 ha, respectively.

Table 1. Results of detection for testing fires

No.	Locations	Number of testing fires		
		Total	Detected	Non-detected
1	U Minh Thuong National Park	18	14	4
2	Ba Vi National Park	4	3	1
3	Ha Noi FDPC	10	10	0
	Sum	**32**	**27**	**5**

The fires were undetectable by the equipment because the view was obscured, or the view overlapped with the horizon. This means that terrain conditions are one of the important factors in the application of ground monitoring equipment for early detection of active forest fires.

3.1.3. Effects of the height and distance for detecting forest fires

The regression equation for the effect of height and distance on fire detection is as follows:

$$Ln(Fire\_Detection) = 7.238 - 0.154 * Height - 1.339.Distance$$

Negative parameters of height and distance variables mean when distance and height increase, the ability to detect fire will decrease. The effect of distance is significant on the ability to detect fire (Sig = 0.017 <0.05), while the effect of height is not significant (Sig = 0.217 > 0.05). The influence from the distance and height factors is greater than those of other indirect factors that have not been considered in the model.

3.1.4. Technical solution for detecting and transmitting forest fire information

The technical solution is shown in figure 4.

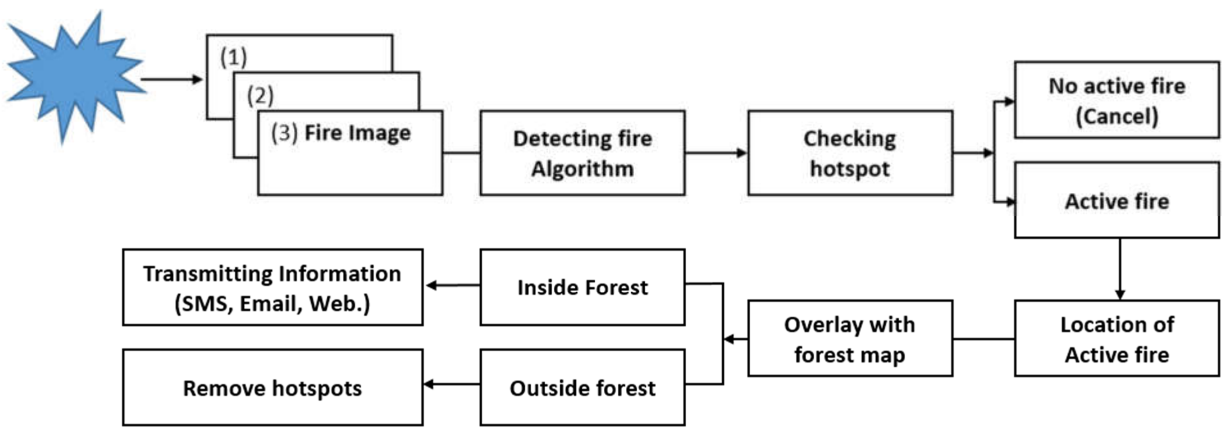


Figure 4. Diagram of detecting forest fires from ground monitoring equipment

The structure and operational mechanism of fire detection and information transmission for ground monitoring equipment is shown in figure 5.

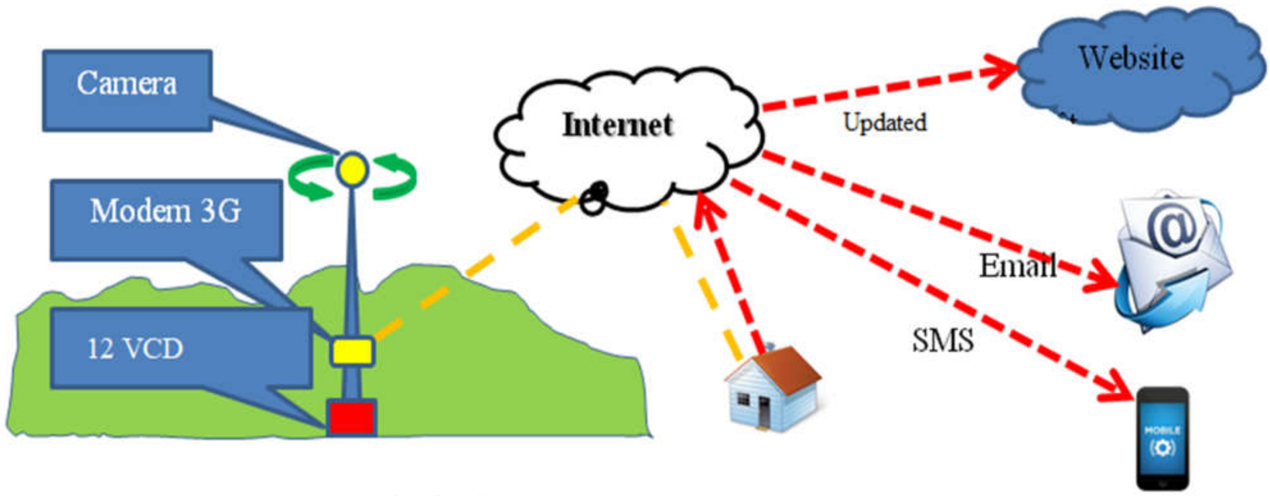


Figure 5. Structure and operation of ground monitoring equipment

Advantages: (i) The ground monitoring system detects active forest fires through smoke color during the day and fire color at night; (ii) useful application for detecting small fires.

Disadvantages: The system cannot monitor for a large forest area; Do not detect fires in complex terrain conditions, limiting the view of the device.

Application conditions: (i) in forest areas with flat terrain and low slope (ii) in high-value forest areas, such as historical and cultural forest, protected areas, national parks with high-risk fire.

3.2. Detect forest fires from satellite images

3.2.1. Selected remote sensing image

From the results of analyzing the characteristics of 14 satellite images that can be used to detect forest fires. Currently, MODIS satellite imagery is the most appropriated for detecting forest fires in Vietnam because it is a free sensor, short flight cycle (4 sessions/day), Multi-spectral image with two channels of 4 µm (band 21 and 22) suitable for extracting hotspots; wide swaths.

3.2.2. Results of thermal anomaly extraction from MODIS

The total number of thermal anomalies extracted from MODIS satellite image from 2010 to 2015 was 123,558 points. This result is shown in figure 6.

The results of using the algorithm with MODIS satellite images to extract hotspots show that (Figure 6): the algorithm analyzes data from MODIS satellite images using near-infrared channels to detect the occurrence of thermal points. A forest fire, depending on the temperature, emit heat into the atmosphere at infrared wavelengths. Therefore, pixels with wildfire will have a strong spectral reflection in comparison with surrounding pixels. A hotspot is identified when it gets a certain level of heat emission and the temperature difference with surrounding pixels. Therefore, the anomalies extracted from the algorithm can be active forest fires, slash, and burn in the upland, factory, building block in the city.

For spatial distribution: thermal anomalies are mainly distributed in the Northwest region; Highland; Central region; then to the Southwest regions; the Northeast region, the Southeast region, and finally the Red River Delta region (Table 2 and Figure 7).

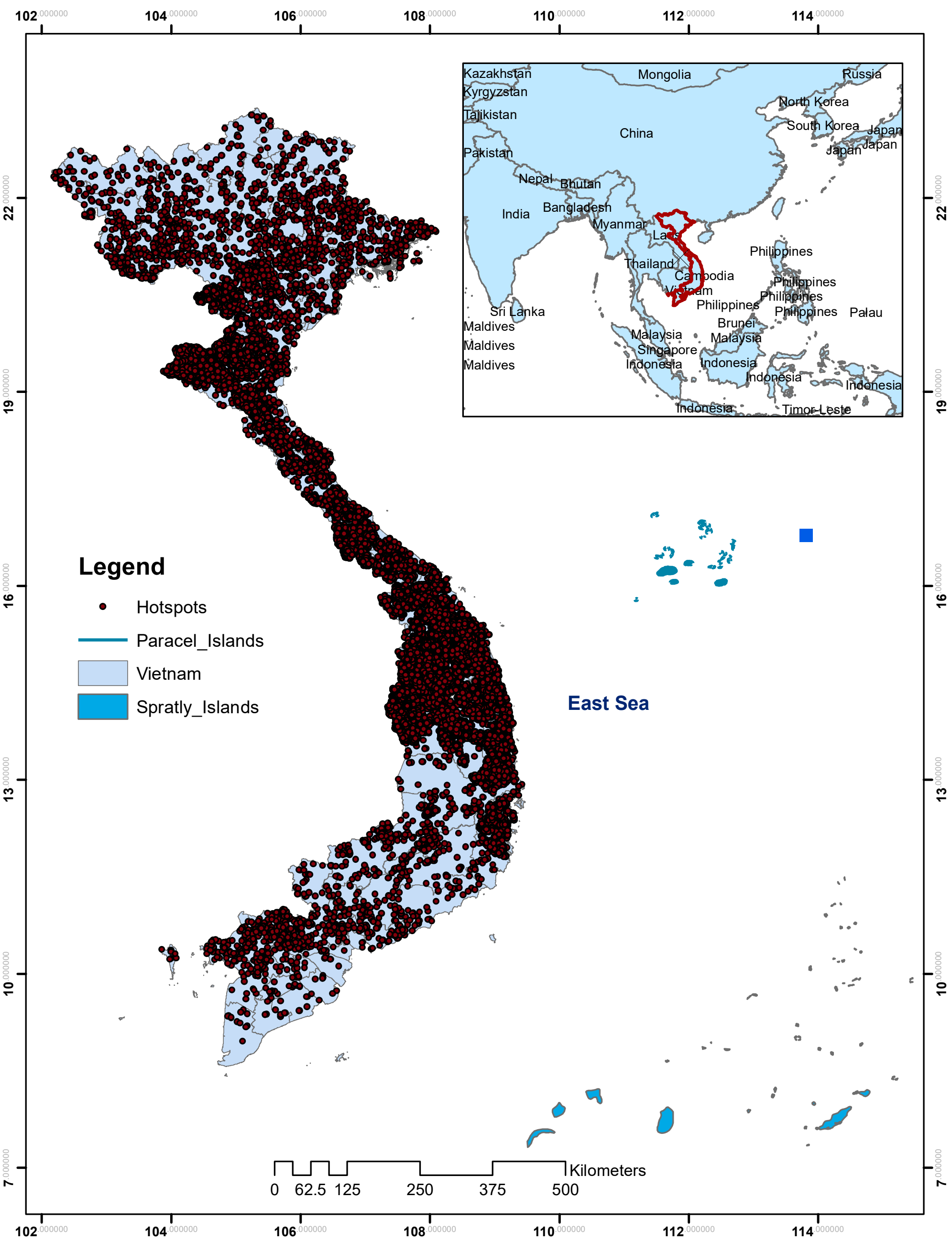
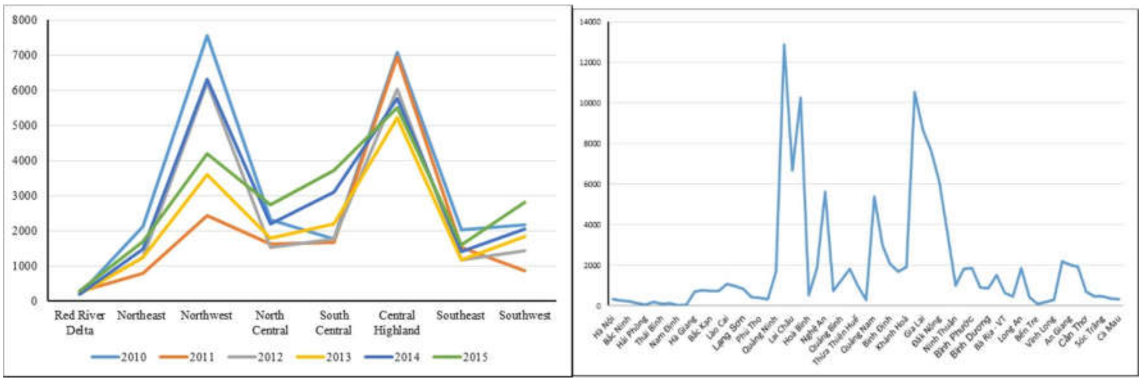


Figure 6. Distribution of hotspots in 2010 - 2015 extracted from MODIS

Table 2. Spatial distribution of potential forest fires

Regions	Spatial distribution by years					
	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	2310	1627	1539	1793	2190	2744
South Central	1771	1671	1783	2199	3105	3718
Central Highland	7073	6962	6029	5214	5766	5502
Southeast	2041	1539	1177	1171	1419	1607
Southwest	2180	876	1436	1850	2056	2830



a b

Figure 7. Spatial distribution of hotspots: a) by geographical region; b) by provinces

By time: the detected hotspots occur mainly from November to June of next year, and mainly from January to May, especially in the Northern provinces. (Figure 8).

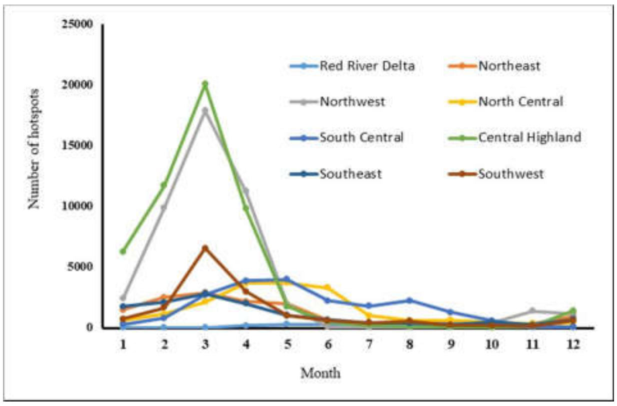


Figure 8. Distribution of hotspots by time for regions

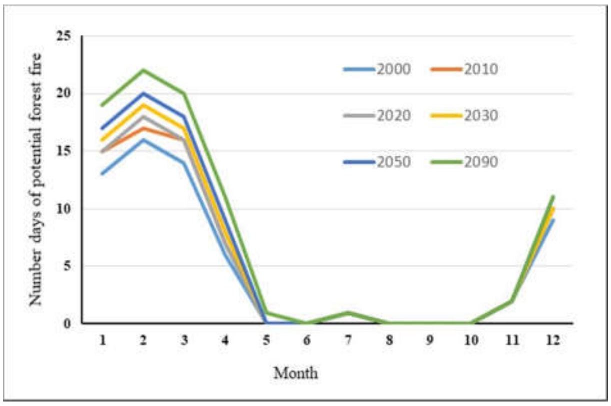


Figure 9. Number days for potential forest fires

The hotspot distribution extracted from MODIS satellite images is similar to those of Vuong Van Quynh and Le Sy Doanh (2014). They have confirmed that the high risk of forest fires in Vietnam is mainly from November to April next year (Figure 9).

3.2.3. The accuracy of forest fire detection from the MODIS satellite image

Applying GIS technology to overlay maps and eliminate hotspots without forest fire, verification results are shown in table 3.

Table 3. Comparison of actual fire and hotspots

No.	Provinces	Real Fires	Real Fires with hotspots		Real Fires without hotspots	
			# points	Ratio (%)	# points	Ratio (%)
1	Hoa Binh	24	18	75.00	06	25.00
2	Ha Tinh	46	31	67.39	15	32.61
3	Da Nang	25	17	68.00	08	32.00
4	Lao Cai	5	5	100	0.0	0.0
	Sum	**100**	**71**	**71.00**	**29**	**29.00**

The results of checking thermal anomalies points in 4 provinces/cities (Table 3) show that there is only 71 actual forest fire out of 100 hotspots. This means that the algorithm's ability to extract anomalous thermal points is relatively good and can be applied to detect forest fires in Vietnam.

With the rate of 29% of past forest fires being inspected without any hotspot from MODIS could be due to many different reasons; the reliability of the fire reported by local authorities to the Forest Protection Department, time of satellite image, scale of the fire.

** Identifying the threshold of brightness level and deviation value (ΔT)*

By checking 71 actual forest fires in the past (Table 4), the value of brightness level reaches from 312 degrees K and above and the highest value is 352 degrees K. With the values of brightness level and deviation value ΔT above. It can be suggested that the brightness value of forest fires or heat anomalies in Vietnam is from 310 degrees K and ΔT is 10 degrees K or more according to the input threshold of the algorithm.

Table 4. Ranging of brightness value and ΔT of actual fires

Indicators	Province/City			
	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

3.2.5. The result of removing hotspots distributed outside the forest

Using 123,558 anomalous thermal points extracted from the algorithm, overlaid the layer with a national forest map by using ArcGIS tools 10.4.1 and Mapinfor 11.0. As a result, 29.74% of the thermal anomalies points were removed outside the forestry land. In addition, the results of the distribution of thermal anomalies points in the four provinces have also been confirmed that the larger provincial forest land, the lower outside hotspots, and vice versa. This result has important implications for improving the effectiveness of forest fire prevention and fighting in Vietnam.

3.2.6. Technical solutions for detecting and transmitting forest fire warnings from satellite images

** For detecting forest fires*

(1) Image acquisition: MODIS images are provided by NASA with four images/day for Vietnamese territory from TERRA and AQUA satellites.

(2) Data processing and identifying thermal anomalies: using the algorithm of Louis Giglio et al. (2003) developed based on the original algorithm of Kaufman (1993).

(3) Overlapping thermal anomalous points with national forest inventory map Eliminating thermal anomalies outside forest land.

** For transmitting forest fire warnings*

The warning forest fire information is sent in the following forms: (i) SMS to mobile phones; (ii) Email; (iii) Online webpage.

** For system structures*

(1) Server: running on Windows operating system, with .NET Framework 4.0 or higher; For Microsoft SQL Server 2008, the Web used is IIS 7.0 or higher; ArcGIS Server 10.5. The device has an internet connection.

(2) Software for extracting and transmitting anomalous thermal points.

(3) Satellite image receiving station: used from the NASA Website or directly from the station of Forest Protection Department, Ha Noi.

(4) Warning device system: phone, tablet, computer.

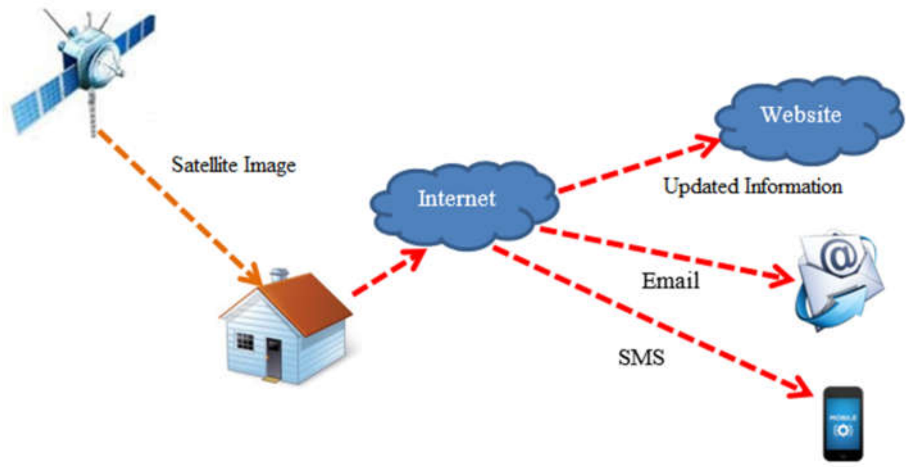


Figure 10. System structure for forest fire detection from Modis satellite image

** Advantages and disadvantages of the system.*

- Advantages: (i) Large scale forest fires are usually detected promptly and effectively in forest fire prevention and fighting; (ii) Detecting temperature anomalies, transferring information to relevant stakeholders to proactively prevent and fight forest fires.

- Disadvantages: (i) Failing to detect small-scale forest fires, including those already occurring; (ii) sometimes the fire warning information is disturbed due to non-fire thermal anomalies (wasting resources for monitoring).

- Using the system: The system for forest fire detection and transmission from MODIS satellite images can be installed and operated nationwide, installed at fixed locations, and managed by the central authority.

4. CONCLUSIONS

The accuracy of the fire detection algorithm for video frames and for digital camera frames is 97% and 100%, respectively; The application of smoke and fire detection algorithm from the "forest fire" image sequence recorded by IP Camera is suitable for forest fire detection in Vietnam. Test results of forest fire detection from ground monitoring equipment reached 84.37%. A device can observe the fire is at a maximum distance of 4 km (5539 ha) and 2.4 km (1808.64 ha) in flat terrain and complex terrain, respectively. The effect of distance factor from the fire is more significant than height factor of the equipment.

The satellite image used to detect forest fires is MODIS; The algorithm to extract the anomalous thermal point was developed by Louis Giglio in 2003, based on the original algorithm of Kaufman in 1993. The accuracy of detecting forest fires from MODIS satellite images is 71%; Threshold of brightness level is from 310K and above, and deviation value (ΔT) is 10K or more according to the threshold of the algorithm's input; Using a national forest status map has improved the results of forest fire detection in Vietnam.

REFERENCES

1. Ahmad A. A. Alkhatib (2014). *A Review on Forest Fire Detection Techniques.* International Journal of Distributed Sensor Networks, Vol. 10 (3).

2. Tran Quang Bao et al. (2017). *Research on using geospatial technology (RS, GIS, GPS) in detecting forest fires and monitoring forest resources*. Report of Research Project, MARD, Ha Noi.

3. Le Sy Doanh, Vuong Van Quynh (2014). *Method of forest fire risk prediction based on climatic conditions in Vietnam. Journal of Forest Science and Technology.* Vol. 01/2014.

4. Eunna Jang, Yoojin Kang, Jungho Im, Dong-Won Lee, Jongmin Yoon and Sang-Kyun Kim (2019). *Detection and Monitoring of Forest Fires Using Himawari-8 Geostationary Satellite Data in South Korea*. Remote Sensing, Vol. 11 (3).

5. Le Ngoc Hoan, Tran Quang Bao, Mai Ha An (2016). *Early Forest Fires Detection Algorithm by Image Processing Captured from IP Cameras*. Journal of Agriculture and Rural Development. Special Issue, 2016.

6. Le Ngoc Hoan and Tran Quang Bao (2018). *Application of Algorithm to Extract Fire Hotspot from MODIS Satellite Images for Forest Fire Detection in Vietnam*. Journal of Forest Science and Technology, Vol. 01/2018.

7. Leonardo Millan-Garcia, Gabriel Sanchez-Perez, Mariko Nakano, Karina Toscano-Medina, Hector Perez-Meana and Luis Rojas-Cardenas (2012). *An Early Fire Detection Algorithm Using IP Cameras*. Sensors 2012, 12, 5670-5686, pp. 5670-5686.

8. Louis Giglio, Jacques Descloitres, Christopher O. Justice, Yoram J. Kaufman (2003). *An Enhanced Contextual Fire Detection Algorithm for MODIS.* Remote Sensing of Environment 87, 273-282.

9. Maryna Zharikova, and Vladimir Sherstjuk (2019). *Forest Firefighting Monitoring System Based on UAV Team and Remote Sensing*. Automated Systems in the Aviation and Aerospace Industries (Chapter 8).

10. Wu Fengbo, Lv Xitong, Zhang Huike (2018). *Design and Development of Forest Fire Monitoring Terminal*. International Conference on Sensor Networks and Signal Processing (SNSP).

ỨNG DỤNG CÔNG NGHỆ ĐỊA TIN HỌC TRONG PHÁT HIỆN CHÁY RỪNG Ở VIỆT NAM

Trần Quang Bảo[1], Lê Ngọc Hoàn[1]
[1]Trường Đại học Lâm nghiệp

TÓM TẮT

Bài báo này trình bày kết quả nghiên cứu ứng dụng công nghệ địa tin học trong phát hiện sớm cháy rừng ở Việt Nam. Cháy rừng được phát hiện bằng 2 phương pháp: (1) Sử dụng thiết bị giám sát mặt đất: ứng dụng thuật toán phát hiện khói và lửa từ chuỗi ảnh *"cháy rừng"* được ghi lại bởi Camera IP, các đặc điểm của khói, như là màu sắc, chuyển động và các thuộc tính dãn nở được sử dụng trong phát hiện đám cháy; độ chính xác của kết quả thử nghiệm thuật toán trong phát hiện cháy với khung hình video là 97% và với khung hình từ máy ảnh kỹ thuật số là 100%; kết quả đốt thử nghiệm bằng thiết bị giám sát mặt đất đạt 84,38%; (2) Sử dụng ảnh vệ tinh MODIS: Ứng dụng thuật toán của Louis Giglio và cộng sự (2003) để trích xuất điểm dị thường nhiệt từ ảnh vệ tinh MODIS; kết quả kiểm chứng khả năng phát hiện cháy rừng từ ảnh vệ tinh MODIS là 71%, ngưỡng cấp độ sáng (brightness) là từ 310 độ K trở lên và giá trị độ lệch (ΔT) là 10 độ K trở lên; ứng dụng công cụ GIS và dữ liệu kiểm kê rừng toàn quốc, để loại trừ các điểm dị thường nhiệt nằm ngoài diện tích đất lâm nghiệp nhằm nâng cao kết quả phát hiện cháy rừng. Nghiên cứu đã đề xuất được mô hình phát hiện cháy rừng từ thiết bị giám sát mặt đất và mô hình phát hiện và truyền tin cháy rừng từ ảnh vệ tinh MODIS, phục vụ công tác phát hiện cháy rừng ở Việt Nam hiện nay.

Từ khoá: Công nghệ địa không gian, MODIS, phát hiện cháy rừng, phát hiện khói và lửa.

Received	**: 11/9/2019**
Revised	**: 13/10/2019**
Accepted	**: 21/10/2019**