International Forest Fire News (IFFN) No. 36 (January – July 2007, 76-86) ISSN 1029-0864 (web)

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Fuel Assessment and Fire Prevention in Pine Plantations during the Tending Stage in Dalat, Lam Dong Province, Viet Nam

Summary

This paper presents some findings on the structure and dynamics of the grass cover under three-needled pine plantations in the tending period from 1 to 4 year old. Twenty-six species of grasses and herbs including both annual and perennial plants were found in these plantations. Dynamics of the green and dried biomass and the moisture content of the materials during the tending period were analysed. An Inflammability Index (k) was then used to form the basis for the grass cover management. The appropriate tending period for pine plantations in Lam Dong province is from August to September. A set of recommendations in for pine plantations and natural forests in Lam Dong province is also provided.

1. Introduction

Pinus kesiya Royle ex Gordon, a fast-growing, coniferous species, has natural distribution in South-east Asia (Pham 1999). In Vietnam, the species is indigenous to Dalat, Lamdong, from an altitude of 1000 to 1800 m a.s.l.. In planting pine forest for any purpose, forest fire is always considered as a main factor causing remarkable damage to plantations. The weight and property of fire materials available to fire (available fuels) provide the essential conditions for the characteristics and impacts of a forest fire (Johnson and Miyanishi 2001). Therefore, research of combustible materials under pine forest canopy for proposing the effective measures of fire prevention become the issue which is concerned by managers as well as scientists.

The concept of combustible material targeted in this paper includes organic material ready to be oxidized. Previous research have divided fuels into the main following groups:

(1) Cured grass cover
(2) Decayed organic matter, peat, and oil plants
(3) Living grass and shrubs
(4) Sprouting plants
(5) Fallen trees, branches
(6) Harvest residuals (branches, tree tops and stumps)
(7) Living saplings

Groups (3); (4) and (7) may serve as fire-preventing fuels. However, these factors change in the course of the development of the plantations and between the seasons of the year. This study contributes to evaluate the dynamics of fuels in *P. kesiya* plantations using different controlled burning methods combined with silvicultural methods.

2. Object and Methods of Research

The research was implemented in vegetation cover of 1-4 year old *P. kesiya* plantations in Tanung commune, Dalat city, Lamdong province, and several surrounding areas. Methods of evaluating the constitution and structure of vegetation cover will be applied to identify characteristics of fire material in pine plantation in the period of tending. Four methods of processing fore material are applied as follows:

- Controlled burning
- Controlled burning in rows
- Controlled burning combined with tending
- Controlled burning combined with tree spacing

3. Results and Discussion

3.1 Fuel characteristics in *P. kesiya* Plantations

3.1.1 Grass cover

The composition of grass species in the fuel layer in *P. kesiya* plantations is provided in Table 1.

Table 1. Constitution of grass species in fire material

#	Family	Scientific name	Vietnamese name	Remark
1	Poaceae	*Cybopogon annamnensis*	Sa Trung bo	Perennial
2		*Panicum previpolium*	Co Ong	Perennial
3		*Ischaeum aristatum*	Mom Nau	Annual
4		*Bothriochloa pertusa*	Huyet thao Lo	Annual
5		*Microstergium vagans*	Vi Phuong lac	Perennial
6		*Eulalia velutina*	Cat Vi Long	Perennial
7		*Erianthus tustigiatus*	Mao Phuong	Annual
8		*Imperata cylindrica*	Co Tranh	Perennial
9		*Arundinela setosa*	Truc tham long	Perennial
10		*Pennisetum alopecuroides*	Co duoi	Perennial
11		*Hemarthria protonsa*	Ban Tiet Trai	Annual
12		*Themeda caudata*	Lo Duoi, Co phao	Perennial
13		*Poa annua*	Sp	Annual
14		*Thysanolaena maxima*	Dot, Chit	Perennial
15		*Aristida cumingiana*	Ba Chia.	Perennial
16		*Eragrostis nigra*	Tinh Thoa Den	Perennial
17		*Zoysia tenuifolia*	Co Long Heo	Perennial
18		*Pennisetum lopecuroides*	Duoi Voi Tim	Perennial
19	Cyperaceae	*Carex nemostachys*	Kiet Mo Phu	Annual
20		*Carex perakensis*	Kiet Thanh	Annual
21		*Cyberus latespicatus*	Cu Gie Rong	Annual
22		*Seleria exigua*	Cuong Nho	Annual
23	Asteraceae	*Eupatorium odoratum*	Co Lao	Annual
24		*Gynura pseudochina*	Co Tau Bay.	Annual
25		*Anaphalis adnata*	Bach Nhung Con	Perennial
26	Pteridoideae	*Pteridium aquilinum*	Duong Xi	Perennial

Remarks: In the investigated areas 26 grass species belonging to 4 families constituting combustible materials are found. These species are mainly belonging to the Poaceae family. Some species are perennial, others are annual. In addition, the constitution of vegetation cover under pine plantation canopy consists of a small proportion of broad-leaved shrub species.

Discussion: The surface fuels in *P. kesiya* plantations during the tending period are mainly grasses. The diversity of species with their different biological characteristics, e.g. different seasonality of growth and curing, result in a non-uniform development of fire risk and fire hazard. The presence of freshly-grown grass species intermixed in cured grass layers is contributing to a decreased ignition risk and fire hazard.

Figure 1. Surface fuels in natural, relatively open pine stands (*Pinus kesiya* Royle ex Gordon) in the highlands of Viet Nam are characterized by grass cover. Under moderate fire weather conditions a surface fire would cause limited damage to the pine overstory.

Figure 2. Young pine regeneration intermixed with grass fuels are at high risk of destructive wildfires.

3.1.1 Fuel structure

The result of studying the structure of vegetation cover in 1-4 year pine plantation is shown in Table 2.

Table 2. Structure of vegetation cover in 1-4 year pine plantation

Year	Level of Abundance	H (m)	M_1 (kg ha^{-1})	m_1 (kg ha^{-1})	m_2 (kg ha^{-1})	M_2 (kg ha^{-1})	W_0 %
1	Cop 1	0.62	6288	1783	4505	3375	51.3
2	Cop 2	0.91	11538	6190	5348	7260	37.10
3	Cop 2	0.95	13672	8580	5092	9714	31.8
4	Cop 2	0.93	14022	9115	4907	10085	28.1

Note: H = Height of dominant grass layer
M_1 = Weight of dry and living grass (kg ha^{-1})
m_1 = Weight of dry grass (kg ha^{-1})
m_2 = Weight of living grass (kg ha^{-1})
M_2 = Weight of dry and living grass after desiccating
W_0 = Moisture content of combustible material (fuels) (%) = $(M_1-M_2) / M_1$

Remarks: The height of the dominant grass layer reaches up to 0.62 m in the first year and up to more than 0.9 m in the second year. Total weight of material (M_1), weight of dry grass (m_1) and weight of dry and living grass after desiccating (M_2) tend to increase year by year. However, the weight of living grass almost has no change and relative humidity of material appear to decrease when the year of plantation increases.

Discussion:

- The more weight of dry grass (m_1), the higher are risk and hazard of forest fires; and the more weight of living grass, the less risk of forest fire.
- In plantations after tending, the vegetation cover has been cut leading the increase of dry grass. That means at that time M_1 will be equal to M_2 and the fire risk and hazard are highest.
- The moisture content of the material depends not only on weather but also the presence of perennial grass species.
- Studies on fuel structure and dynamics will be the foundation for determining the relationships between the parameters m_1, m_2, M_1, and M_2. Based on these relationships and the level of abundance effective measures of fire prevention will be determined.

3.1.2 Fuel loads and structure through the periods of plantation tending

Structure of fire material through the periods of plantation tending is presented in Table 3

Table 3. Structure of fire material through the periods of plantation tending

Periods of Tending	M_1 (kg ha^{-1})	m_1 (kg ha^{-1})	M_2 (kg ha^{-1})	$k = m_1 / M_1$	h^-tb(m)
20-08-98	11 000	3 150	7 850	0.29	0.61
20-09-98	11 750	4 875	6 875	0.41	0.58
20-10-98	11 573	5 250	6 325	0.45	0.40
18-01-98	11 225	7 700	3 525	0.70	0.05

Note: M_1 = Total weight of material (dry + living)
m_1 = Weight of dry material (kg ha^{-1})
m_2 = Weight of living material (kg ha^{-1})
k = Inflammability Index
h tb = Mean Height of vegetation cover after tending

Remarks:

- Through the periods of tending the total fuel weight does not show considerable differences thanks to the replacement of living fuel cover
- The weight of dry material increases gradually from 3150 kg ha^{-1} to 7700 kg ha^{-1}
- The weight of living material decreases gradually from 7850 kg ha^{-1} to 3525 kg ha^{-1}
- The Inflammability index is always less than or equal to 1 and depends on periods of tending
- The shorter the time for tending, the decreasing the mean height of living material (from 0.61m to 0.05m)

Discussion: The lower the Inflammability Index the less possibility of fire risk and hazard, and vice versa. The Inflammability Index becomes maximum after the vegetation cover is cut. The Index also increases in the year 4 of plantation when the weight of falling material increases.

The Inflammability index has been identified through experiments (Table 4).

Table 4. Inflammability index and fire risk derived from experiments

Inflammability Index	Fire Risk
<0.2	No fire
0.2-0.29	Little possibility of fire
0.3-0.49	Possibility of starting fire
0.5-0.7	High possibility of fire
>0.7	Very high possibility of fire

Apart from the Inflammability Index k, fire also depends on other factors such as the contacting time of fire material to fire, temperature, speed of wind, direction of slope. However, the Inflammability Index k can be useful for plantations, without applying the method of controlled burning of fuels, and in natural forests.

- In the rainy season, the grass species grow very fast. For both annual and perennial species, this is the only growing season of year. Once the cutting of vegetation cover is implemented in suitable time possibility for the recovery of plants will decrease and they can be replaced by other plant species. This is easier to happen for generative reproduction species.
- For plant species sprouting from roots, the possibility for recovery is very high because of little competition with other species. The species with high recovery possibility will have less number of individuals than before cutting. However, in the dry season the weight of these species will be high thanks to the water content in the already existing root system.
- Perennial species also recover. The species with the possibility of the strongest recovery include Co Tranh (*Imperata cylindrica*) and Rang Rang (*Ormosia pinnata*) due to their dense-woven, 20-30cm deep system of roots.
- For grass species of dispersion by seed, when they are cut before their seeds are mature and ready for dispersion, the possibility of reproduction of these species is minimized. If this process of cutting is repeated for several years, these species can be excluded from constitution of vegetation cover under pine plantations and can be replaced by other grass species.
- Through the experiment, some invasive species have been identified. A large number of dicotyledon grass species occur but the number of individuals of each species is low. However, some species become dominant after cutting, for example Co Lao (*Eupatorium odoratum).*

Table 5. Some dicotyledon grass species after tending

Scientific name	Vietnamese name
Eupatorium odoratum	*Co Lao*
Anaphalis adnata	*Bach Nhung*
Vernonia squanosa	*Bach Dau Long*
Gynura pscudochina	*Tau Bay*
Sericocalyx scaber	*To Dai Nham*
Polytrema anamensis	*Da Kim*

- The result of experiments shows that in the plantations tended in August and September the fuel weight is decreasing remarkably and the weight of living material is increasing, resulting in reduced forest fire hazard. Another factor contributing to the reduction of fire risk is the wrapping effect of living material cover over the layer of dry material resulting in a reduction of wind speed (and drying effect) in the cover of living material, at the same time increasing the moisture of the cover of dry grasses.
- Tending plantations in August and September will also help raising the soil nutrient status due to decomposing of this organic substance. This is proven by the appearance of earthworm and termite nests.

However, the possibility of forest fire still exists, largely influenced by topography and weather. When the Inflammability Index k is small, the possibility of a fire to start and spread is limited if the wind speed is low and the direction of fire spread is downslope. When the wind speed is high and the direction of fire spread is upslope fires can happen but the damage is not very serious.

From the results mentioned above, some technical proposals for fire prevention combined with tending are as follows:

3.2 Fuel Management Methods

3.2.1 Controlled Burning

Based on the experience in other countries the use of controlled fire to reduce surface fuels and thus wildfire hazard (see De Ronde et al. 1990, Goldammer 1983). Besides observing general basic principles of applying controlled fire the following steps of implementation include

- Cutting vegetation cover on the whole area of plantation, drying out cut plants to a moisture content Wo = 13-15%;
- Creating a firebreak surrounding the compartment to be burned;
- Using fire preventing material to protect main trees (*P. kesiya*);
- Choosing suitable time to burn material;
- Protecting main trees by pruning and a surrounding fire line.

3.2.2 Controlled burning in rows

This method is the application of controlled fire between tree bands with space of 3.0. It facilitates the collection and burning of grass and fine fuels and reduces negative impacts on standing trees. Steps of implementation include:

- Cutting the whole or ¾ grass cover in the compartment of the plantation;
- Cutting branches (pruning) close to the foot of trees;
- Raking grasses and branches to rows between tree bands;
- Burning them in appropriate time.

3.2.3 Controlled burning combined with tending

The results of the research mentioned above show dynamics of fire material through the period of tending. Concluding it is recommended to combine controlled burning with tending. Based on the changes in season, tending of the plantations in years 2 to 4 is recommended to be implemented in August and September. For plantations in year 1, tending should be implemented in October (1-3 months after planting). Steps of implementation include:

- In the first year tending should be implemented in October (1-3 months after planting);
- In years 2 to 4: tending the plantations in August and September;
- In year 2, weeding and creating a fire line around main trees (diameter: 1 m), and cutting the whole plantation surface, collecting cut plants and piling them on the middle bands for natural decay. In November and December, burning the rest of cut plants using the row-burning technique

- In years 3 and 4, cutting the whole vegetation cover combined with cutting branches from 1/3 height of tree down to the foot of tree and doing next steps the same as in year 2.

Figure 3. A similar situation in a young pine stand in which the grass cover represents a high risk of destructive wildfires.

Figure 4. Setting a prescribed fire in a mature, open pine stand.

3.2.4 Controlled burning combined with tree spacing

The density and the method of tree spacing in forest plantation establishment is affecting the fuel dynamics through the period of tending. Currently, two popular methods of tree spacing are applied in Lam Dong province:

- Density of 2,200 trees/ha; line to line: 3.0 m, and tree to tree 1.5 m
- Density of 1,666 trees/ha; line to line: 3.0 m, and tree to tree 2.0 m

These methods have considerable impacts on controlled burning in young pine plantation. In conclusion from the research the spacing of trees is proposed as follows:

- After burning the surface fuels whole vegetation cover, compartments should be divided into 9 metre bands with the length of bands equal to the length of compartments and parallel to contours. On bands, arranging 3 lines of tree with line to line 2m and tree to tree 1-1.5m
- In each band, a smaller band about 5 m wide should be leaved for putting fire material
- Other steps are similar to 3.2.3

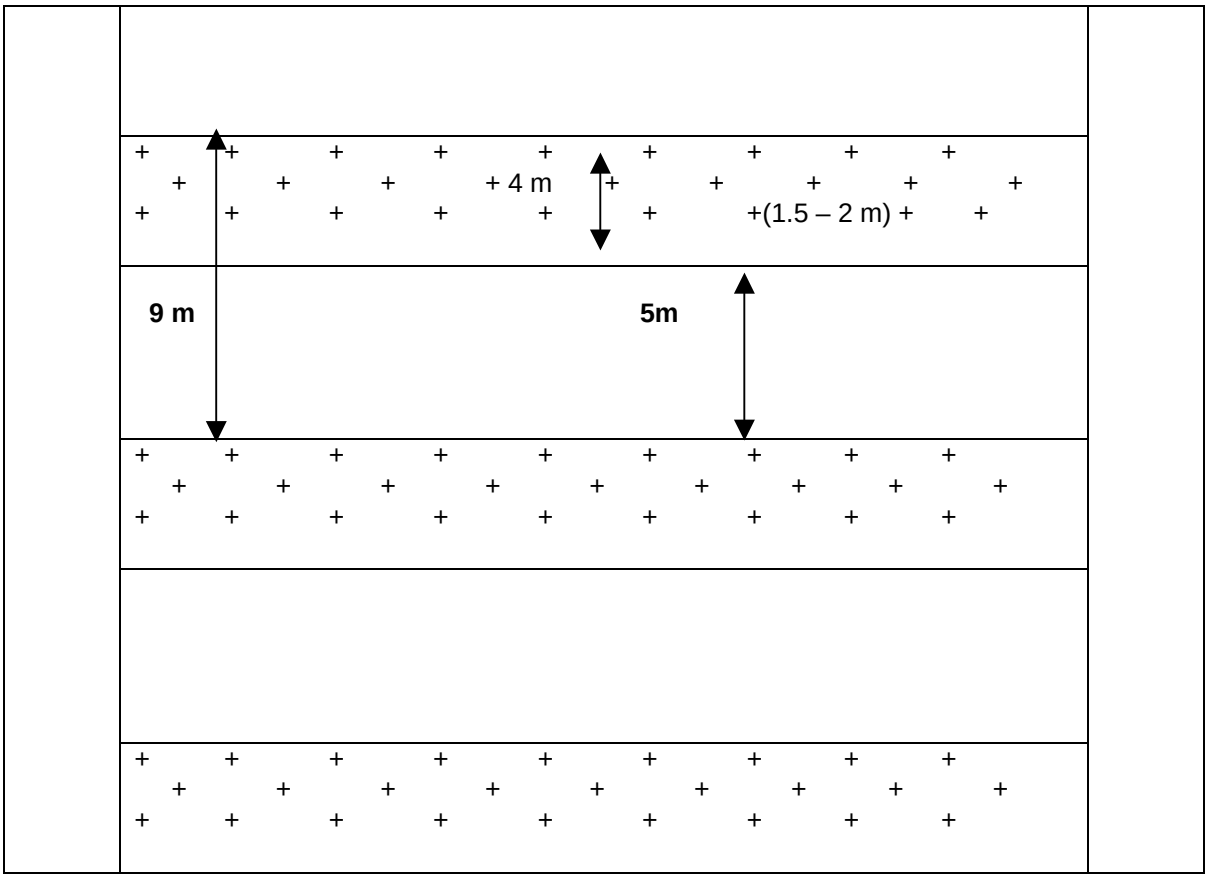

Figure 5. Proposed spacing in pine plantation establishment

Figure 6. Creation of a fire break (black line) using prescribed fire.

Figure 7. Burning of a 3-m wide fire break (black line).

Figure 8. Successfully burned 5-m wide fire break.

4. Conclusions

Grass cover plays an important role in the structure of fire material of plantation. Dynamics of grass cover in the course of tending have considerable impacts on establishing an effective method of processing fire material for fire prevention in both plantation and natural forest in Lam Dong province. The result of this research identifies species constitution and changes in weight and moisture of fire material. On this foundation, some proposes in tree spacing, appropriate time of tending and methods of processing fire material aimed at increasing efficiency of forest fire prevention are presented. Application of these measures will contribute to increase quality of planting forests in Lam Dong province.

Figure 9. Successful burn under canopy of a mature pine stand.

Figure 10. Post-fire regeneration of the grass-herb layer in a mature pine stand.

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