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STUDY ON PROPOSING FOREST FIRE MANAGEMENT SOLUTIONS FOR HOANG LIEN NATIONAL PARK

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THESIS SUMMARY

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INTRODUCTION

1. The necessity of the thesis

In Vietnam and many countries over the world, forest fire is a common phenomenon causing damage to forest resources, environment, property and human life. According to the report of the Forest Protection Department, in the period from 2003 to 2016, Vietnam had 40,838.85 ha of burnt forest, of which planted forest was the most b urnt object, accounting for 69%, and natural forest (31%). Therefore, forest fire prevention and suppression (FFPS) is one of the most important tasks in the management and protection of forest resources in Vietnam in general, in forest ecological zones and national parks in particular.

Hoang Lien national park with a total area of 28.509 ha, belongs San Sa Ho, Lao Chai, Ta Van and Ban Ho communes in Sa Pa district, Lao Cai province and Muong Khoa and Than Thu communes in Than Uyen district, Lai Chau province. It is identified as one of the most biodiverse centers in Vietnam, where many endemic rare and precious species, as listed in the Vietnam Red Book and the World Red Book, are living. However, in recent years, in association with the raising of climate change and human impacts, forest fires have appeared more frequently in this area. Statistics show that during the period from 2009 to 2016, forest fires caused damage to 937.85 ha of forest the national park. In particular, the fires in 2010 destroyed 718 ha, causing many losses in terms of resources, wealth, environment, biodiversity, and tourist landscapes.

Given that situation, forest fire management and restoration have received special attention from authorities at all levels, sectors and people in this area. Comprehensive research is needed to propose synchronous and effective solutions for FFPS and forest restoration based on scientific and practical basis.

Therefore, the problem in the current context for this region is to build FFPS solutions effectively. In order to contribute to solving this problem, I has implemented the thesis **"Study on proposing forest fire management solutions for Hoang Lien national park"**. The thesis will supplement scientific data on the situation of forest fires, the impact of forest fire on soil, plants, the ability to recover of forests after fire, and propose comprehensive solutions for FFPS and forest restoration based on a scientific and practical basis for the study area.

2. Objectives of the thesis

2.1. Goals

- Contributing to the development of scientific and practical solutions for forest fire management (FFM), in order to reduce forest fire risk (FFR) at Hoang Lien national park.

2.2. Objectives

- Evaluating basic characteristics of forest resources in Hoang Lien national park;
- Assessing the characteristics of forest fire, factors affecting forest fire and the current situation of FFM at Hoang Lien national park;
- Evaluating forest recovery ability after fire at Hoang Lien national park;
- Proposing solutions for FFPS and forest restoration after fire for Hoang Lien national park.

3. Subjects and scope of the research

3.1. Research subjects

- Forest before fire and regenerating forest after fire;
- The main factors affecting forest fires and the stakeholders involved in FFPS at Hoang Lien national park.

3.2. Research scope

- Content: including studies to evaluate the complete situation of forest fire, resilience of forest ecosystems after the fire in February 2010, the current FFM solutions, focusing on solutions for forest fire prevention and forest restoration.

- Space: Hoang Lien national park's areas in of Ban Ho, Ta Van, San Sa Ho communes in Sapa district, Lao Cai province.

- Time: from 2010 to 2016.

4. New contributions of the thesis

- Successfully assessing the restoration ability of forest plants and forest land after fire at Hoang Lien national park;

- Successfully identifying a group of plants supporting fire prevention;

- Successfully building a map of FFM for Hoang Lien national park area;

- Proposing a number of solutions for FFM and forest restoration after fire with scientific basis, suitable with the scientific orientation of community-based FFM model for Hoang Lien national park.

5. Scientific and practical significance

5.1. Scientific significance:

The thesis has supplemented the scientific proof of the impact of forest fire on soil, organisms and the ability of forest regeneration after fire at Hoang Lien national park.

5.2. Practical significance:

The thesis has identified a list of fire-proof and fire-resistant plants in the study area, proposed solutions for FFM and forest restoration after fire, and provided scientific orientation of community-based FFM model for Hoang Lien National Park.

Chapter 1. LITERATURE REVIEW

Based on a general review of 99 related studies that have been published in the world and in the country according to the following topics: (1) Specific concepts; (2) Overview of documents related to FFM; (3) Overview of documents on studying the effects of forest fire on ecosystems and forest restoration after fire; (4) Overview of FFM documents at Hoang Lien National Park, the author summarized:

- In the world, research on FFM has been carried out in many countries since the beginning of the 20th century, mostly in countries with developed economies and forest industries. During the period after the 60s, research contents in this field focused on the following issues: conditions and causes of forest fires, types of forest fires, fire characteristics, interactions between fire, forest and the environmental ecosystems, methods and technologies for assessment and warning of forest fire risk, forest fire prevention and control measures.

- In Vietnam, research on FFM only started in the 80s of the 20th century and has rapidly developed since 2002. The main achievements include the following issues:

+ The effect of environmental factors on forest fire.

+ Enhancing methods and software for forest fire forecasting for local regions.

+ Solutions for FFPS: green belt, controlled burning of fuels, hydrology management in FFPS.

+ Improving equipment for FFPS

+ Select fire-resistant plants for fire prevention.

+ Using high technology in forecasting and early detection of forest fires.

+ The impacts of climate change on forest fires.

The research work has helped to significantly improve the ability of FFPS in the country in recent years. However, the research on FFM in our country still has some limitations:

+ There are no studies to develop specific FFPS solutions for national parks and protected areas in the northern mountainous area. These are areas where many people believe that there is little or no chance of serious forest fires.

+ The participation of the community has a great influence on the success of local FFM. However, the method of community-based fire management and the construction of these models is not really interested in northern mountainous localities.

+ There are no comprehensive and long-term studies on the dynamics of forest biome after forest fires in order to build a basis for forest restoration.

Hoang Lien national park is one of the biggest biodiversity centers in the country. Forest fires are identified as one of the important factors that negatively impact on forest resources in this area. Therefore, it is necessary to conduct comprehensive research to propose solution for FFM and forest restoration after fire for the national park.

Chapter 2. RESEARCH CONTENT AND METHOD

2.1. Research content

In accordance with the research objectives, the thesis identifies the following specific contents:

1) Basic characteristics of forest resources in Hoang Lien national park;

2) The characteristics of forest fire, factors affecting forest fire and the current situation of FFM at Hoang Lien national park;

3) The ability of forest regeneration after fire over time at Hoang Lien national park (2010 - 2016);

4) Solutions for FFPS and forest restoration after fire at Hoang Lien national park.

2.2. Research Methods

2.2.1. Approach

The thesis follows approaches including: Systems approach, multidisciplinary approach, development approach, and participatory approach.

2.2.2. Research Methods

(1). Methods to identify basic characteristics of forest resources in Hoang Lien national park area

a. Identifying distribution of forest resources: Inheriting documents and forest maps according to the inventory results in 2016 of Hoang Lien national park in combination with field survey.

b. Identifying structural characteristics of main forest types:

At high elevation areas and where forest fires often occur, the study established 47 sample plots (SPs) of 500m^2 representing forest conditions in Hoang Lien national park.

Table 2.1: Description of SPs used in the study

Commune	**Number of SPs by forest type**							**Total**
	TXG	TXB	TXN	TXP	HG1	RTG	DT2	
Ta Va	0	2	4	7	3	2	2	20
Ban Ho	0	2	2	4	0	1	5	14
San Sa Ho	2	2	2	5	0	0	2	13
Total	***2***	***6***	***8***	***16***	***3***	***3***	***9***	***47***

In each SP, the study conducted:

- Investigation of woody tree layer: Applying common research methods in forestry to collect data on the main characteristics of woody tree, including: tree species, DBH, canopy diameter (Dt), top height (Hvn), trunk height (Hdc), canopy cover, growth assessment.

- Investigation of shrubs, understory vegetation, and regenerating trees: intensively collecting data on 5 sub-plots $9m^2$ distributed evenly in each SP, including: top height, stem diameter, quality and regeneration type of regenerating trees, and understory vegetation coverage.

- Identifying composition of woody trees and regenerating trees: determining tree species and the number of individuals by species, counting the number of species and the total number of individuals of the species, calculating the average number of individuals per species (Ntb) and the coefficient of composition (Ki).

(2) Methods to determining forest fire characteristics, factors affecting forest fire, and the current FFM situation at Hoang Lien national park

a. Determining forest fire characteristics: inheriting documents, using Landsat 8 satellite images to monitor burnt forest area, investigating SPs of $500m^2$ on burnt forest locations where forest fires occurred in 2010, and interviewing indigenous people to supplement necessary information to assess the level of damage caused by fire.

b. Determining main factors affecting forest fires

- General methods: inheriting documents, interviewing National Park staffs, officials and local people with PRA and RRA tools.

- Determining characteristics of fuel in each forest types:

+ On 9 sub-plots of $1m^2$ distributed evenly in each SP, collecting data of basic characteristics of fuel, including: composition, volume, humidity, height of shrub vegetation, dry layer thickness, and combustibility.

+ Measuring volume of fuel by types and determining material moisture content by collecting samples in each SP and analyzing in laboratory.

c. Determining the participation of people in FFM at Hoang Lien national park

- Referring to documents of Hoang Lien National Park Forest Protection Department to assess the strengths and weaknesses of community participation as a basis for proposing fire management solutions for the study area.

- Interviewing local people, forest rangers, officials in the 3 communes where forest fires have often occurred (Ta Van, Ban Ho and Lao Chai) using the RRA and PRA toolset. In Ta Van and Ban Ho communes, interviews were conducted with 60 people each; in Lao Chai commune, interviewing 25 people. The total number of questionnaires was 145.

- Using M. Hosley's method to assess the level of participation of people in FFM (according to Be Minh Chau, 2012). From the collected data in combination with group discussions to assess the situation and to propose a model of FFPS for local communities in Hoang Lien national park.

(3) Methods to evaluate the possibility of forest restoration after fire over time (2010 - 2016)

a. Determining forest vegetation characteristics after fire:

- Conducting a preliminary investigation through 3 routes: From Tram Ton-Nui Xe area to trails to sub-area 272 and 274, from National Park Centre to Ta Van Commune and from National Park Centre to Ban Ho Commune.

- Intensively investigating in 15 SPs in two large areas of burned forest in 2010 in Ta Van and Ban Ho communes. On each plot, conduct a detailed survey of plants including: woody trees,

shrubs and understory vegetation, and regenerating trees. The investigation in Ta Van commune was carried out in 3 phases: August 2010; April 2013 and February 2016. The survey in Ban Ho commune was conducted in two phases: April 2013 and February 2016.

b. Determining the characteristics of soil after fire: implementing on 15 SPs, which represent forest types of DT2, HG1, and TXP, have not been damaged by fire and the counterparts in burnt areas 6 months, 38 months and 72 months after fire. On each SP, the study collected 03 soil samples of 0.5 kg and 3 soil density samples to determine the porosity. Soil samples were treated and analyzed for criteria including: density, porosity, moisture, pH, organic content and content of easily digested NPK.

c. Identification of fire resistant plants

- Interviewing 45 people to collect information on potential species resistant to fire from the knowledge of local people in Ban Ho, San Sa Ho and Ta Van communes.

- Collecting data in 18 SPs representing burnt and unburnt natural forests (2-3 SPs of 500m^2 each forest type) on the characteristics of high tree structure and regenerating plants.

- Identifying neighboring species of fire-resistant trees capable of preventing fire in 60 samples of 6 individual trees. Trees capable of fire prevention were selected as the center of interest, surveying the 5 nearest trees around it with the following criteria: top height (Hvn), trunk height (Hdc), canopy diameter (Dt), DBH (D1.3), growth situation, and distance between trees.

Based on the survey results, the study preliminarily identified fire-proof and fire resistant plants in the study area and collected samples of leaves and barks for analysis of criteria such as total water content, coarse ash content, burning time of leaf and bark, thickness of leaf and bark. Each experiment was repeated at least 3 times to record average results. Criteria for evaluating tree canopy structure, regeneration ability, adaptability to site conditions, economic values were determined through direct observation, references from published documents, and consultation of experts.

- Applying the method of Multi-Criteria Analysis [Nguyen Hai Tuat, 2008 and 2010] and consulting experts to select fire-proof and fire resistant species in the study area.

(4) Method for proposing solutions to optimize FFPS and forest restoration after fire

- Inheriting documents of Hoang Lien national park in association with interviewing and expert consultation.

- Forest classification by fire risk using Multi-Criteria Analysis.

- Using the efficiency indicator method of E_{CT} to classify forest types according to fire risk. Using some mathematical models and SPSS software to evaluate fire risk of forest types in the study area.

- Application of GIS and remote sensing technology to create maps, including fire risk classification maps for forest types, high fire-risk zoning maps, green belt maps and risk management maps.

Chapter 3. RESEARCH RESULTS AND DISCUSSION

3.1. Basic characteristics of forest resources in Hoang Lien national park

3.1.1. Forest resources distribution

Forest inventory results in 2016 show that: Forest resources of Hoang Lien National Park are mainly natural forest land (accounting for 86.42%), with the main types including: regenerating evergreen broadleaf natural forest on soil mountains (TXP), poor (TXN) and medium (TXB) natural

timber forests. Rich (TXG) natural timber forests accounts for only 2.94%. Plantation forest (RTG) accounts for 0.92%. Land without forest (DT1 and DT2) accounts for 11.11% of the total area. TXG and TXB are often distributed in strictly protected zones that are at high levels of biodiversity and of special interest and protection. Forest fires almost never occur in these areas. TXP and TXN account for a high proportion, were often characterized by low canopy cover, high coverage of shrubs and understory vegetation that are high potential for forest fires.

3.1.2. Structural characteristics of main forest types

3.1.2.1. Woody tree layer structure

The results of the study on the characteristics of woody tree structure mainly in Ta Van commune, Ban Ho commune and San Sa Ho commune are summarized in Table 3.1.

Table 3.1. Woody tree layer structure in the study area

Commune	Forest type	$\overline{N}$ (tree/ha)	$\overline{Hvn}$ (m)	S (%)	$\overline{Hdc}$ (m)	S (%)	$\overline{Dt}$ (m)	S (%)	$\overline{D1.3}$ (cm)	S (%)	Canopy cover
San Sa Ho	TXN	320	13.9	23.4	9.6	34.0	4.2	42.8	17.5	35.3	0.32
	TXP	460	8.8	33.0	3.9	55.6	3.2	42.7	14.7	41.3	0.43
	TXB	660	13.5	19.7	9.3	37.8	4.1	45.4	18.2	53.1	0.58
	TXG	890	13.4	46.1	6.8	64.4	4.3	79.5	18.4	81.5	0.72
Ta Van	TXN	520	10.9	18.0	5.4	13.0	3.8	8.0	14.5	40.4	0.35
	TXP	555	10.1	22.3	3.1	7.8	3.6	10.0	10.9	37.3	0.51
	TXB	630	11.6	24.0	6.0	16.0	5.0	14.0	17.8	55.0	0.65
	HG1	520	11.7	27.9	7.2	44.7	3.3	46.7	16.2	41.0	0.65
	RTG	470	9.8	24.4	2.8	43.2	4.4	31.5	17.8	32.9	0.53
Ban Ho	TXN	180	11	51.6	6.7	53.7	4.0	55.3	18.1	55.4	0.33
	TXP	213	10.5	31.7	6.5	40.4	4.0	39.1	20.8	38.8	0.41
	TXB	560	11.6	47.7	6.9	44.9	2.6	67.8	15.4	103	0.54
	RTG	420	4.4	17.0	1.5	18.7	2.7	19.1	10.7	20.6	0.29

The data in Table 3.1 show that the density (tree/ha) and the average growth indicator of woody tree layer in different natural forest type are different. Except for TXG, most of the natural forest here has been heavily disturbed that made the forest canopy structure has been broken and the forest cover was only at medium or even low levels as of TXN (San Sa Ho commune is 0.32; Ta Van commune is 0.35). The difference in growth characteristics in the studied forest types is clear. The large coefficient of variations (S%) indicate that the dispersion of observed values is considerable. This is also in line with the fluctuations of growth indicators in uneven-age natural forests.

Woody tree composition includes the main species: *Schima wallichi, Alnus nepalensis, Rhododendron densifolium, Thea dupifera, Lithocarpus hemisphaericus, Cinnadenia tonkinensis* that are able to grow and well developed in the study area. Through field survey, forests in the ecological restoration sub-zone have low volume, low density and forest cover and most of them were planted for restoration after fire or of natural regeneration. Therefore, it is necessary to improve the effectiveness of reasonable and timely measures for forests and needs strict protection measures to maintain forest resources, especially to prevent forest fires.

3.1.2.2. Regenerating trees, shrubs and understory vegetation

The composition of regenerating trees compared to the woody tree layer is insignificantly different. The species of regenerating trees are mainly identified as: *Schima wallichi*, *Alnus nepalensis*, *Adinandra sp*., *Thea dupifera,* and *Lithocarpus hemisphaericus*. These are valuable plants in the forest restoration process and need care and protection.

Characteristics of shrubs and understory vegetation: The vegetation cover in the non-forest area in Ban Ho commune has the lowest height and coverage (30%). The coverage of this tree layer in San Sa Ho and Ta Van is high (73% and 71%), with the main species easy to catch fire: *Sinarundinaria petelotii, Xiphopteris sikkimensis, Dicranopteris linearis, Setaria palmifolia*, and *Pogonatherium crinitum*. This is an extremely vulnerable source of fuel. In the regenerating and poor forest types, shrubs and understory vegetation have average height (42.5 - 64 cm), with a coverage of approximately 50%. In these forest types, there are also many fire-proof regenerating trees that contribute to reducing the risk of forest fires. In medium forest, the vegetation layer has an average height (85-92cm), with the coverage of 75% - 85%. This is a forest type with high-growth shrubs and understorey vegetation including many flammable species such as *Dicranopteris linearis, Chromalaena odorata*, vines, small-sized regenerating trees with horizontal distribution, shrubs and understorey vegetation in the plantation forest in Ta Van commune have average height and coverage. However, this forest type in Ban Ho is no longer being cared for and cleaned, so the vegetation cover is thick, with a high height. It is necessary to maintain and protect this forest type regularly.

3.2. Characteristics of forest fire, factors affecting forest fire and the situation of forest fire management in Hoang Lien national park

3.2.1. Characteristics of forest fire

From 2009 to 2016, the fires damaged 937.85 ha of forest in Hoang Lien National Park. Forest fire occurred mainly in TXP (79.51%), followed by grassland, shrub (14.16%), TXN (6.15%) and plantation forest (0.18%). In particular, the largest area of forest fire occurred in 2010 with 718ha (accounting for 76.56% of the area of burning forest in 8 years). Forest fires occurred during February and March. The area where forest fires occurred was concentrated in the following villages: Ta Trung Ho, Seo Trung Ho, Ma Quai Ho (Ban Ho commune), Seo Ma Ty (Ta Van commune), Sin Chai (San Sa Ho commune). The main cause of forest fires in these communes is slash-and-burn cultivation, forest cleaning, and harvesting activities. In the communes, people often use measures of complete burning to treat vegetation, in many cases, causing fires that spread to the forest. In addition, in natural forest areas, people often hunt and take bee. These activities using fire and are very difficult to control. However, in recent years, the assessment of the direct cause of fire has not been accurate.

3.2.2. Characteristics of major factors affecting forest fires

3.2.2.1. Topographic characteristics

The forest and forest land area by elevation level in the national park is shown in Figure 3.1.

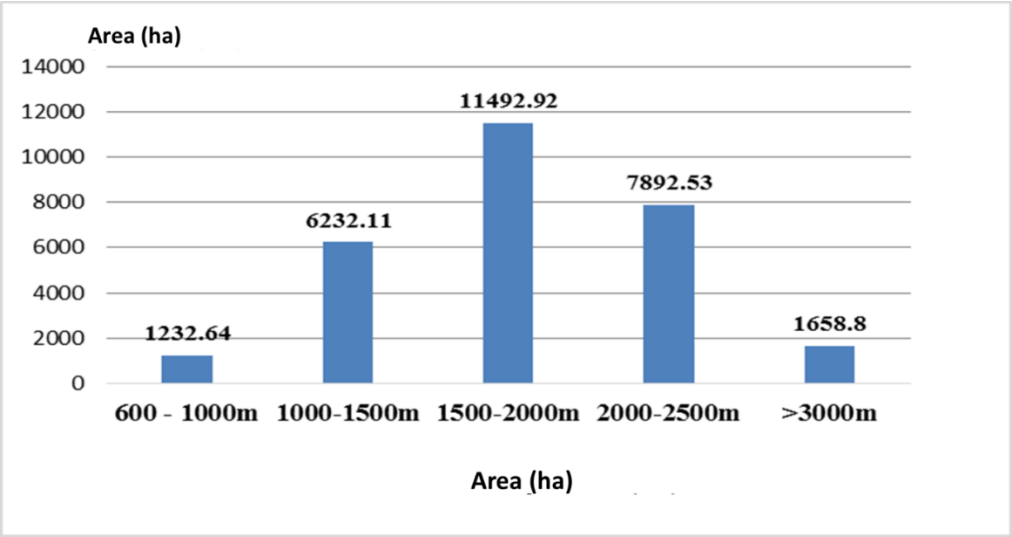


Figure 3.1. Forest and forest land area by elevation level in Hoang Lien national park

The area of Hoang Lien national park is mainly distributed at altitudes above 1500m to 3000m (accounting for 68%). The area at altitudes above 3000m accounts for 5.82% (1,658.8 ha). This area has a high-roughness terrain, with many steep slopes. Thus, the ability to access to forest fire for suppression is very difficult. It is hard to apply modern facilities. In addition, with a steep slope, strong winds facilitate the rapid spread of the fire.

3.2.2.2. Climate and hydrological

Climate characteristics of Hoang Lien national park are shown in Figure 3.2.

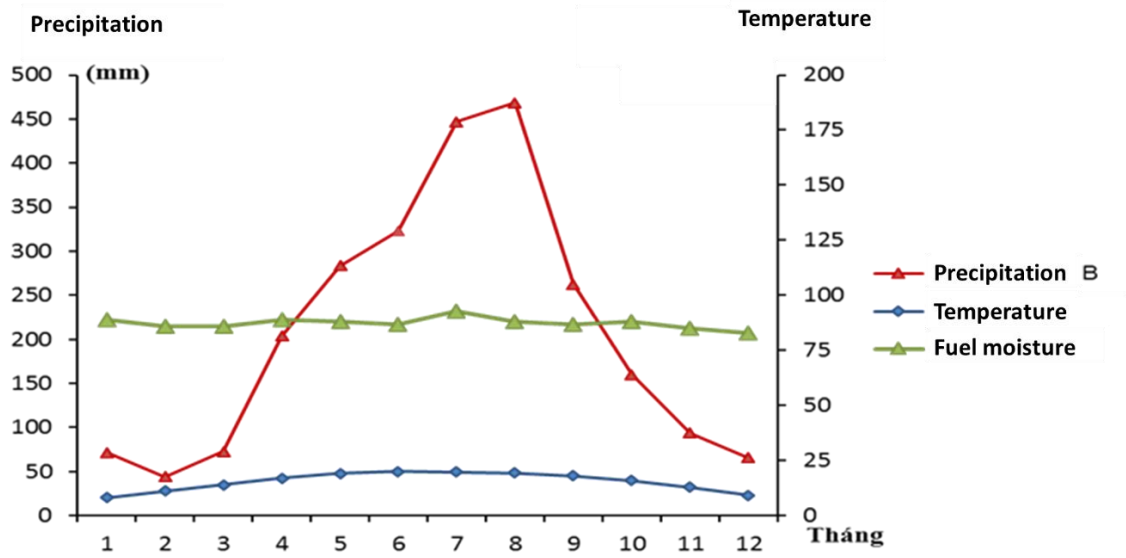


Figure 3.2. Monthly temperature, humidity and precipitation in Hoang Lien national park

Hoang Lien national park has relatively high average air humidity, low average air temperature and relatively high average rainfall compared to many other localities in Vietnam. The dry season lasts from November to April the next year. During this time, air humidity is low with low rainfall, cold weather and hoar frost that makes the vegetation die massively and increases the risk of forest fire. In addition, the area is under the influence of O Qui Ho wind (local wind) blowing very strongly and carrying hot dry air that often appears in December to April. This period of time is also the time local people carry out activities of slash-and-burn field preparation (slash-and-burn cultivation near forests). Therefore, the period from December to April next year was considered as the forest fire season in Hoang Lien national park.

3.2.2.3. Traffic, communications, labor and customs

Transport system and communication in the region face many difficulties: inter-village roads mainly for motorbike only, roads to access areas with high fire risks including only walking or even no access. These are difficulties in the implementation of FFPS.

3.2.2.4. Labor, agricultural cultivation and acts of damaging forest resources

In Hoang Lien national park, there are six ethnic groups residing. In which HMong people are the most crowded (40%), followed by Dao, Tay, Day, Xa Pho, and Thai people. Most of local people are highly dependent on forest resources. Illegal exploitation of forest resources, hunting of birds and animals, slash and burn cultivation still occur that put great pressure on forest protection and FFPS. *Amomum tsaoko* is a plant with high economic value and is being strongly developed by local people. However, *A. tsaoko* cultivation contains a high risk of forest fire because in the harvest season (early November every year), local people go to the forest to harvest and dry fruit using fire (on average 1.2 m^3 of firewood/100 kg of fresh fruit). Controlling the people using fire in the forest for living and drying *A. tsaoko* is very difficult. In Hoang Lien national park, there are people who still hide into the forest to harvest timber, firewood, and other forest products. In addition to affecting forest resources, these activities can cause forest fires.

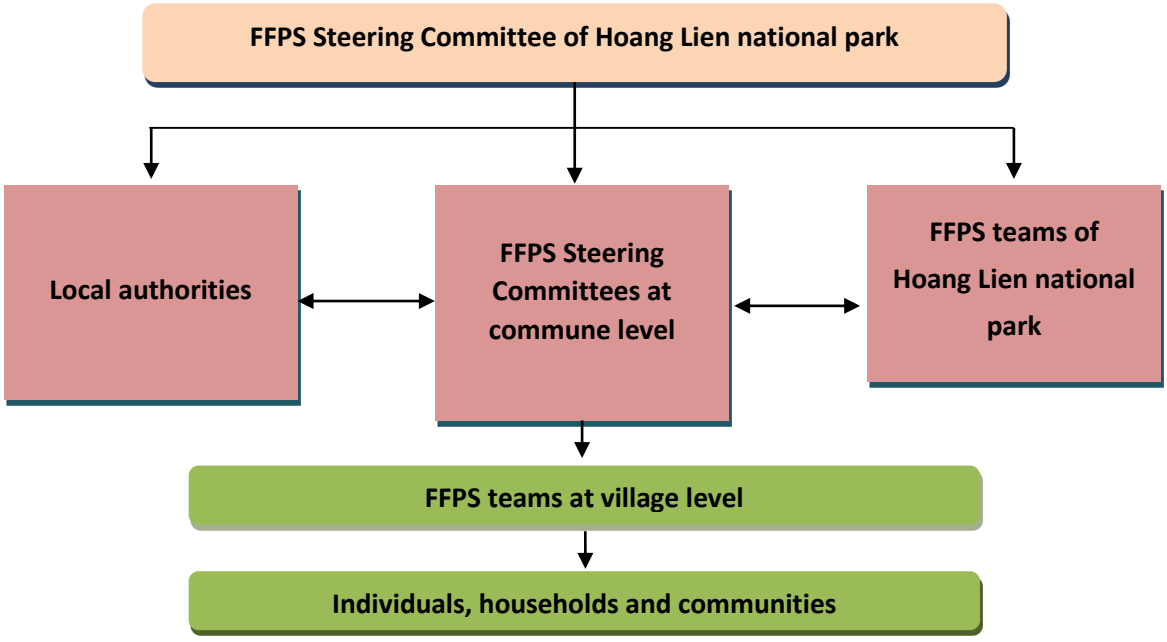
3.2.2.5. Other adverse factors

Other adverse factors including the awareness of observing the law on forest protection of a number of people is still low, the influence of weather (hoar frost, ice and snow, cold weather, etc.), the large area of bamboo, pressure on forest resources from the increase of tourism.

3.2.3. Actual situation of forest fire management in Hoang Lien national park

3.2.3.1. The work of organizing forces, directing and executing fire prevention and fighting tasks

At Hoang Lien national park, the Steering Committee (PSC) implementing the Forest Protection and Development Plan has developed a plan and organized the implementation of forest fire prevention and fighting according to the plan of Hoang Lien National Park. The Steering Committee has advised the People's Committees of the communes in the area to build and carry out the inspection on FFPS according to the plan, to consolidate the Steering Committee at commune level for six communes, towns of Tan Uyen town and Cable Joint Stock Company that establish 59 forest FFPS teams in villages. The diagram in Figure 3.3 shows the FFPS force organization.



Figures 3.3. Coordination between FFPS forces

3.2.3.2. Propaganda and education of people on FFPS

All of the forest fires occurring in the national park have been related to the fire-using activities of people in the communes. The propaganda about FFPS in recent years to people living near forests and in forests is broadcasted through radio. Especially, the organization of training courses at the commune level to improve the FFPS ability for officials and people in forest protection sector is carried out annually by the national park and Forest Protection Department of Sapa.

3.2.3.3. People's participation and community-based model for FFPS

The main FFPS activities with the participation of people in Hoang Lien national park include: participating in FFPS teams, participating in developing regulations on FFM and FFPS, propagating information on FFM and FFPS, and participating in detecting forest fires.

100% of interviewees have participated in developing village regulations on FFPS. The people's commitment to protect and prevent forest fire has been widely implemented. Communication and advocacy activities have been often carried out by forest rangers and local authorities, especially village heads and village elders, who have prestige and reputation in the community. Villagers were mainly given instructions on issues related to forest fires and common FFPS measures.

The results of evaluating the participation of the people in FFM are summarized in Table 3.2.

Table 3.2. The participation of the people in FFM in Hoang Lien national park

No.	FFM activity	Participation (%)	Rate of participation by level (%)						
			Lv 1	Lv 2	Lv 3	Lv 4	Lv 5	Lv 6	Lv 7
1	Participating in FFPS teams	43.4	37.2					6.2	
2	Propagating information on FFM and FFPS	58.6	28.3	20.0					10.3
3	Creating FFM and FFPS local regulations	100.0			40.7			35.2	24.1
4	Creating FFPS plan	26.2			10.3			15.9	
5	Detecting forest fire	91.0				4.8			86.2
6	Forest suppression	57.2		16.6		1.4		29.7	9.7
7	Signing of FFPS contract	100.0	100.0						
8	Using fire in control	58.6	25.5	15.9					17.2
9	Participate FFPS training	36.6	29.0	7.6					

Table 3.2 shows that all the activities related to FFM have the participation of local people. Developing forest protection regulations, signing of FFPS agreements and detecting forest fires are the most popular activities (91% -100%). Activities of developing FFPS plan have the lowest participation of local people (26.2%). The majority of people participated in the activity level (level 1), followed by the participation in the active, self-advocacy and organization (level 7), and on average is 29.5. However, the participation at level 7 are mostly leaders and forest protection teams

of commune and village. It is necessary to have solutions to improve people's participation in FFPS in a more proactive, self-conscious manner and to play a more leading role.

In the villages of the 3 communes in Hoang Lien national park, there is currently no model of community-based FFPS. FFPS is being implemented in communities based on the FFPS plan of Hoang Lien national park. The current task of FFPS has not highly appreciated the role of the community, not encouraged or allowed the community to see that everyone is responsible in FFPS. Therefore, it is necessary to change the operation of FFPS in villages to encourage the participation of the community in forest protection and fire prevention.

3.2.3.4. FFPS measures are applied

- Fire prevention measures: increasing forest protection staffs coming to local areas to guide people; Checking and urging households and individuals to perform forest protection contracts obligations in FFPS; Implement forest fire risk assessment; enhancing building FFPS constructions such as fire signs, ban signs, message boards, and fire watchtowers.

Fire suppression measures: Follow the 4 on-site guideline (i.e. on-site command, on-site forces, on-site vehicles and on-site logistics). The main fire suppression method in the national park is direct suppression. Fire suppression measures mainly use manual means and professional fire suppression of officers and fire fighting teams have not been intensively trained that limits the effectiveness.

3.2.3.6. FFPS equipment

Hoang Lien national park has invested in equipment for FFPS to improve the ability to deal with forest fire. However, with the conditions including complex terrain, large slopes, poor infrastructure, and large forest fires often far from residential areas, the use of mechanical equipment, such as machines pumps, blowers and packaging machines, are very limited and ineffective that the manual tools used are commonly adopted.

*** Overall assessment of FFM in Hoang Lien national park**

- Strengths: forest management of Hoang Lien national park has received the attention of the authorities. Officials, organizations, individuals and unions are entitled to study legal documents on FFPS. Provinces with forests and forest owners have actively implemented FFPS. FFPS plans and close coordination among units have been regularly organized, trained and practiced. FFPS equipment and tools are generally diverse in types.

- Weaknesses: forest protection and FFPS have faced many difficulties due to difficult terrain, difficult transportation, lack of facilities and equipment; pressure on invasive forest resources from people and tourists is high that increases the risk of forest fire; funding support for forest protection contracts is at low level; rangers are inefficient and scattered; investing in equipment for FFPS and communication has not met the requirements; awareness of a number of people living near forests being contracted for forest protection is still limited; FFPS options are developed in stages, with additional adjustments every year but there is no FFM map; there is no current community-based model for FFPS; the area of high forest fire risk in the national park is large, but the facilities for FFPS are still very few. The empty belt for forest fire obstruction are mainly combined with trails and limited width; no green-belt for fire prevention has been established yet; the selection of tree species capable of growing on green belt and improving the fire prevention capacity of the forest has not been studied; Measures to reduce fuel in the dry season have not been thoroughly implemented.

The above limitations would contribute to an important basis for proposing solutions to improve FFPS in Hoang Lien national park. Especially, it is important to have options for selecting plants with fire resistance and community-based FFM models.

3.3. The possibility of forest restoration after fire in Hoang Lien national park

Landsat 8 satellite images of the forest area before fire (December 2009), 2 months after the fire (April 2010) and 75 months after the fire (May 2016) in the area are represented in Figure 3.4 that shows a visualization of changes in the area before and after fire.

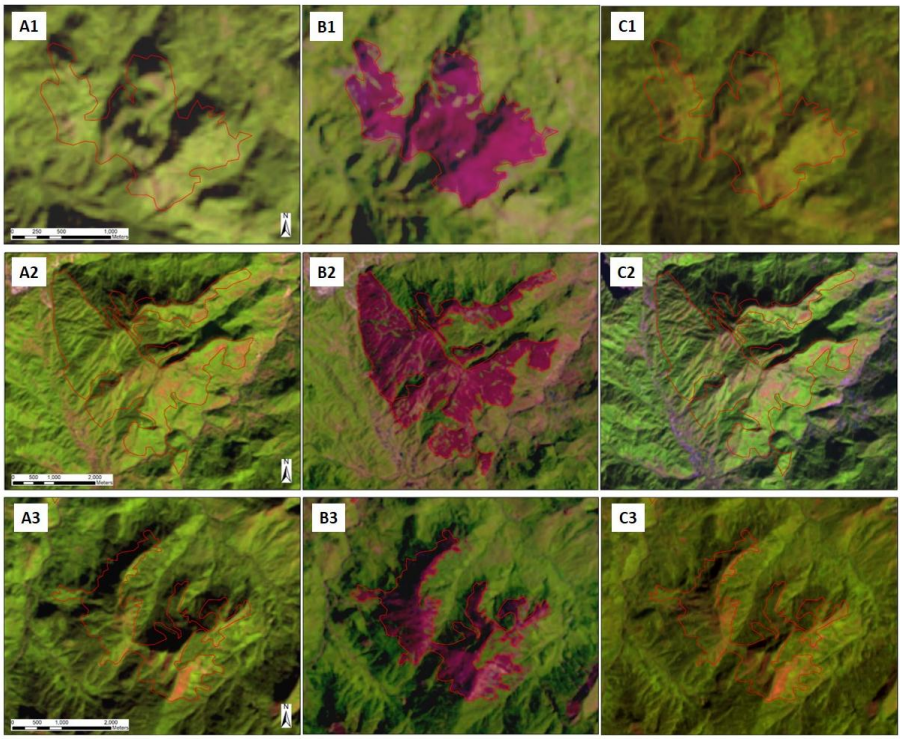


Figure 3.4. Pictures of forest area of Hoang Lien National Park before burning, immediately after the fire (April 2010) and 6 years after the fire

A – San Sa Ho commune; B – Ta Van commune; C – Ban Ho commune; 1 – before fire (December 2009); 2 – immediately after the fire (April 2010); 3 – 6 years after the fire (May / 2016)

3.3.1. Characteristics of forest plants after fire

3.3.1.1. Characteristics of the woody tree layer

a. Tree density and canopy cover

In Ta Van commune, after fire, the average density of woody tree layer in burnt SPs of all forest types was approximately 12% compared to unburnt forests. The canopy cover determined at the time after 6 months after fire was 0.18. More than three years after the fire, this figure was only 0.23 and reached 0.3 at 72 months after the fire. Forests had not recovered the forest canopy.

In Ban Ho Commune: After 38 months of fire, many trees have died irreversibly, the average number of survivals is only about 30% (170 trees/ha) with an average canopy cover of 0.28. After 6 years, the density and canopy improved (i.e. density of 220 trees/ha; canopy cover of 0.33) but was at low level.

b. Tree species composition

Ta Van commune area: after the fire, most of the woody species died, the density decreased sharply, the number of species decreased by the average of 75%. Six years after the fire, there were 02 species in the new forest composition*: Schima wallichi, Alnus nepalensis, Adinandra sp.,* and *Thea dupifera*.

Ban Ho commune area: after 38 months of fire, the number of tree species decreased 58%. The remaining woody tree species were mainly *Schima wallichi*, *Alnus nepalensis*, *Adinandra sp*., and *Thea dupifera* with great height and strong ability to regenerate shoots. Six years after the fire in the SPs, there was a change in coefficients and number of species in the composition but insignificantly. Woody tree layer composition had the additional appearance of the species *Alangium Chinensis* and *Alangium yunnamensis.*

c. Forest layer structure

The woody tree layer in the unburnt SPs in two areas of Ta Van and Ban Ho communes clearly showed the forest structure in 2-3 canopy layers, specifically as follows:

+ The top layer consisted of the main species including *Lithocarpus sp*., *Alangium yunnamensis, Elaeocarpus sylvestris, Betula alnoides, Cinnadenia sp., Vernicia sp.*, with the average height of 12-16m.

+ The second layer consisted of small woody tree species including *Schima wallichi, Cryptocarya concinna, Wendlandia paniculata, Adinandra sp*. with the average height of 6-8m.

+ The bottom floor consisted of regenerating trees, shrubs and understory vegetation with the average height of 1-2m.

3.3.1.2. Characteristics of regenerating trees

The quantity and quality of regenerating trees are considered as important criteria reflecting the success of forest rehabilitation. Survey results on characteristics of regenerating trees in forest types in Ta Van and Ban Ho communes are summarized in Tables 3.11 and 3.12.

Table 3.11. Characteristics of regenerating trees in forest types in Ta Van commune

TT	Forest type	Characteristics of regenerating tree			
		N (tree/ha)	Number of species	Average height (m)	Rate of high potential tree (%)
1	**Unburnt forests**				
1.1	Woody + bamboo species (G+TN)	1200	13	2.03	86.7
1.2	Restoration forest 1 (TXP1)	960	10	1.62	75.0
1.3	Restoration forest 2 (TXP2)	480	6	1.50	83.3
1.4.	Regenerating trees only (DT2)	640	7	1.75	62.5
2	**Forest after fire 6 months**				
2.1	Woody + bamboo species (G+TN)	800	8	0.31	0
2.2	Restoration forest 1 (TXP1)	880	10	0.28	0
2.3	Restoration forest 2 (TXP2)	1040	10	0.26	0
2.4	Regenerating trees only (DT2)	560	5	0.36	0
3	**Forest after fire 38 months**				
3.1	Woody + bamboo species (G+TN)	1120	11	1.06	64.3
3.2	Restoration forest 1 (TXP1)	1120	11	1.58	71.4
3.3	Restoration forest 2 (TXP2)	1520	16	1.35	68.4
3.4	Regenerating trees only (DT2)	880	9	1.37	63.6
4	**Forest after fire 72 months**				
4.1	Woody + bamboo species (G+TN)	1360	14	1.97	76.5
4.2	Restoration forest 1 (TXP1)	1280	13	2.27	81.2
4.3	Restoration forest 2 (TXP2)	1600	17	2.10	80.0
4.4	Regenerating trees only (DT2)	1040	10	1.98	69.2

Table 3.12. Characteristics of regenerating trees in forest types in Ban Ho commune

TT	Forest type	Characteristics of regenerating tree			
		N (tree/ha)	Number of species	Average height (m)	Rate of high potential tree (%)
1	**Unburnt forests**				
1.1	Restoration forest (TXP)	2489	22	1.2	55.4
1.2	Regenerating trees only (DT2)	1600	11	1.44	70.0
2	**Forest after fire 38 months**				
2.1	Restoration forest (TXP)	1520	11	1.56	73.7
2.2	Regenerating trees only (DT2)	1360	12	1.65	76.5
3	**Forest after fire 72 months**				
3.1	Restoration forest (TXP)	1440	13	2.54	83.3
3.2	Regenerating trees only (DT2)	1280	10	2.86	93.7

Under the impact of forest fires, the forest structure in the study areas has been significantly changed. In the area after fire, there had been a strong regeneration of plants, especially native plants with high resistance and good regeneration ability such as: *Schima wallichi, Cinnadenia sp., Symingtonia tonkinensis,* and *Lithocapus sp*. In Ta Van commune, the density of regenerating trees in burnt areas ranged from 1040 trees/ha (DT2) to 1600 trees/ha (TXP). The high potential tree proportions were from 69.2% to 81.2%. In Ban Ho commune, this figure ranged from 1440 trees/ha (DT2) to 1280 trees/ha (TXP) and the rates of high potential tree were 83.3-93.7%.

It is feasible for the forests to successfully recover after fire. However, the shrubs and understory vegetation, especially grasses growing quickly with the large coverage will be one of the factors that greatly affects the growth and development of regenerating trees in burnt areas.

3.3.1.3. Characteristics of shrub and understory vegetation layer

In the studied states of Ban Ho and Ta Van communes, the shrub and understory vegetation layer also recovered over time. They had the average height of approximately 1.0 m and the high coverage of 75.4-82.0%.

A noticeable feature is that grasses were well developed in areas after forest fire, such as *Sinobambusa sat, Thysanolaena latifolia, Pennisetum purpurrerum, Imperata cylindrica, S. petelotii, Schizostachyum sp.* and common species were characterized by light demanding, flammable, high height and thriving in open land. In areas after the fire, there are many mineral nutrients exposed from the burning process. Strongly growing shrubs and vegetation played a role in protecting the forest land from the risk of erosion in the context of broken forest canopy. High shrub layer was also a favorable condition for shade-tolerant timber trees in the early stages of regeneration and development. However, they also cause a hard competition with regenerating plants for space, light and nutrient. This may also be an important reason to explain the decrease in the number of regenerating species surveyed at more than 3 years after fire compared with which was at the time after 6 months of fire in Ta Van and Ban Ho communes. Therefore, there should be appropriate actions to adopt the advantages of this tree layer without negatively influencing the forest restoration process.

3.3.2. Characteristics of forest soil after fire in Hoang Lien national park

The main physical and chemical indicators of forest soil characteristics in burnt and unburnt forest in Ta Van commune are shown in Table 3.14 and Figure 3.10.

Table 3.14. Main physical and chemical indicators of forest soil characteristics in Ta Van commune

Time after forest fire	Forest type	Indicator					
		Porosity (%)	pH	Organic content (%)	N_2O (mg/100g)	P_2O_5 (mg/100g)	K_2O (mg/100g)
Unburnt forest	DT2	58.7	3.9	5.8	21.3	2.5	10.7
	HG1	57.6	4.0	6.2	21.3	3.3	7.3
	TXP	59.6	3.9	3.9	13.4	1.7	9.0
After 6 months	DT2	57.6	4.1	7.7	16.5	2.6	10.7
	HG1	52.7	4.2	6.5	16.7	2.9	14.6
	TXP	58.0	4.2	6.2	11.3	2.7	8.9
After 38 months	DT2	52.2	4.0	5.2	9.9	3.4	5.8
	HG1	45.6	4.0	6.8	6.7	4.7	6.7
	TXP	56.2	4.2	4.8	5.4	3.1	6.1
After 72 months	DT2	56.2	4.3	6.2	10.9	4.4	6.2
	HG1	59.6	4.6	6.8	8.7	5.2	7.7
	TXP	58.2	4.6	6.8	6.4	4.3	8.1

The parameters reflecting soil properties in burnt and unburnt forests were considerably differences. In general, the porosity of soil in burnt forest was lower than that of non-burnt forest. Particularly at the time of 38 months after the fire, the studied forest types had the lowest porosity. In general, the porosity of the soil in the studied SPs was at a satisfactory level for cultivation.

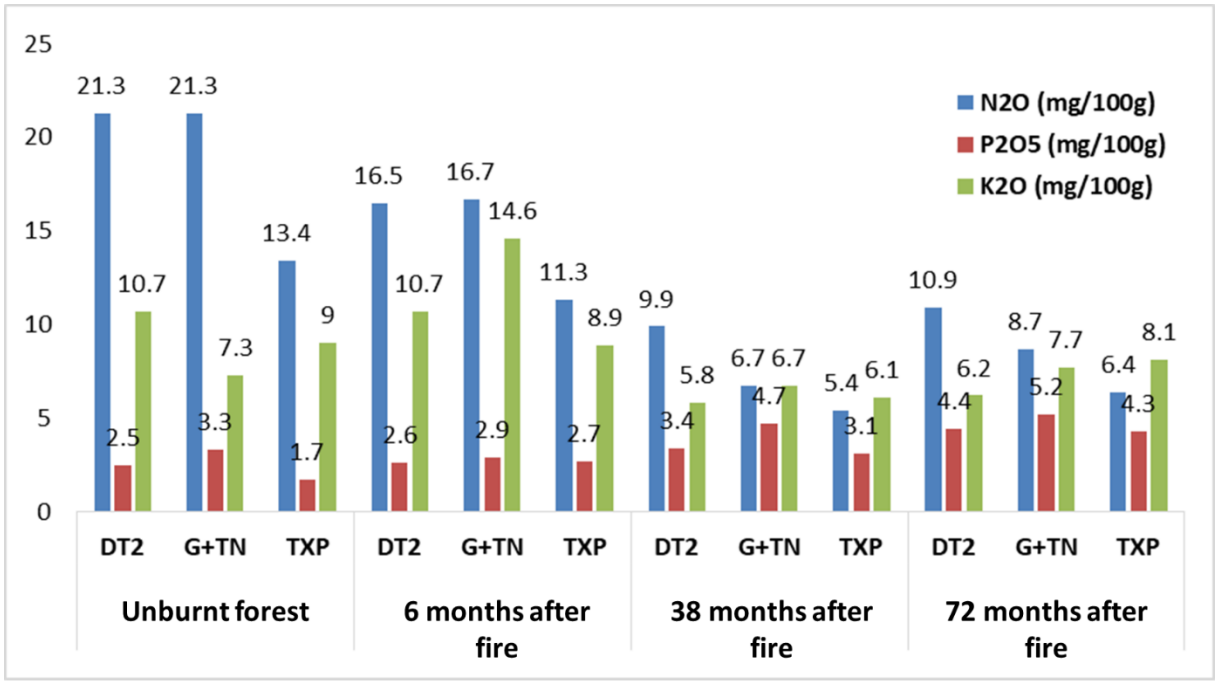


Figure 3.10. Changes of indicators of soil characteristics after forest fire over time

Under the impact of heat and smoke from forest fires, the physical and chemical properties of forest soil had changed. After 6 and 38 months of forest fires, the moisture content, porosity, organic content and N_2O content of the forest soil decreased; the content of easily digestible nutrients in soil such as P_2O_5 and K_2O and soil pH increased. 72 months after fire, the rate of variation of these parameters varied between forest types but they generally followed an upward trend.

3.3.3. Identification of plant species resistant to fire in Hoang Lien national park

3.3.3.1. Identification of plant species resistant to fire

From the knowledge of indigenous people in combination with field survey, the study identified 15 tree species as candidates that were resistant to fire and currently distributed locally (Table 3.18). Most of the above species were in the species composition formula of the woody tree and the regenerating tree layers that have the ability to grow and develop well in the local areas.

3.3.3.2. Species selection

To ensure the success of plantation forest and the ability to serve local forest management, the selected species had to: (1) be adaptive to local conditions and many types of soil; (2) be resistant to fire; (3) provide a number of economic benefits. The study identified nine criteria related to fire-proof, fire resistance, the ability to adapt to local sites, and the economic value.

Through the quantification and standardization steps, using SPSS software to determine the weight of the criteria, score and ranking in terms of the fire-proof and fire resistance for the species are in Table 3.18.

Table 3.18. Species ranking of the fire-proof and fire resistance

No.	Species	Fire-proof and fire resistance		No.	Species	Fire-proof and fire resistance	
		Score	Ranking			Score	Ranking
1	*A. nepalensis*	0.892	1	9	*M. mediocris*	0.655	9
2	*S. wallichi*	0.819	2	10	*C. tonkinensis*	0.643	10
3	*S. populnea*	0.753	3	11	*A. yunnamensis*	0.621	11
4	*L. chinense*	0.725	4	12	*D. indica*	0.593	12
5	*L. hemisphaericus*	0.711	5	13	*M. odoratissima*	0.583	13
6	*B. alnoides*	0.711	5	14	*Adinandra sp.*	0.538	14
7	*M. insignis*	0.710	7	15	*S. vestitum*	0.446	15
8	*T. dupifera*	0.673	8				

Score and ranking reflecting the ability to support FFPS in the local area for the species are in Table 3.19.

Table 3.19. Species ranking of the ability to support FFPS

No.	Species	Ability to support FFPS		No.	Species	Ability to support FFPS	
		Score	Ranking			Score	Ranking
1	*S. wallichi*	0.843	1	9	*L. hemisphaericus*	0.689	8
2	*A. nepalensis*	0.779	2	10	*M. insignis*	0.688	10
3	*M. mediocris*	0.777	3	11	*D. indica*	0.680	11
4	*S. populnea*	0.710	4	12	*T. dupifera*	0.670	12
5	*A. yunnamensis*	0.710	4	13	*M. odoratissima*	0.625	13
6	*C. tonkinensis*	0.705	6	14	*S.vestitum*	0.556	14
7	*L. chinense*	0.696	7	15	*Adinandra sp.*	0.536	15
8	*B. alnoides*	0.689	8				

According to the ranking, the study selected 10 top plant species of plants with the highest ability to be developed supporting FFPS in Hoang Lien national park, including: *S. wallichii, A. nepalensis, M. mediocris, E. tonkinensis, A. yunnamensis, L. chinense, B. alnoides., L. hemisphaericus, M. insignis, C. tonkinensis* to consult experts and technical staffs of Hoang Lien national park.

Of the 11 consulted questionnaires, 100% of the respondents agreed that the species: *S. wallichii and A. nepalensis* were suitable for green belt. Species including *E. tonkinensis, A. yunnamensis, M. mediocris* had over 80% comments that agreed. *L. hemisphaericus and C. tonkinensis* were considered as inappropriate (72.7% disagreed) because they *contained* aromatic oils or thin leaves that were easy to burn.

3.3.3.3. Identifying neighboring species of selected trees for planting in green belt

The results of surveys on a number of species, which often exist together (neighboring species) with those considered as FFPS-supporting species, are presented in Table 3.20.

Table 3.20. Một số loài cây thường đi kèm với cây có khả năng phòng cháy

No.	Target species	Neighboring species
1	*M.mediocris*	*S. wallichi, T. dupifera, A. nepalensis, M. insignis, Adinandra sp., A. yunnamensis.*
2	*S.populnea*	*Ramnus sp., Cunninghamia lanceolata (Lamb.) Hook., Lithocarpus echinophorus A. Camus, A.nepalensis D.Don, Adinandra SP.*
3	*S.wallichi*	*Dillenia heterosepala Finet Gagnep, A.nepalensis D.Don, M.insignis (Wall.) Blume, Ramnus sp., Adinandra SP.*
4	*A.nepalensis*	*M.mediocris Dandy, C.tonkinensis Pitard, Helicia SP., Ramnus sp., S.wallichi (DC.) Korth*
5	*B.alnoides*	*Lithocarpus fissus Champ. ex benth, Acer amplum Rehder, A.nepalensis D.Don, A.yunnamensis Rehd. etWils., S.wallichi (DC.) Korth, C.tonkinensis Pitard, Mý Lysidice rhodostegia Hance.*
6	*C.tonkinensis*	*Adinandra SP., Giổi lá bạc, M.insignis (Wall.) Blume, Thea dupifera Pierre, Rhododendron SP., Altingia SP.,*
7	*Adinandra SP.*	*Lithocarpus fissus Champ. ex benth, A.nepalensis D.Don, M.insignis (Wall.) Blume, M.mediocris Dandy*
8	*M.odoratissima*	*A.nepalensis D.Don, A.yunnamensis Rehd. etWils., Syzygium vestitum Merr. et Perry.*
9	*T.dupifera*	*Adinandra glischroloma Hand.-Mazz. var., Rhododendron densifolium K. M. Feng, M.odoratissima Nees, T.dupifera Pierre, Adinandra SP.*
10	*L.hemisphaericus*	*A.nepalensis D.Don, Altingia SP., S.wallichi (DC.) Korth, C.tonkinensis Pitard, Helicia SP.*
11	*Lithocarpus echinophorus*	*M.insignis (Wall.) Blume, A.nepalensis D.Don, S.wallichi (DC.) Korth, Adinandra SP.*

In Table 3.20, many neighboring species are also considered as trees with good fire resistance. In general, the target and neighboring species have growing ability from moderate to good. This is a very important factor to select species for green belt.

3.4. Proposing solutions FFPS and forest restoration after fire in Hoang Lien national park

3.4.1. Proposing solutions for FFPS

3.4.1.1. Science and technology solutions

a) Building map of forest fire risk

The average value of the indicators reflecting forest fire risk by forest types are summarized in Table 3.22

Table 3.22. The indicators reflecting forest fire risk by forest types

Forest type	Fuel moisture (%)	Fuel volume (ton/ha)	Shrub height (cm)	Understory cover (%)	Trunk height (m)
DT2	14.41	23.37	46.30	72.00	0.00
TXN	18.70	20.41	60.00	65.00	4.50
TXP	22.50	19.46	48.20	47.67	4.73
TXB	31.52	18.10	65.00	80.00	10.6
TXG	32.80	20.20	75.00	52.00	6.80
HG1	16.73	15.22	85.00	80.00	0.00
RTG	14.41	20.11	68.00	56.50	3.21

In Table 3.22, the indicators were used to classify forest fire risk using standardization. Based on the variation range of the combined indicator, fire risk was classified into 4 levels according to fire danger level as follows: Level I - Low fire risk: Ect < 0.55; Level II - Average fire risk: 0.55≤ Ect <0.65; Level III - High fire risk: 0.65 ≤ Ect < 0.75; Level IV: - Very high fire risk: Ect≥ 0.75.

From the forest fire risk classification, the thesis built a fire risk classification map for forest types in Hoang Lien national park. Each level of fire was represented by a color on the map (Figure 3.11).

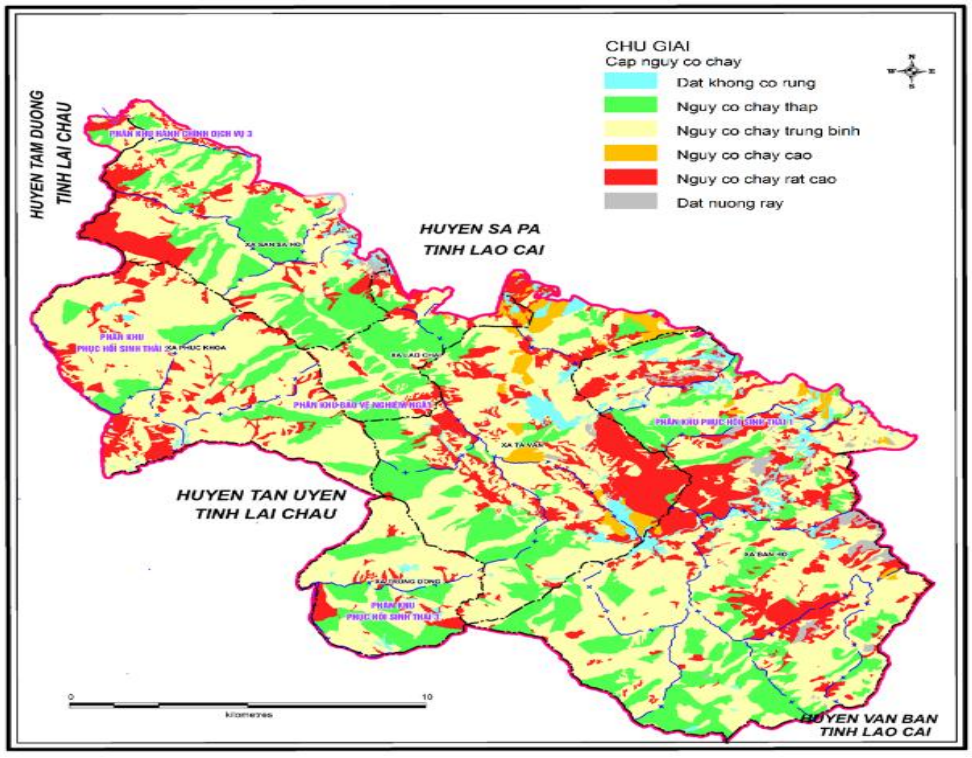


Figure 3.11. Fire risk classification map for forest types in Hoang Lien national park (Dat khong co rung: non-forest land; nguy co chay thap: low risk; nguy co chay trung binh: medium risk; nguy co chay cao: high risk; nguy co chay cao: extremely high risk; Dat nuong ray: cultivation land)

In Figure 3.11, the forest areas at low risk of fire are few and scattered in all 4 communes. Most of these areas are located in strictly protected sub-zones with high elevation and complex

terrain. High-risk forest plantations are distributed near the national highway from Sa Pa to Lai Chau province and the area of Seo My Ty - Ta Van commune. The forest areas of high and extremely high risk of fire are scattered in all communes. However, these areas concentrated in Seo My Ty, Den Thang and Seo Trung Ho villages, Ta Van commune; Ta Trung Ho village and Ma Ma Ho village - Ban Ho commune; and Xe mountain (adjacent to Lai Chau) - San Sa Ho commune. These also are areas with annual fire occurrence.

b) Building high fire-risk zoning map for Hoang Lien national park

Based on information on the situation of forest fire and the fire risk classification for forest types, a map of high fire-risk zoning for Hoang Lien National Park was built as in Figure 3.12.

High fire-risk areas in the national park were divided into 6 concentrated areas: (1) Tram Ton - Nui Xe area (San Sa Ho commune) - 199.8ha; (2) Seo My Ty, Den Thang, and Ta Van Giay (Ta Van commune), Seo Trung Ho (Ban Ho commune) - 3000.1ha; (3) Ma Ma Ho and Ta Trung Ho area (adjacent to Ta Van commune) - 497.6 ha; (4) Phuc Khoa commune (Tan Uyen town) - 1098.2 ha; (5) Trung Dong commune (Tan Uyen town) - 697.6 ha; (6) Central area of Ban Ho commune - 1124.2 ha.

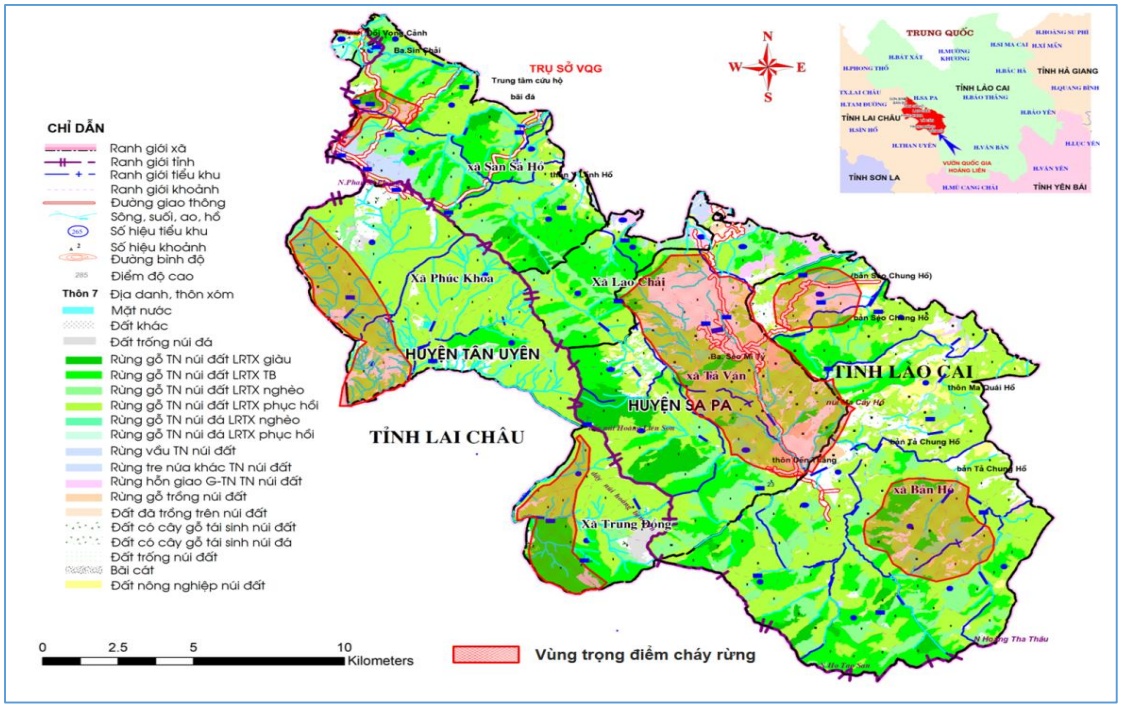


Figure 3.12. High fire risk zoning map for Hoang Lien national park
(Vùng trọng điểm cháy rừng: High forest-risk zone)

c) Establishing green belt to prevent fire

Under specific conditions in Hoang Lien national park, forest fires often occur in ecological rehabilitation sub-zones. In the Park there have been many ethnic minority households living, cultivating and having frequent impacts on the forests that increased the chance of fire occurrence. Indeed, most forest fires have occurred due to human activities. From the above basic characteristics in association with the actual survey and consultation with the leader of Hoang Lien National Forest Protection Department, the thesis proposed to build a fire-blocking green belt system as shown in Table 3.10 and the forest fire management map (Figure 3.14).

Table 3.24. Description of green belt in Hoang Lien national park

No.	Location (Village/Commune)	Sector	Plot	Length (m)
1	Ta Trung Ho/Ban Ho	296	4	1665
2	Den Thang/Ta Van	295a	4.5	1980
3	Seo My Ty /Ta Van	286	16	690
4	Seo My Ty /Ta Van	286	16	1160
5	Seo My Ty /Ta Van	286	8	1800
6	San Sa Ho commune	274	1	2110
	Total			**9405**

Some technical specifications for constructing the green belt: width of 15-20m; plant species: *S.wallichi*, *A.nepalensis*, S.*populnea*, *M.mediocris* and *A.yunnamensis*; planting methods: single species with the density of 2660 to 2800 tree/ha, or mixed planting (*S.wallichi* - *A.nepalensis* - *M.mediocris* Dandy - *A.yunnamensis* Rehd. or *M.mediocris* - *A.nepalensis*); Silviculture techniques: following the regulations and norms of MARD and Lao Cai province.

d) Building forest fire management map

FFM map shows the high forest-fire risk areas, FFM constructions, FFPS stations, forest fire watchtowers, steering boards and public administration and so on. FFM map is very important in FFPS, especially for fire suppression when forest fires occur.

FFM map for Hoang Lien national park is in Figure 3.9.

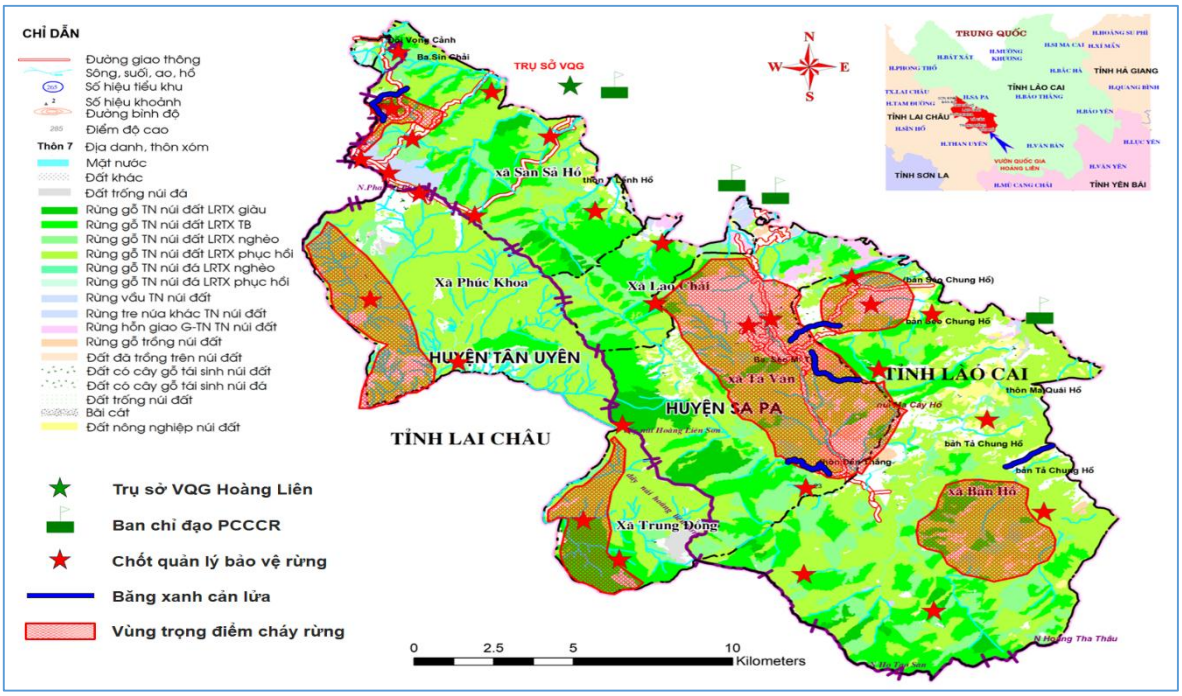


Figure 3.14. Forest fire management map for Hoang Lien national park (Trụ sở VQG Hoàng Liên: Hoang Lien national park headquarters; Ban chỉ đạo PCCCR: FFPS steering committee; Chốt quản lý bảo vệ rừng: FFM station; Băng xanh cản lửa: green belt; Vùng trọng điểm cháy rừng: High forest-risk zone)

The FFM map represents 6 concentrated high fire-risk zones, the locations of FFPS steering committee at commune level, FFPS stations, locations of green belt, roads, and paths. For more convenience for FFPS in local area, it is possible to build a FFM map for each commune, with a larger map scale.

e) Other technical solutions

- Managing burning fuels
- Forecasting and warning the threats of forest fire according to the risk levels.
- Building dam systems supporting fire suppression

3.4.1.2. Socio-economic solutions

a) Organizing and guiding on FFPS

There must be a good coordination between the Steering Committee for implementation of Forest protection and Development Plan of the national park with the Steering Committee for implementation of Forest protection plan of Sa Pa District. There is also a need for consolidating the steering committees and developing working regulations of FFPS teams in 6 communes.

b) Establishing a community-based FFM model at village level

Community participation in FFPS is an important factor to follow the 4 on-side guideline. The current situation of forest management activities in Hoang Lien national park shows that the national park needs to establish a community-based forest management model. This model works on the opinion of "relying on local people to prevent and suppress forest fires".

**Policy:* the People's Committee of Lao Cai province should encourage the coordination between Department of Agriculture and Rural Development (Forest Protection Department of Lao Cai Province), Hoang Lien national park and Sa Pa District People's Committee coordinate to develop and establish community-based forest management models.

**Quantity, components and model structure:*

+ Quantity: in each village, a community group is established to manage, protect and prevent forest fire (FFPS team);

+ Composition and structure: the model leader is the Forest Management Board at village level, followed by the FFPS teams of the village. FFPS teams support and cooperate with each other in conducting FFPS tasks (Figure 3.15).

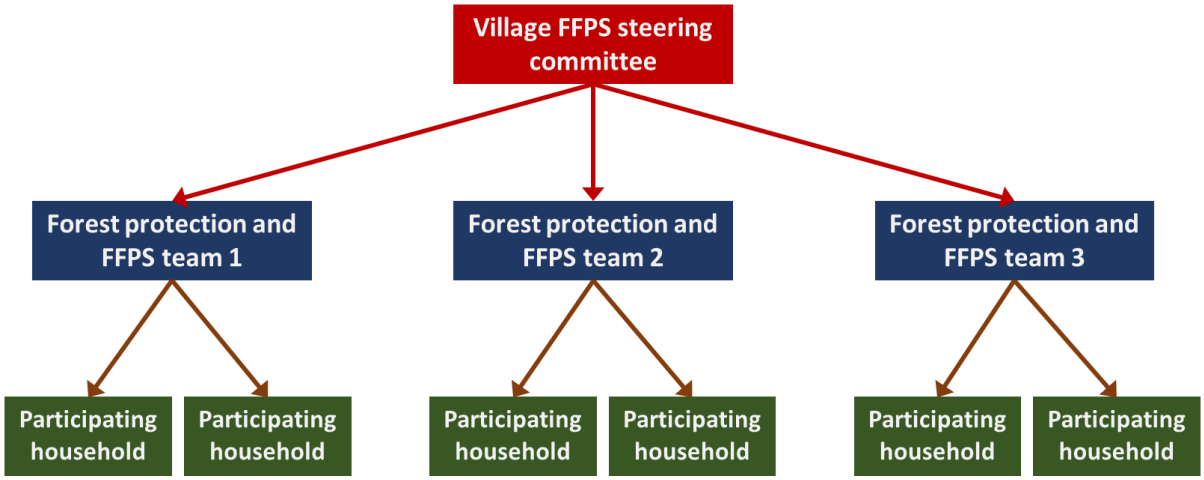


Figure 3.15. Community-based forest management model at village level

**Operation:* the model operates based on the voluntariness of local people in combination with the FFPS forces of the park and the communes; the Communities have the task to patrol, control and detect forest fire in time.

** Building village regulations and improving the awareness of FFPS for the community:* after establishing community-based FFM models in villages, it is necessary to develop regulations on FFM and raise awareness and knowledge of local people about community-based FFM.

** Advantages and disadvantages of community-based QLLR models in villages:*

+ Advantages: (i) It is easy to access to protected forest areas as well as forest areas at high risk of fire; (ii) It will be more proactive in FFPS; (iii) It can achieve the participation of local people and households in the village; (iv) improve the solidarity in the whole village.

+ Disadvantages: (i) As a new model, the application will have certain difficulties, such as low rate of people who voluntarily register to join the model; (ii) Most of local people have not been trained on FFPS; (iii) Most of local people are at low educational level that limits the implementation of FFPS.

3.4.1.3. Solutions on policy mechanisms

- Strengthening the development and implementation of legal regulations on FFPS; Strengthening mechanisms and policies that makes the district and communes authorities can promote the management role and well carry out the tasks of propaganda, education, persuasion and guidance; increasing responsibilities of committees, authorities and related industries for FFPS implementation.

- Implementing priority policies for indigenous people living near forests; implementing forest land allocation contracting; prioritizing families living among and near forests edge to receive long-term contracted forest land; solving the land dispute issue in contracting and providing preferential treatment; provide reasonable compensation for households participating in FFPS.

3.4.2. Solutions for forest restoration after fire

3.4.2.1. Protecting and regenerating disturbed forests

**Subjects:* areas after fire with low density of woody trees, bare land with regenerating trees (height of >0.5m; a density of >500 tree/ha) in the ecological restoration sub-zone will be considered as the target of protecting and regenerating activities.

**Implementation*: Determining of location and boundaries of sector, plot and forest stand on the field; designing map for objects put into the regenerating zone; specific technical measures following the guideline in the Circular No. 29/2018/TT-BNNPTNT.

3.4.2.2. New plantations

Hoang Lien national park needs to continue afforestation in severely damaged areas after fire with low resilience and regenerating trees dominated by grasses and shrubs. These area should be planted by mixing native species. These area are mainly in the area of Ta Van and Ban Ho commune and adjacent to the residential areas.

3.4.2.3. Forest protection

**Subject:* the entire burnt natural forest area in the ecological restoration zone, which was put into protection and the planted forest area with 100 ha planted in 2010 belongs to the ecological restoration sub-zone. At the end of the care period, an annual protection plan must be drawn up (delineated on map).

* Technical measures: following the guideline in the Circular No. 29/2018 / TT-BNNPTNT with specific conditions applied.

CONCLUSION - SHORTCOMINGS - RECOMMENDATIONS

1. Conclusion

a) Basic characteristics of forest resources in Hoang Lien national park

- Hoang Lien National Park has a total area of 28,509 ha, which is one of the most important special-use forests in Vietnam. In particular, natural forests (25,080.09 ha) account for a very large proportion (86.46% of the forest land area). The forest types with large areas include: TXB, TXN, TXP, HG1, RTG, DT2 and DT1. Otherwise, TXG is concentrated mainly in strictly protected areas.

- The TXN, TXP and HG1 forest types in Hoang Lien National Park had been greatly disturbed. The forest canopy structure here had been broken, the canopy cover is at low to medium level (0.31-0.63). Among the forest types, the growth of woody tree layer, shrubs, understory vegetation and regenerating trees showed clear differences. The composition of woody trees and regenerating trees are diverse. Species, such as: *S. wallichi*, *A. nepalensis*, T. *dupifera*, L. *hemisphaericus* , *M. odoratissima*, were dominating in studied forest stands. Understory vegetation developed very well, however, bringing many flammable fuels in the dry season.

b) The characteristics of forest fires, factors affecting forest fires and current situation of forest fire management in Hoang Lien national park

- From 2009 - 2016, forest fires damaged 937.85 ha of forest in the national park, of which the most damage was occurred in 2010 with 718 ha. Forest fire mainly occurred in TXN and TXP forest types (85.66%).

- The dry season in Hoang Lien national park was determined from December to April next year. The main factors causing forest fires were: complex terrain; high slopes; the forest resources distributed mainly at elevations from 1500m - 2500m; the influence of O Qui Ho wind (local hot dry wind); forest types providing much fuel and many activities of local people impacting on the forest.

- Forest management work of Hoang Lien National Park has made many progress but still shows some main shortcomings as follows: limited funds for FFPS; Fire suppression actions showing insignificant results; late direction and administration from local authorities; ineffective activities of FFPS; unquantified high forest fire risk zoning; no model of community-based FFM; limited FFPS construction; no FFM map to FFPS; and so on.

c) The possibility of forest restoration after fire in Hoang Lien national park

- Burnt forests 6 years after fire had clearly recovered with the growth of plants with good regeneration ability, such as *S. wallichii*, *M. odoratissima*, and *E. tonkinensis* with the density of regenerating trees reaching over 1,000 tree/ha; the rate of high potential tree of 69.2% -81.2%; and understory vegetation and shrubs with the average height of approximately 1.0 m and the coverage of 75.4-82.0%.

- After forest fire, the humidity, porosity, organic content and N_2O content of the studied forest soil reduced and the NPK content along with the soil pH increased. In the following years, these indicators tended to increase gradually.

- The study identified 10 species in Hoang Lien national park area with relatively good fire resistance, suitable for site conditions, providing certain economic benefits and able to use for forest restoration, including: *S.wallichii, A. nepalensis, M. mediocris, E.t onkinensis, A. yunnamensis, L. chinense, B. alnoides, L. hemisphaericus, M. insignis, C. tonkinensis*.

d) Solutions to improve FFPS and forest restoration after fire in Hoang Lien national park

- Solutions to enhance FFPS: forest fire risk classification with 4 levels: non-forest land and bamboo forest at extremely high risk (level IV); plantation and poor forests at high risk level (level III); regenerating forests (level II); Rich and medium forests at low risk (level I); developing forest fire risk map; determining and mapping 6 high fire risk zones: (1) Tram Ton - Nui Xe area (San Sa Ho commune); (2) Seo My Ty, Den Thang, and Ta Van Giay (Ta Van commune), Seo Trung Ho (Ban Ho commune); (3) Ma Ma Ho and Ta Trung Ho area (adjacent to Ta Van commune); (4) Phuc Khoa commune (Tan Uyen town); (5) Trung Dong commune (Tan Uyen town); (6) Central area of Ban Ho commune; designing 9,405 m of green belt for forest fire blocking.

- Developing FFM map; proposing to build community-based FFM model; proposing forest restoration solutions including protecting and regenerating disturbed forests, and afforestation.

2. Shortcomings

+ The thesis has only used a number of factors that mainly affect forest fire for analysis without quantitative studies;

+ The community-based FFM model was only proposed on paper that there is a need to have empirical model validation;

3. Recommendations

- Continuing to research additional factors influencing forest fire to evaluate the impacts and suggesting solutions to improve FFPS in Hoang Lien national park.

- It is necessary to test the community-based FFM model as proposed.

- Continuing to assess the ability of forest regeneration after fire to select appropriate silviculture solutions to contribute to improving the ability of forest restoration after fire.

- Building greed belt with fire resistant plants to contribute to improving the effectiveness of FFPS for Hoang Lien national park.

LIST OF PUBLISHED ARTICLES

1. Be Minh Chau, Le Thai Son, Nguyen Van Thai, Tran Minh Canh (2014), *The characteristics of forest plant after fire in Hoang Lien national park, Lao Cai province*, Science and Technology Journal of Agriculture and Rural development, Special issue, pg. 143-149.

2. Canh T.M, Son L.T., Thang L.X. (2018), *Characteristics of fuels and fire risk among the main forest types in Hoang Lien national park*, Journal of forestry science and technology, No.2, pg. 85-95.

3. Tran Minh Canh, Le Thai Son (2018), *Identifying plant species with fire- resistant abilities in Hoang Lien national park*, Science and Technology Journal of Agriculture and Rural development , 5/2018, pg. 119 - 127.