CHARACTERISTICS OF FUELS AND FIRE RISK AMONG THE MAIN FOREST TYPES IN HOANG LIEN NATIONAL PARK

Tran Minh Canh[1], Le Thai Son[2], Le Xuan Thang[3]

[1]*Hai Duong University*
[2]*Vietnam National University of Forestry*
[3]*Hoang Lien National Park*

SUMMARY

Hoang Lien National Park has 25,113.66 ha of forest under its management, including the main forest types as natural broadleaf evergreen forest (poor; average and rehabilitation forests), bamboo, bamboo and mixed forests, and plantation forest. There are small areas of natural rich forest left, mainly located in strictly protected zone, and 2,143.75 ha of uncovered land or area of regenerating woody plants. There are clear differences in terms of fuels among forest types that were clarified by using indicators as trunk height, height and cover of understory vegetation, load and moisture of fuels. From the characteristics of fuels, the study divided fire risk for forests, shrublands and grasslands into 4 levels of danger. As a result, shrubs and grasses and bamboo forest are at highest fire risk (level IV); Plantation forest and evergreen poor forest are at high risk of fire (level III); Rehabilitation forests are at medium risk (level II); and evergreen average and rich forests are at low risk (level I). From the results above, this study also has created a map of fire risk division for forest types in Hoang Lien National Park.

Keywords: Characteristics of fuels, forestfire prevention and suppression, forestfire risk, forest types, Hoang Lien National Park.

I. INTRODUCTION

Forest fire is one of the most important causes of deforestation and forest degradation, affecting many aspects of socio-economic development. Therefore, forest fire prevention and suppression is always of interest in many countries around the world, including Vietnam. The presence of forest fires requires the interaction of three elements: heat source, oxygen and fuels (combustible materials). In fact, fuels have great influence on both the emergence and spread of forest fire and this element is the most preferred object by humans control the fire (Heikkila et al., 2007). To assess the risk of fire among forests in different statuses, as the basis for proposing solutions for forest fire prevention and suppression to a local or forest protection units, it is necessary to study on the characteristics of fuels.

Hoang Lien National Park, with a total area of 28,509 ha, consists of 27 sub-zones distributing in 7 communes and towns in Sa Pa district in Lao Cai province and Tan Uyen district in Lai Chau province. Hoang Lien National Park is one of the top biodiversity centers in Vietnam. This is a home for many endemic species listed in the Red Data Book of Vietnam as well as the The International Union for Conservation of Nature (IUCN) Red List. However, in recent years, forest fires have occurred in this park, thus affecting both the area and quality of forests along with the local socio-economic development.

This paper presents the results of the study, which has assessed the fuel characteristics and identified the fire risks of the main forest types to build up basis for proposing solutions for forest fire prevention and suppression in Hoang Lien National Park.

II. RESEARCH METHODOLOGY

2.1. Study subjects and site

The study subjects include characteristics of fuels under the main forest types in Hoang Lien National Park: medium evergreen natural forest (TXB); poor evergreen natural forest (TXP);

poor evergreen natural forest (TXN); woody + bamboo mixed forest (HG1, TNK); plantation forest (RTG) and non-forest land (DT1, DT2) in Ta Van, Ban Ho and San Sa Ho communes (three communes with frequent forest fires) in Sa Pa district, Hoang Lien National Park (Fig. 1).

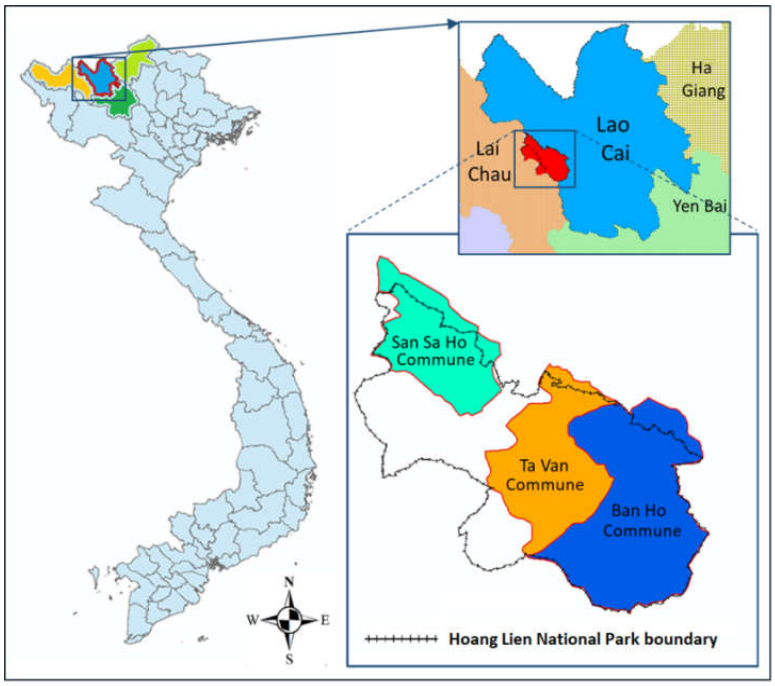

Fig. 1. Maps of study sites in Sa Pa district, Lao Cai province

2.2. Methodology

2.2.1. Secondary data

The study has used secondary data and information in relation to natural and socio-economic conditions, forest fire situation and forest fire prevention and suppression activities in the study area (Fig. 1).

2.2.2. Field survey

a) Survey on forest and fuel characteristics of the main forest types

The study has executed forest classification according to the Circular 34/2009/TT-BNNPTNT by the Ministry of Agriculture and Rural Development (Vietnam Government, 2006). After identifying the main forest types in high elevation areas that forest fires often occur, the study has established permanent sample plots (PSPs). Within each forest type, there were 2 ÷ 4 PSPs of 500 m^2 established depending on the area available. There was a total of 45 PSPs set up this study.

- Survey on overstorey trees: identifying plant species and measuring their diameter at breast height (DBH), crown diameter, tree top height, trunk height and canopy cover were conducted.

- Survey on regeneration trees and unverstory vegetation: surveying on 9 quadrats with area at least 4 m^2 inside each PSP to identify species, height, cover, growing status (good, medium, poor) and type (seeding or coppice) of regeneration trees was carried out.

- Survey on fuel characteristic: surveying on five quadrats with area of 1 m^2 inside each PSP to collect information on composition, mass, moisture, height of understorey vegetation, thickness of litter layer, combustible ability to build a basis for assessing risk of forest fires among different forest types was conducted.

b) Forest classification by fire risk

Forest classification by fire risk was carried out according to the multi-criteria method. Criteria used for analyis and ranking of forest fire risk included volume, fuel

distribution, cover, trunk height and understorey vegetation height. To classify forests by fire risk, the study uses E_{ct} - the Effective Indicator of Farming system (Nijikam, 1982). E_{ct} can be calculated as followings:

(1)- Characteristic table in association with fire risk of forest types was created;

(2)- Computing Fij values for each criterion: Fij refers to a distinct value for the criterion "j" in the PSP "i". There many ways to calculate Fij values.

If an indicator benefits with increasing, it is standardized as $Fij = x_{ij}/x_{max}$, in which x_{ij} is the value of the criterion j from the PSP i, X_{max} is the maximum value existing as in the criterion j. In contrast, if an indicator benefits with decreasing, the standardized value is $Fij = 1 - (x_{ij}/x_{max})$. To enhance the accuracy of the analysis, the study defines the weight coefficient Pj for the criterion j by expert consultation.

(3)- Ect calculation

$$Ecti = \sum_{j=1}^{n} (Fij*Pj) \qquad (1)$$

Where: Ecti is the total effective indicator of all the criteria from the PSP i; Pj is the weight coefficient referring to the importance of the criterion j; n is the number of criteria used for Multi-Criteria Analysis (MCA).

(4)- Forest classification by E_{ct} (or Fire Risk Index)

The average of E_{ct} indices from PSPs in the same forest type is used for forest classification by fire risk. Forest types with familiar E_{ct} are categorized into the same group that means different groups contain forest types with different risk of fire.

III. RESULT AND DISCUSSION

3.1. Status of forest resources and forest fire situation in Hoang Lien National Park

3.1.1. Status of Forest and Forest land

According to the forest inventory result of Hoang Lien National Park in 2016 (Hoang Lien National Park Forest Protection Service, 2016), area by forest types and non-forest land are shown in table 1.

Table 1. Status of forest and forest land in Hoang Lien National Park

	Land use	Area (ha)	Proportion to total natural area (%)	Proportion to forest area (%)
	Total natural area	**28,509.00**	**100**	
1	***Forest area***	***25,113.66***	***88.09***	***100***
1.1	Natural forest	24,857.00	87.19	98.98
1.1.1	Woody evergreen forest	*24,243.19*	85.04	96.53
	- Rich forest	826,87		
	- Medium forest	5,835.19		
	- Poor forest	14,127.82		
	- Rehabilitation forest	3,453.31		
1.1.2	Wood + bamboo mixed forest	*215.57*	0.76	0.86
1.1.3	Bamboo forest	*398.28*	1.40	1.59
1.2	Plantation forest	256.66	0.90	1.19
2	***Non-forest land***	***2,143.75***	***7.52***	
3	***Others***	***1,251.58***	***4.39***	

Source: Hoang Lien National Park Forest Protection Service (2016)

The statistics show that the natural forest area of Hoang Lien National Park is quite large of 24,857.0 ha (accounting for 87.19% of the natural area and 98.98% of the total forest area). There are 24,243.19 ha of forest (equivalent to 97.53% of natural forest area),

mixed wood and bamboo forest (0.87%), bamboo forest (1.6%); plantation forest accounts for only 0.9% of the natural area and land without forest is 7.52%. Forest area includes rich forest (826.87 ha), medium forest (5,835.19 ha), poor forest (14,127.82 ha), rehabilitation forest (3,453.31 ha). It is remarkable that there is non-forest land (DT1; DT2) of 2,143.75 ha, accounting for 7.52% of the total natural area in Hoang Lien National Park.

The above results show that the forest types with large area of Hoang Lien National Park include evergreen broad-leaved poor forest (poor forest), medium evergreen broad-leaved medium forest (medium forest), natural broad-leaved evergreen rehabilitation reforest (rehabilitation forest), bare land or regenerating woody tree (non-forest land), bamboo forest and woody plantation forest (plantation). There is very small area of natural rich forests (3.29% of total forest area) along with medium timber forests, which are usually distributed in strictly protected areas. These forest types have high levels of biodiversity and are areas of interest for protection.

3.1.2. Forest fire situation in Hoang Lien National Park

According to the statistics by Hoang Lien National Park Forest Protection Service, forest fires in Hoang Lien National Park in the last 8 years are described as in table 2.

Table 2. Forest fire area in Hoang Lien National Park (2009 - 2016)

Time	Commune	Village	Sub-zone	Area (ha)	Forest type area (ha)			
					TXP	TXN	RTG	DT1 & DT2
2/2009	Ta Van	Seo My Ty	286	83.95	3.40			80.55
		Ma Quai Ho	287	36.00	36.00			
2/2010	Ban Ho	Ta Trung Ho	291	299.00	283.00	16.00		
			295b	51.00	51.00			
			296	75.00	69.00	6.00		
			302	59.00	54.00	5.00		
3/2012	Ta Van	Seo My Ty	286	154.00	145.00	9.00		
	San Sa Ho	Sin Chai	272	44.00	42.20	1.80		
	Ta Van	Seo My Ty	295a	13.85	8.5	5.35		
			292a	59.75	45.25	14.5		
3/2013	Ban Ho	Seo Trung Ho	283b	3.42				3.42
3/2014	Ban Ho	Ta Trung Ho	296	21.00	1.6			19.40
	Ta Van	Seo My Ty	292a	12.70	5.2			7.50
2/2015	Ban Ho	Ta Trung Ho		12.70	0.54			12.16
2/2016	Ta Van	Seo My Ty, Ta Van Giay	208	12.48	0.98		1.70	9.80
Total				**937.85**	**742.27**	**57.65**	**1.70**	**132.63**

Source: Hoang Lien National Park Forest Protection Service (2017)

As in the statistics, in the period 2009 - 2016, fires damaged 937.85 ha of forest within Hoang Lien National Park. Forest fires occurred mainly in rehabilitation forest (79.51%), followed by grassland and shrubland (14.16%), poor forest (6.15%) and plantation forest (0.18%). Particularly, the largest area of forest fire occurred in 2010 with 718 ha (76.56% of total forest fire area in the 8 - year period). Forest fires usually occurred in February and March. During this period, the weather was favorable for the emergence and spread of forest fires. It also coincided with the time indigenous people prepare for cultivation.

Areas with the most frecquencies of forest fire occurrence are Ta Trung Ho, Seo Trung Ho, Ma Quai Ho (Ban Ho Commune), Seo My Ty (Ta Van Commune), Sin Chai (San Sa Ho Commune). The main drivers of forest fires here are using slash-and-burn fire, farmland preparation, cardamom cultivation and natural honey harvesting. These activities are very difficult to be managed.

3.2. Forest and combustible material characteristics in the main forest types

3.2.1. Overstorey trees

The characteristics of some overstorey species among the main forest types in the communes Ta Van, Ban Ho and San Sa Ho are summarized in table 3.

Table 3. Overstorey tree survey's results

Commune	Forest type	Tree density (tree/ha)	Top height (m)	Trunk height (m)	Canopy diameter (m)	DBH (cm)	Canopy cover (%)
San Sa Ho	TXN	295	10.05	3.48	2.86	10.64	33
	TXP	411	10.20	4.36	3.08	13.38	46
	TXB	688	14.80	11.23	4.27	25.48	57
	RTG	820	8.20	3.20	2.70	10.50	60
Ta Van	TXN	220	9.50	3.17	3.00	7.00	31
	TXP	355	11.64	5.33	2.95	13.60	51
	TXB	667	16.99	9.94	5.63	28.73	62
	RTG	780	8.80	3.25	2.90	10.69	63
Ban Ho	TXP	560	11.80	6.85	2.59	15.36	52

Table 3 shows that the density and the average growth of overstorey trees are at relatively low levels and different between forest types. The natural forest here has been affected significantly; the canopy layer structure is broken; forest cover is only at medium (from 46 to 62%) or even low levels such as Poor forest - TXN (San Tu Ho commune: 0.33, Ta Van commune: 0.31). Between forest types, the DBH is in large variation. When comparing forests in San Sa Ho and Ta Van communes, the density and growth of the same forest type are relatively homogeneous.

Medium forest - TXB has the best growth rate, most of which are trees > 25 cm in diameter and have grown well. Due to the regeneration time in this forest type longer than the rest, an ecologically dominant tree layer has been formed. Rehabilitation forest - TXP, including typically fast-growing light-demanding species, is with unstably medium growth rate. Trees of this forest type grow slowly; the average height is quite low; the density is only from 355 to 411 trees ha^{-1}, except in the Ban Ho commune, the density is quite high at 560 trees ha^{-1}. Plantation forest, planted with mainly *Cunninghamia lanceolata* (Lamb.) Hook., *Schima wallichii* (DC.) Korth and *Alnus nepalensis* D. Don, has well grown. This forest type, with high density and cover, needs high-quality treatment, management and protection to avoid any negative influence.

In Ta Van commune, some dominant trees such as *S. wallichii* (DC.) Korth, *Camellia sp, Lithocarpus hemisphaericus, Rhododendron densifolium* K. M. Feng... are able to fast grow and develop well. However, most of them are not economically valuable. In San Sa Ho commune, plants such as *S. wallichii* (DC.) Korth, *Cinnamomum tonkinensis* Pitard, *A. nepalensis* D. Don, *R. densifolium* K. M. Feng

and *Magnolia nana* Dandy are dominant. In Ban Ho commune, forest is mainly rehabilitation; the number of species is much lower than that of Ta Van and San Sa Ho communes. There are only four dominant species here: *Claoxylon cascarrioides, Camellia sp., S. wallichii* (DC.) Korth and *C. tonkinensis* Pitard.

3.2.2. Regeneration trees

The survey on the characteristics of regeneration trees shows that some species, such as *S. wallichi* (DC.) Korth*, R. densifolium* K. M. Feng*, C. tonkinensis* Pitard, several of the genus *Michelia*, *A. nepalensis* D. Don*, Exbuclandia tonkinensis* (Lecomte) V. Steen., *Lantana camara* and *Vernicia montana* Lour. are present in both understorey and overstorey forest layers in the study area. This has partly demonstrated that they are adaptable to site conditions. In addition, some species, including *Michelia fuscata*, *Quercus sp.* and *Alangium chinense,* participate in building rich and diverse forest structures in terms of species composition. These are native species with good regeneration ability. They, especially *A. nepalensis* D. Don and *S. wallichii* (DC.) Korth, can appear as individuals or big clusters along paths or deeply within forests. Regenerating tree composition is not much different with which from overstorey trees. Indeed, natural seedlings of many species, such as *S. wallichii* (DC.) Korth*, A. nepalensis* D. Don*, Eurya ciliate, Camellia sp.* and several of the genus *Castanea,* are growing under seed bearers which contribute to overstorey composition. However, there is still a need to have more management measures from the Forest Protection Services, local government and people to achieve a more effective regeneration from these forest types.

3.2.3. Characteristics of combustible materials from forest types within the study area

a) Composition and height of the understorey layer

Composition and height of the understorey layer, which are the results of the survey in this study, are summarized in table 4.

From the results in table 4, characteristics of understorey layer in the study area can be concluded as folowings:

The understorey cover in grasslands and shrublands in Ban Ho commune is of medium height and low coverage. In contrast, the coverage of this layer in San Sa Ho and Ta Van communes is quite high (71 - 73%) with the composition including flammable plants such as *S. petelotii* (A. Camusa) A. Camus, *X. sikkimensis* (Hieron.) Copel., *D. linearis* (Burm.f.) Underw, *S. palmifolia* (Koen) Stapf, etc. This is a high-risk source of combustible materials. Especially in the dry season, they will die and be naturally dried that become a massive source of fuels. Hence, if forest fire occurs, it will spread rapidly on a large scale. In rehabilitation forest and poor forest, in general, the understorey layer is at medium level, with the height of 41 - 64 cm and the coverage of roughly 50%.

In medium forests, the understorey layer is of medium height (92 cm in San Sa Ho commune and 85 cm in Ta Van commune) with the corresponding coverage of 75% and 85% respectively. This is a relatively high level of forest cover, in which some species are hygric and contain high water content. Plantation forests are at medium level of height and cover. However, this forest type is often treated and cleaned by people that make the understorey composition quite simple.

Table 4. Results from survey of understorey layer

Commune	Crop type	Main species	Average height (cm)	Cover (%)
San Sa Ho	Grassland, shrubland	*Sinarundinaria petelotii* (A. Camusa) A. Camus, *Melastoma imbricata* Wall. ex C.B. Clarke, *Setaria palmifolia* (Koen) Stapf, *Xiphopteris sikkimensis* (Hieron.) Copel.	55	73
	Poor forest	*M. imbricata* Wall. ex C.B. Clarke, *X. sikkimensis* (Hieron.) Copel., *S. palmifolia* (Koen) Stapf, *Dicranopteris linearis* (Burm.f.) Underw., *Bidens pilasa* L., *Rubus Alceaefolius* Poir., *Physalis angulata*.	41	49
	Rehabilitation forest	*X. sikkimensis* (Hieron.) Copel., *D. linearis* (Burm.f.) Underw., *S. palmifolia* (Koen) Stapf, *Pogonatherium crinitum* (Thunb.) Kunth, *Herminium lanceum* (Thunb. ex Sw.) Vuijk., *R. Alceaefolius* Poir., *S. petelotii* (A. Camusa) A. Camus, *P, angulata, Chromalaena odorata* (L.).	45	45
	Medium forest	*S. palmifolia* (Koen) Stapf, *X. sikkimensis* (Hieron.) Copel., *Dysoxylum tonkinense* Chev. ex Pellegr., *R. Alceaefolius* Poir. (R. moluccanus L), *Tradescantia pallida*, *Psychotria rubra* (Lour.) Poir (P. reevesii Wall), *M. imbricata* Wall. ex C.B. Clarke, *Phrynium placentarium*...	92	75
	Plantation forest	*X. sikkimensis* (Hieron.) Copel., *Dicranopteris linearis* (Burm.f.) Underw., *Setaria palmifolia* (Koen) Stapf, *R. Alceaefolius* Poir., *C. odorata* (L.).	67	60
Ta Van	Grassland, shrubland	*S. petelotii* (A. Camusa) A. Camus, *P. angulata*, *S. palmifolia* (Koen) Stapf, *M. imbricata* Wall. ex C.B. Clarke, *D. linearis* (Burm.f.) Underw., *X. sikkimensis* (Hieron.) Copel…	49	71
	Poor forest	*D. linearis* (Burm.f.) Underw., *C. odorata* (L.), *M. imbricata* Wall. ex C.B. Clarke, *Piper chaudocanum* C. DC, *R. Alceaefolius* Poir., *S. palmifolia* (Koen) Stapf, *X. sikkimensis* (Hieron.) Copel., *P. angulata*...	64	41
	Rehabilitation forest	*S. palmifolia* (Koen) Stapf, *Setaria glauca* (L.) P. Beauv., *X. sikkimensis* (Hieron.) Copel., *M. imbricata* Wall. ex C.B. Clarke, *D. linearis* (Burm.f.) Underw., *P. angulata*, *Amomum aromaticum* Roxb., *R. Alceaefolius* Poir. (R.moluccanus L)...	41	53
	Medium forest	*X. sikkimensis* (Hieron.) Copel., *S. palmifolia* (Koen) Stapf, *M. imbricata* Wall. ex C.B. Clarke, *D. linearis* (Burm.f.) Underw., *Psychotria rubra* (Lour.), *A. aromaticum* Roxb.	85	55
	Bamboo forest	*S. petelotii* (A. Camusa) A. Camus, Bamboo, *S. palmifolia* (Koen) Stapf, *Amomum lacteum* Ridl., *D. linearis* (Burm.f.) Underw., *Phrynium placentarium*…	85	80
	Plantation forest	*Setaria palmifolia* (Koen) Stapf, *X. sikkimensis* (Hieron.) Copel., *R. Alceaefolius* Poir. (R. moluccanus L), *A. aromaticum* Roxb.	69	53
Ban Ho	Rehabilitation forest	*Calamus* sp., *Maesa* SP., *X. sikkimensis* (Hieron.) Copel., *S. palmifolia* (Koen) Stapf, *M. imbricata* Wall. ex C.B. Clarke, *Clerodendron infortunatum* L, *Dysoxylum tonkinense* Chev. ex Pellegr....	32	45
	Grassland, shrubland	*Sinobambusa sat* (Bal.) T.Q. Nguyen Lau, *Setaria palmifolia* (Koen) Stapf, *X. sikkimensis* (Hieron.) Copel., *Achyranthes aspera* L., *Bidens pilasa* L., *S. petelotii* (A. Camusa) A. Camus…	25	30

b) Mass and water content of fuels from forest types

Mass and water content (relative moisture content) of fuels is a significant factor because of its direct effects on the flammable ability, emergence and spread speed of forest fires as well as the level of damage caused by the fires. These characteristics are in table 5.

Table 5. Mass and water content of fuels from forest types

Commune	Forest type	Mass (tons/ha)			Water content (%)
		Dried material	Green material	Total	
San Sa Ho	Grassland, shrubland	11.21	11.31	22.52	13.33
	Poor forest	8.74	10.93	19.67	23.10
	Rehabilitation forest	11.04	8.49	19.53	21.31
	Medium forest	13.99	3.02	17.01	30.41
	Plantation forest	13.24	6.43	19.67	22.23
Ta Van	Grassland, shrubland	11.49	13.10	24.59	14.47
	Poor forest	7.11	13.30	20.41	21.37
	Rehabilitation forest	7.35	12.04	19.39	25.66
	Medium forest	6.52	21.61	28.13	32.63
	Bamboo forest	6.50	8.72	15.22	16.73
	Plantation forest	13.56	6.98	20.54	24.09
Ban Ho	Rehabilitation forest	7.52	11.32	18.84	20.65
	Grassland, shrubland	10.75	12.24	22.99	15.43

The results show that water content is quite high in medium forests (30.41% in San Sa Ho commune and 32.63% in Ta Van commune). This may be caused by high canopy cover. The canopy layer is capable of partly blocking solar radiations along with the ability of water retaining that make combustible materials on the ground always of certain moisture. In rehabilitation and poor forests, the content of water in fuels is average from 20.65% - 25.66%.

Combustible materials in grasslands and shrublands have average water content at the lowest level in the study area (13.33% in San Sa Ho commune, 14.47% in Ta Van commune and 15.43% in Ban Ho commune). All they are at high level of fire risk. The understorey composition includes flammable plants, such as *D. linearis* (Burm.f.) Underw., *C. odorata* (L.) King et Robinson and *X. sikkimensis* (Hieron.) Copel., etc., that push the probability of fire outbreak and spread to a high level if fire occurs. Most of the plantation forests is located in a lower-elevation area or people have planted *Amomum aromaticum* Roxb. under the canopy that decrease fire risk to the medium level. Indeed, *A. aromaticum* Roxb. is a broad-crown plant that can cover the soil and save water to hold fuel moisture at a moderate level.

Table 5 shows that there is a massive amount of combustible materials among forest area. Grasslands, shrublands and medium forests have the largest mass of fuels (> 20 tons/ha) that is very dangerous to forest fire.

In other forest types, the amount of fuels is medium. However, well-developed understorey layers along with the severe weather condition in the North West (i.e. long periods of dry and hot weather) make the fire risk here need to be considered.

3.2.4. Assessment on fire risk of forests and forest lands in Hoang Lien National Park

From the analysis in the previous sections, the study classified fire risk of studied forest types by standardizing the criteria by the opposite method

(Nguyen Hai Tuat, 2010), in which: Criterion 1 is fuel water content - Wv (%); Criterion 2: fuel mass - Mv (ton/ha); Criterion 3: height of understorey trees - Hcb (cm); Criterion 4: trunk height - Hdc (m); Criterion 5: understorey coverage - CP (%). The weight coefficients of these criteria are defined by expert consultation: coefficient of 0.25 for Criterion 1 and Criterion 2; 0.2 for Criterion 3; and 0.15 for Criterion 4 and Criterion 5. The statistics of the criteria are in table 6.

Table 6. Criteria for assessment on fire risk of forests and forest lands

Forest type	Wv (%)	Mv (ton/ha)	Hcb (cm)	CP (%)	Hdc (m)
Grassland, shrubland	14.41	23.37	52.0	72.0	0.0
Poor forest	22.23	20.41	52.5	45.0	4.5
Rehabilitation forest	23.49	19.46	46.2	47.7	4.7
Medium forest	31.52	18.10	65.0	80.0	10.6
Bamboo forest	16.73	15.22	85.0	80.0	0.0
Plantation forest	14.41	20.11	68.0	56.5	3.2

The criteria above were standardized by the opposite method to calculate the E_{ct} index. The quantification results are in table 7.

Table 7. Results of criterion standardization

Forest type	Wv (%)	Mv (ton/ha)	Hcb (cm)	CP (%)	Hdc (m)	Ect
Grassland, shrubland	0.136	0.250	0.122	0.135	0.150	0.793
Poor forest	0.074	0.218	0.124	0.084	0.086	0.689
Rehabilitation forest	0.064	0.208	0.109	0.089	0.083	0.553
Medium forest	0.000	0.194	0.153	0.150	0.000	0.497
Bamboo forest	0.117	0.163	0.200	0.150	0.150	0.780
Plantation forest	0.136	0.215	0.160	0.106	0.105	0.721

Based on the range of changes in the overall indicator E_{ct}, the study has classified the fire risk into 4 level as below:

+ Level I - Low risk of fire ($E_{ct} < 0.55$);

+ Level II - Medium risk of fire ($0.55 \leq E_{ct} < 0.65$);

+ Level III - High risk of fire ($0.65 \leq E_{ct} < 0.75$);

+ Level IV - Extremely high risk of fire ($E_{ct} \geq 0.75$).

According to the classification: shrublands and grasslands (category Ic) and bamboo forest are at highest fire risk (level IV); Plantation forest and evergreen poor forest are at high risk of fire (level III); Forest without volume is at medium risk (level II); and evergreen average are at low risk (level I). Rich forests with a small area are classified as level I due to their conditions unsuitable for forest fire.

The results of the classification may also be relative because forest fires are actually influenced by many other factors such as site condition, impact of people, and especially weather. Rehabilitation forests now are only at medium level because of high moisture, but during hot and windy periods, heavy winds can push the fire risk to the highest level. In reality, the burnt areas of regeneration forest is the largest compared to other forest types because in the subsequent years from fire, these areas have been partly counted as regeneration forest.

3.2.5. Building fire risk map of forest types in Hoang Lien National Park

From the fire risk classification, the study have built the fire risk map for the study area. Each level is represented by a single color as in fig. 2.

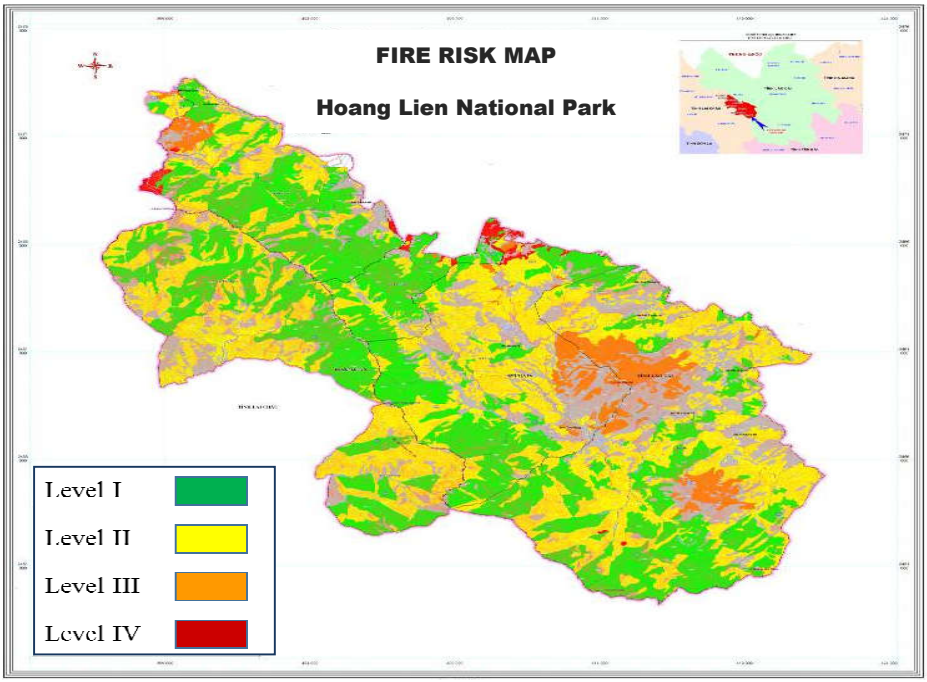

Fig. 2. Fire risk map of forest types in the study area

According to Fig. 2, there is not large area of forest with low fire risk, especially a very small area of medium and rich forests. These forest types are scattered over 4 communes but often located in area within strictly protected sub-zones, with rugged terrain or at high elevation. Plantation forests at high fire risk are often located near the national highway from Sa Pa to Lai Chau province.

The high and very high fire risk forests are scattered throughout all communes in Hoang Lien National Park. However, the risk is concentrated in the villages Seo My Ty, Den Thang and Seo Trung Ho - Ta Van commune; the villages Ta Trung Ho and Ma Quai Ho - Ban Ho commune; and area on Nui Xe mountain (adjacent to Lai Chau) - San Sa Ho commune. These high risk forest types concentrate to the North East of the communes. This is where fires occur annually that prove the high level of fire risk in these locations. In addition, there are ethnic minorities living in these areas that is difficult to control sources of fire.

IV. CONCLUSION

- Hoang Lien National Park currently has 25,113.66 ha of forest, with the main types as poor and medium evergreen broad-leaved lowland forest, bamboo forest and plantation forest. There are very small area of natural rich forest often located in strictly protected sub-zones. The rest of national park area is 2,143.75 ha of bare land with or without regeneration trees.

- From 2009 to 2016, fires damaged 937.85 ha of forest in Hoang Lien National Park. Forest fire has occured mainly in rehabilitation forest (79.51%), followed by grasslands and shrublands (14.16%), poor forest (6.15%) and plantation forest (0.18%). The fire season is during February and March, mainly due to slash-and-burn agriculture, hunting and honey-making. Frequent-fire area are concentrated in Ban Ho, Ta Van and San Sa Ho communes.

- Poor and rehabilitation forests have been greatly influenced; the canopy structure is broken down, the forest cover is at low level (31 - 52%) facilitating the understorey vegetation layer to

well develop. In each forest type, there are different vegetation characteristics, thus forming different fuel sources for fire.

- There is a clear difference in fuel characteristics among forest types, including trunk height, height and coverage of understorey trees, mass and moisture of combustible materials.

- Based on characteristics of combustible materials, the study successfully classified forest types by fire risk into 4 levels as follows: shrublands and grasslands (category Ic) and bamboo forest are at highest fire risk (level IV); Plantation forest and evergreen poor forest are at high risk of fire (level III); Forest without volume is at medium risk (level II) and evergreen average are at low risk (level I).

From those results, it is necessary to further study on other factors, such as terrain, climate, forest fire characteristics and other socio-economic factors, to propose solution for forest fire prevention and suppression following scientific and practical bases.

REFERENCES

1. Heikkila T. V., Gronqvist R., Jurvelius R. M. (2010). *Wildland Fire Management*. Forest Management Team, Forestry Department, FAO. Rome.

2. Hoang Lien National Park (2014). *Adjustment and supplement to the plan for forest fire prevention and suppression in the dry season 2014-2015.*

3. Hoang Lien National Park (2016). *Statistics of forest area in Hoang Lien National Park.*

4. Hoang Lien National Park (2017). *Report on fire situation in Hoang Lien National Park*.

5. Nguyen Hai Tuat, Tran Quang Bao, Vu Tien Thinh (2010). *Quantitative ecological research methods*. Agriculture publisher, Ha Noi.

6. Vietnam Government (2006). The *decree No. 09/2006/ND-CP on fire prevention and supppression*. Ha Noi.

ĐẶC ĐIỂM VẬT LIỆU VÀ NGUY CƠ CHÁY Ở CÁC TRẠNG THÁI RỪNG CHỦ YẾU TẠI VƯỜN QUỐC GIA HOÀNG LIÊN

Trần Minh Cảnh[1], Lê Thái Sơn[2], Lê Xuân Thắng[3]

[1]Trường Đại học Hải Dương
[2]Trường Đại học Lâm nghiệp
[3]Vườn Quốc gia Hoàng Liên

TÓM TẮT

Vườn quốc gia Hoàng Liên hiện quản lý 25.113,66 ha rừng, với các trạng thái chủ yếu: rừng gỗ tự nhiên lá rộng thường xanh nghèo, trung bình, rừng phục hồi, rừng tre nứa và rừng trồng. Rừng tự nhiên giàu hiện còn rất ít, thường phân bố ở phân khu bảo vệ nghiêm ngặt và 2.143,75 ha đất trống không hoặc có cây gỗ tái sinh. Có sự khác nhau khá rõ về đặc điểm vật liệu cháy (VLC) ở các trạng thái rừng, qua những chỉ tiêu gồm: Chiều cao dưới cành tầng cây cao, chiều cao và độ che phủ của lớp thảm tươi cây bụi, khối lượng và độ ẩm VLC. Từ đặc điểm VLC, phân nguy cơ cháy của các trạng thái rừng và trảng cỏ, cây bụi thành 4 cấp theo mức độ nguy hiểm với lửa như sau: trạng thái trảng cỏ cây bụi và rừng tre nứa có nguy cơ cháy cao nhất (cấp IV); trạng thái rừng trồng và rừng thường xanh nghèo có nguy cơ cháy ở mức cao (cấp III); rừng phục hồi có nguy cơ cháy ở mức trung bình (cấp II); rừng thường xanh trung bình và giàu có nguy cơ cháy thấp (cấp I). Từ kết quả phân cấp nguy cơ cháy rừng như trên, xây dựng bản đồ phân cấp nguy cơ cháy cho các trạng thái rừng ở Vườn Quốc gia Hoàng Liên.

Từ khóa: Đặc điểm vật liệu cháy, nguy cơ cháy rừng, phòng cháy - chữa cháy rừng, trạng thái rừng, Vườn Quốc gia Hoàng Liên.

Received : 07/02/2018
Revised : 06/3/2018
Accepted : 14/3/2018