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Original article

Effect of Burning Fire on Fuel Bed Properties in the Dry Deciduous Dipterocarp Forest at Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province

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ABSTRACT

Effect of burning fire on fuel bed properties in the dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary was studied in twelve 30 m x 30 m plots with completely randomized design. Three plots were monthly burned starting from January to April in 2003. Four plots, 1 m x 1 m size of each were selected to study the effect of burning fire on the fuel bed properties. The fuel bed properties were determined before, an immediate after and one, three, six, nine and twelve months after burning. Comparisons of the result differences between pre-burn and post-burn and among the four months burning were made.

The results revealed that in pre-burn conditions the average height/depth, moisture content, coverage and load of fuel were 25.57 cm, 50.80 percent, 70.10 percent and 6.86 t ha^{1}, respectively. Fuel loads ranged from 5.15 t ha^{1} to 8.10 t ha^{1}. The highest total fuel load was found in April. Litter is the main fuel contributing to the forest fire in the dry deciduous dipterocarp forest. Most fuel bed properties were slightly decreased after an immediate burning and showed significantly different after 1 month burning. However, the properties of fuel bed were changed by the weather condition. Fuel moisture contents in this study were relatively high, while fire intensities were low, thus, fuel consumption was relatively low compared to natural forest fires. However, there was a significant loss in load of gross fuel after burning. The mean gross load decreased 49.34 percent after an immediate post-burn. However, the results indicated that one year (twelve months) after a burn, grass was the dominant fuel type as the same as in the pre-burn condition, while height/depth, moisture content and fuel load were roughly 70 percent of the pre-fire state.

Keywords: Fire effect, Fuel bed properties, Huai Kha Khaeng Wildlife Sanctuary.

INTRODUCTION

Although forest fire affects the plant community, prescribed burning is a very useful tool for silvicultural practice. It can be used to prepare a site for planting by reducing logging debris or to prepare a seedbed for seed fall. Prescribed burning can also be used later in the life of a forest for silvicultural purposes and to reduce the hazard of wildfire. In addition, prescribed burning is the controlled use of fire to reduce or eliminate undesirable species. The fell-and-burn site preparation technique is an effective means of regenerating low-quality hardwood stands in the southern Appalachian mountains to more productive pine-hardwood mixtures. The advantages of this technique included lower cost, increased vegetation diversity within the stand, improved aesthetics, and maintained high production (Evans *et al*., 1990).

Van Lear (1990) reported that fire frequency over an indefinite time period favours oak establishment by reducing understory and midstory competition from fire-intolerant species and by creating preferred conditions for acorn catching by squirrels and bluejays. Fire also reduces populations of insects which prey on acorns and young oak seedlings. Intense fires in logging debris also favour establishment and development of high quality oak-dominated stands. In addition, low-intensity prescribed burning is important for reducing the hazardous build-up of dead fuels on the forest floor. This, in turn, reduces the risk of damaging high-intensity wildfires.

The studies on fuel bed properties in Thailand, Akaakara (2000) studied on fuel bed properties in the dry deciduous dipterocarp forest by conducting during the fire season (December to April) in Salakpra Wildlife Sanctuary, Kanchanaburi province. The results showed the total load of fuel was 5.01 t ha^{1}. This was composed of 1.92 tons of litter, 1.47 tons of grasses, 1.05 tons of undergrowth, and 0.57 tons of twig. Fuel arranged to cover 89 percent of the forest floor in average. Litter alone covered 43 percent of the forest floor while grass, undergrowth and twig covered 31, 23 and 8 percent of the forest floor, respectively. However fuel arranged to completely cover the floor (100 percent) during mid March to mid April. Fuel depth/height averaged 14 cm. Height of grass and undergrowth were 27 and 19 cm, respectively. While depths of litter and twig were 7 and 4 cm, respectively. Average fuel moisture was 20 percent. The fuel moisture reached its lowest point of only 7 percent in early April. The most dominant fuel in this forest was litter with its highest Importance Value Index.

Samran *et al*. (2002) reported fuel bed properties all the year in the dry deciduous dipterocarp forest in the buffer zone of Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province were composed of litter, twig, grass and undergrowth. Average fuel load of gross fuel was 3.74 t ha^{1}, average coverage of gross fuel was 50.70 percent, average height/depth of gross fuel was 27.7 cm, average moisture content of gross fuel was relatively high at 88.48 percent and average dispersal of each fuel type were 67.2, 95.2, 90.7 and 92.6 percent, respectively. The litter was the most dominant fuel type in the dry deciduous dipterocarp forest.

The results of the study of change after forest fire occurrence in natural resource, the dry deciduous dipterocarp forest in the buffer zone of Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province showed that after the forest fire occurrence, the twig fuel load and coverage increased 284.36 t ha^{1} and 18.3 percent respectively. While all properties of litter, grass and undergrowth fuel, such as, fuel load of those were decreasing 97.5, 100.0 and 88.24 percent, respectively, height/depths of those were decreasing 88.29, 100.0 and 84.92 percent, respectively and coverage of those were decreasing 47.5, 21.7 and 10.0 percent, respectively. (Samran and Thongton, 2002)

Boonplian (1985) studied the effect of fire on soil and plants at Doi Angkhang : the first year results after burning, the dominant species was found to be *Imperata cylindrica*. The maximum and minimum fuel moistures were 256.74 percent in September and 72.07 percent in April, respectively. Sompoh (1998) studied fuel complex in the dry dipterocarp and the mixed deciduous forests at Huai Kha Khaeng Wildlife Sanctuary, Changwat Uthai Thani and found that fuel loads of duff, litter, herb, seedling, shrub, cycad and sapling were 0.17, 3.41, 1.18, 0.35, 0.09, 0.14 and 5.86 t ha^{1}, respectively, the average total fuel loads was 11.21 t ha^{1}. The loads of fuel in the mixed deciduous forest were 0.18, 4.14, 0.65, 0.07, 0.32 and 6.04 t ha^{1}, respectively, the average total fuel loads was 11.39 t ha^{1}.

The accumulation and arrangement of ground fuels are the major factor in determining the intensity of a surface fire (Van Wagtendohk, 1974; Burrow and Sneeuwjagt, 1991). As fuels are permitted to accumulate fires increase in severity and damage and are much more difficult to control (Zimmerman and Leon, 1983). Moreover, the natural conditions, apart from the high fuel load, like the fact that rain did not occur combined with a dry microclimate in the dry season had resulted in an extreme condition that increased the ignition potential. Prescribed fire can be used later in the life of a forest for silvicultural purposes. Fire will clear not only the forest floor, but will also induce limbing up or burning off the lower branch of pines which will eventually die and fall off, effectively raising the crown height of the living tree. This makes the tree more fire resistant from later fire (Prescott National Forest, 2003). Moreover, prescribed fire speed up the recycling of nutrients into a usable form for the trees. Therefore, fuel management as prescribed burning, which in order to maintain long-term site productivity, must be identified as a valuable land management practice to reduce fuel loading and fire hazard.

Because almost 50 percent of Huai Kha Khaeng Wildlife Sanctuary, where UNESCO established the World Heritage Site in December 1991, comprised mixed deciduous, dry deciduous dipterocarp, and bamboo forests, they are the main forest fire fuel in the sanctuary. The dry deciduous dipterocarp forest in the protected area serves as a "buffer" for the World Heritage area from the agricultural development area. This buffer zone is very important for both wildlife and livestock. This forest type is maintained by fire, so intensive fire suppression and prevention activities are not only decreasing the frequency of forest fires, but also understory shrubs and hardwoods are becoming denser and fuel is accumulating which will increase the risk of large and damaging wildfires. Fuel is one of the three components for forest fire occurrences called fire triangle principle. The type, amount and condition of the fuels is one of the most important factors to evaluate in the development of plan to attack and control a forest fire because when the fuel dry and continuous, they will support the fastest rate of spread of any surface fuel. This study was designed to examine the fuel bed properties in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary. The results are not only represent knowledge of the effect of burning fire on the fuel bed properties in each month of the forest fire season of this area (January to April), but it is also the important strategy for fuel management.

MATERIALS AND METHODS

The effect of burning fire on fuel bed properties was conducted in the dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary in 2003. Twelve 30 m x 30 m plots were completely randomized design. Three plots of 30 m x 30 m size each were burned in each month from January to April in 2003. Four fuel sampling plots, 1 m x 1 m size of each were studied within the 30 m x 30 m plots. The fuel bed properties (depth/height, moisture content, coverage, frequency, fuel load and IVI) were collected before burning, an immediate, one month, three months, six months, nine months and twelve months post-burn.

In pre-burn conditions, fuel was separated into litter, twigs, grass and undergrowth. Coverage and dispersal of each fuel type were recorded. Fuel depths/heights were measured and a sample of each fuel type was collected and weighed before and after oven drying at 85 ^{o}C for 24 hours for determining moisture content. After each burn (an immediate, 1, 3, 6, 9 and 12 months) coverage and dispersal of each fuel type were determined. Fuel depths/heights were measured and a sample of each fuel type was clipped and weighed before and after oven drying at 85 ^{o}C for 24 hours for determining moisture content. Calculation of the moisture content, average fuel load, coverage, depth/height, frequency and dominant fuel types (IVI) were performed.

Fuel bed properties were determined as follows (applied from Akkaakara and Kittisatho, 1992):

$$\text{Moisture content of fuel (\%)} = \frac{\text{Fresh weight (g) - dry weight (g) x 100}}{\text{dry weight (g)}}$$

$$\text{Average of fuel depth (cm)} = \frac{\text{Total of fuel depth (cm)}}{\text{Number of samples fuel depths}}$$

$$\text{Fuel load (ton.ha-1)} = \frac{\text{Total weight of fresh fuel (ton) x 100 x 10,000}}{\text{(100+ avg. of fuel moisture) x total sample area (m}^2\text{)}}$$

$$\text{Fuel coverage (\%)} = \frac{\text{Total area of a fuel type coverage x 100}}{\text{Total observed area (m}^2\text{)}}$$

$$\text{Fuel frequency (\%)} = \frac{\text{No. of observed plots of a fuel type present x 100}}{\text{Total observed plots}}$$

$$\text{IVI (\%)} = \text{\% RL + \% RC + \%RF}$$

where, IVI = Important value index provides an indication of the dominant fuel type.

$$\text{RL = Relative fuel load (\%)} = \frac{\text{Fuel load of a fuel type x 100}}{\text{Gross of fuel load}}$$

$$\text{RC = Relative fuel coverage (\%)} = \frac{\text{Coverage of a fuel type x 100}}{\text{Gross of fuel coverage}}$$

$$\text{RF = Relative fuel frequency (\%)} = \frac{\text{Frequency of a fuel type x 100}}{\text{Gross of fuel frequency}}$$

The mean of fuel bed properties values in an immediate and twelve months post-burn were compared to the pre-burn value by Independent T-test of $p < 0.05$ unless otherwise indicated and percentage of fuel bed properties changing from pre-burn among the four burn months were compared. The statistical differences were tested by Least Significance Difference confidence limit of $p < 0.05$ unless otherwise indicated.

RESULTS AND DISCUSSION

Effect of burning fire on fuel bed properties was conducted in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sancturay, Uthai Thani Province. The fuel bed properties included fuel depth, moisture content, coverage, fuel load and the dominant fuel type. Fire behavior in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sancturay, Uthai

Thani Province in 2003 was presented in Himmapan *et al.* (2006). The results of the study on fuel bed properties are as follows:

Fuel Bed Properties in the Pre-burn Condition

Fuels included litter, twig, grass and undergrowth. Fuel bed properties included depth/height, moisture content, coverage, frequency, load and important value index (IVI) of different components (litter, twig, grass and undergrowth) in pre-burn conditions from January to April, 2003 were shown in Table 1.

Table 1. Fuel bed properties in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary in pre-burn conditions (2003)

Fuel bed properties	Month	Litter	Twig	Grass	Undergrowth	Average	Total
Height (cm)	January	4.42	3.75	93.42	68.98	42.64	
	February	8.08	4.17	53.92	74.50	35.17	
	March	5.00	3.25	59.92	85.08	38.31	
	April	5.33	3.00	45.50	50.75	26.15	
Moisture content (%)	January	43.10	29.87	63.56	80.59	54.28	
	February	41.80	22.40	78.67	92.09	58.74	
	March	21.28	31.15	29.68	42.57	31.17	
	April	22.22	21.66	82.86	109.35	59.02	
Coverage (%)	January	15.42	5.75	37.08	27.08	21.33	75.83
	February	28.33	6.50	15.83	25.00	18.92	72.92
	March	31.42	5.83	28.19	24.17	22.40	66.67
	April	38.75	5.83	25.00	19.17	22.19	65.00
Fuel load ($ton.ha^{-1}$)	January	0.95	0.98	2.88	1.77	1.65	6.58
	February	1.23	2.29	0.61	1.02	1.29	5.15
	March	2.00	2.50	1.36	1.74	1.90	7.60
	April	3.87	1.61	1.93	0.69	2.02	8.10
IVI	January	59.50	42.51	120.66	87.17	59.50	42.51
	February	86.71	77.63	57.86	77.81	86.71	77.63
	March	103.00	58.31	85.93	84.74	103.00	58.31
	April	134.11	52.72	86.92	63.92	134.11	52.72

The litter depth in February (8.08 cm) was higher than in other months because of the left fall in last December and January. Grass was the highest in January (93.42 cm), after that it dried and began dead, thus the grass's height in January was higher than in other months. The average height/depth of gross fuel was highest in January (42.64 cm), and lowest in April (26.15 cm). The undergrowth was highest in March after that the grass began dead. Since there was no fire in the previous year, the average fuel depth of fuel in the present study was rather high.

The average moisture content of fuel ranged from 31.17 percent to 59.02 percent. The lowest moisture content was in March which was the lowest moisture content of the undergrowth. The moisture content of the live fuel type as grass and undergrowth were higher than litter and twig.

The average coverage of gross fuel in each month (January to April) was also over 65 percent. Litter made up most of the fuel coverage in February (28.33 percent), March (31.42 percent) and April (38.75 percent), while grass made up most fuel coverage in January (37.08 percent). The litter coverage was lower in January than in other months. All of fuel types could be found in every month, the average frequency of each fuel type in each month was over 90 percent.

Fuel loads of each fuel type showed that the highest total fuel load was in April (8.10 t ha^{1}) due to the litter load (3.87 t ha^{1}), while the lowest one was in February (5.15 t ha^{1}). The important value index (IVI) of each fuel type and of each month showed that the dominant fuel type in January was grass, while litter was dominant in February to April. The results indicated that litter was the main fuel burned by the forest fire in dry deciduous dipterocarp forest.

Fuel Load Reduction after an Immediate Post-burn

The fuel load was measured after the fuels in all plots were burnt. Fuel moisture contents in this study were high (80-89 percent), while fire intensities were rather low (24.64-152.03 kW.m^{1}; Himmapan, 2005). Thus, fuel load reduction was relatively low. The gross fuel in each months were less than pre-burn condition were 46.17 percent, 41.72 percent, 58.14 percent and 65.55 percent in January, February, March and April, respectively. The average gross fuel reduced from 6.86 t ha^{1} to 3.47 t ha^{1} in an immediate post-burn or 54.38 percent less than that of the pre-burn value. Grass was the greatest fuel load reduction, which was 68.01 percent, while twig was the lowest fuel load reduction, which was 35.59 percent. However, an immediate after the burning, there was a significant loss in gross load of fuel ($t=5.272$, $p<0.01$) (Figure 1).

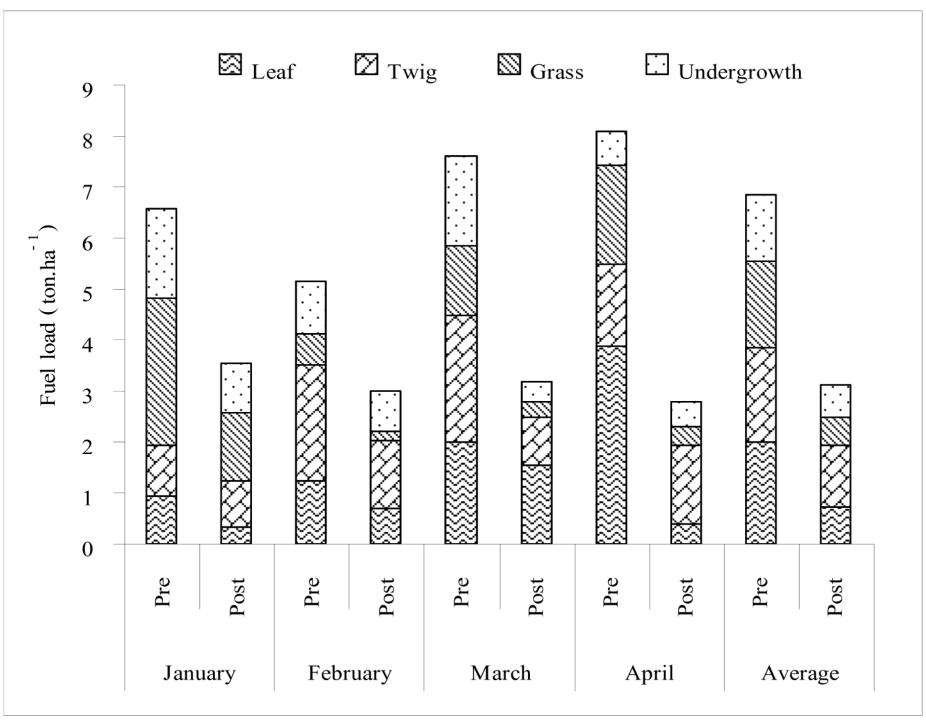

Figure 1. Fuel load reduction after an immediate post-burn in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, 2003.

Fuel Bed Properties in the Post-burn Condition

The fuel bed properties varied due to the weather condition and season (rainy season is July to October, summer season is March to June). Fuels were found well adapted to disturbance. Most of the fuel bed properties decreased dramatically in the first month after burning, but they were slightly recovered since three month post-burn. In addition, fuels rapidly regenerate especially in the rainy season (Figure 2).

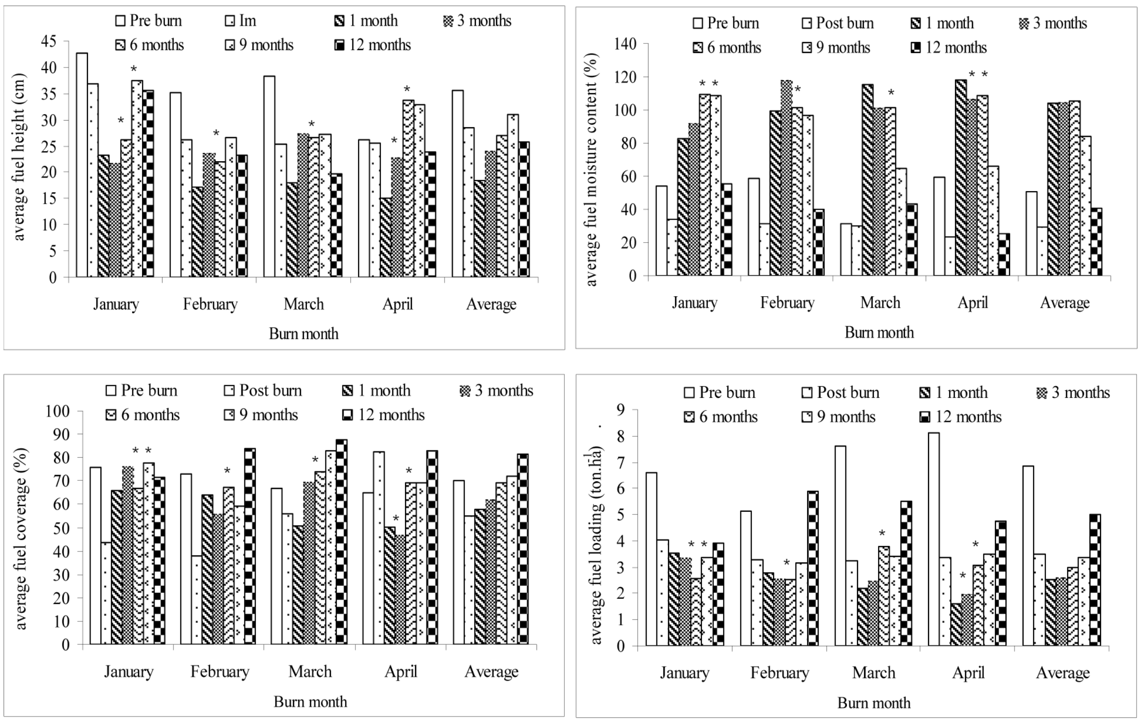

Figure 2. The change of fuel bed properties (height, moisture content, coverage and fuel loading) in pre-burn and post-burn in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, 2003.

Remark: * indicates the rainy season.

The fire consumed most fuel types reducing it from average pre-burn depth of 35.57 cm to 28.51 cm in an immediate post-burn. The average fuel depth was reduced in the first month after burning (18.39 cm), and gradually increased in the subsequent months (23.97 cm, 27.07 cm, 31.05 cm and 25.64 cm in the 3rd, 6th, 9th and 12th month, respectively). Fuels exhibited the highest level in terms of depth during the rainy season. The recovery of fuel depth in each burn month was not so obvious due to the presence of rain. The average fuel moisture content was reduced from the pre-burn condition (50.80 percent) to an immediate post-burn (29.59 percent). Because the average fuel moisture contents varied due to the weather conditions, the moisture contents in the 3rd, 6th and 9th post-burn periods were higher than those in the pre-burn value shown in Table 2. After twelve months post-burn, the fuel moisture content exhibited similar to the value in pre-burn condition.

The average fuel coverage was reduced from 70.10 percent in the pre-burn condition to 55.00 percent in an immediate post-burn. The fuel coverage began recovered since one month (57.81 percent) to three months (62.19 percent) and six months (69.27 percent). In twelve month post-burn, the fuel coverage value (81.46 percent) was higher than pre-burn value. All fuel types remained both in each burn month and in different periods after the forest was burnt. In general, the frequency of fuel varied with the season. Dead fuel as litter and twigs was reduced, while grass was also reduced due to the growth of trees during rainy season. Then, fallen leaves increased during the summer season (March to June) and they eventually became to litter. However, the fuel frequencies were not different either among the burn month or among the post-burn periods.

Fuel loading exhibited a similar pattern as shown in other fuel bed properties. The highest loading was found in pre-burn conditions. During post-burn conditions, fuel loadings varied due to the presence of rain. Undergrowth and grasses in January were still able to survive one-month after burning. Undergrowth, grasses and total fuel loading were higher in January than in other months. Three months after burning in January and February plots were the summer season, litter loading occurred as the leaves were shed. It was found that the litter loadings were higher than those in March and April plots. Eventually, the tremendous growth of grasses was due to the reduction in tree crown cover, grass loadings of the 3 months after burning period in January plots (April) and April plots (July) were higher than those in other months. As earlier anticipated, the mean gross fuel loading in April (3 months after burning in January) was greater than those in the other months. Moreover, the results indicated that one year (twelve months) after a burn, fuel load was roughly 70 percent of its pre-fire state.

The fallen leaves or litter were high after burning and were also high during the summer, while undergrowth increased greatly during the rainy season. From these results, the study indicated that grass was the dominant fuel type in January before burning. However, litter became dominant in the first few months after that. Litter contributed to be a dominant fuel type in February, March and April both of before burning and one-month after burning. Tremendous growth of the undergrowth after rain had driven the undergrowth to be the dominant fuel type in every burn month at the six months of post-burning conditions. Because the growth of grass and undergrowth including the dry leaves falling during the rainy season, the dominant fuel type varied among these fuel types. However, the dominant fuel type in twelve months post-burn returned to the same type of pre-burn condition.

Table 2. The dominant fuel type in dry deciduous dipterocarp forest at Huay Kha Khaeng Wildlife Sanctuary, 2003

Burn Month	**Pre-burn**	**Post-burn Immediately**	**1 month**	**3 months**	**6 months**	**9 months**	**12 months**
January	Grass	Grass	Litter	Litter	Litter	Grass	Grass
February	Litter	Undergrowth	Litter	Litter	undergrowth	undergrowth	Litter
March	Litter	Twig	Litter	undergrowth	undergrowth	Litter	Litter
April	Litter	Twig	Litter	Grass	undergrowth	undergrowth	Litter

Percentage of fuel bed properties changing from the pre-burn condition in an immediate post-burn and in twelve months post-burn showed in Table 3. In an immediate post-burn, the percentage of fuel bed properties changing from pre-burn condition showed that only the fuel height/depth showed significant differences among the burn months ($F=4.171$, $p=0.047$). The higher fire line intensity than other burn months (76.91 kW.m-1; Himmapan, 2005), fuel height/depth in February decreased from pre-burn (33.20 percent) and these values were significantly different among the burn months. The value in this period compared to pre-burn condition showed that the average height/depth and moisture content decreased from the pre-burn

31.15 percent and 40.95 percent, respectively. The height/depth was significantly different (t=2.299, p=0.031), while the moisture content was highly significantly different (t=3.884, p=0.001) to pre-burn condition. Even though fuel was reduced from fire, fuel in January still alive after the rain occurred in last December (2002), there was no significant difference to pre-burn. Moreover, the fallen leaves or twig during burning was the reason why the fuel height/ depths and moistures in March and April were not significantly different to in pre-burn. The average coverage changed from pre-burn value only 38.19 percent. After burning the ash covered all the plots instead of other fuel types, the total coverage after immediate post-burn was not significantly different to pre-burn. The fuel loads were significantly different to pre-burn in February (t=4.351, p=0.012) and April (t=5.120, p=0.007) due to the grass began dry in February, while the higher fire behavior in April. The average gross fuel load were changed 60.52 percent, there was significantly different to pre-burn (t=4.725, p<0.01).

Table 3. Percentage of fuel bed properties changing in dry deciduous dipterocarp forest at Huay Kha Khaeng Wildlife Sanctuary, 2003

Fuel bed Properties	Burn Month	Immediate post-burn Average	12 months post-burn Average
Height (cm)	January	13.38 a[1]	23.36
	February	25.02 ab *[2]	34.42*
	March	33.20 b **	48.27**
	April	11.86 a	35.33
	Average	20.85*	35.35**
Moisture content (%)	January	33.13	22.59
	February	46.25**	32.83 *
	March	48.07	42.26 *
	April	57.08	50.65
	Average	46.13**	37.08
		Total	Total
Coverage (%)	January	42.28*	14.09
	February	47.22*	18.02
	March	36.18	32.74*
	April	27.08*	29.17*
	Average	38.19	23.51**
Fuel load ($ton.ha^{-1}$)	January	39.31	41.27*
	February	35.80*	32.05
	March	54.85	20.38
	April	57.77**	39.96*
	Average	46.93**	33.41*

[1] Means followed by a different letter are significantly different (p < 0.05) among the monthly (a, b, c).
[2] The value is significantly different to pre-burn value (* at p< 0.05, ** at p< 0.01).

The percentage of fuel bed properties changing from pre-burn condition were no significant differences among the burn months in twelve months post-burn. There was no fire in this area and the rain still occurred in last December (2002), most of fuel bed properties in twelve months post-burn were not similar to in pre-burn. The averages of fuel height/depth, coverage and load were significantly different to the pre-burn condition (t=3.092, p=0.005; t=-3.371, p=0.003 and t=2.525, p=0.019, respectively). The percentages of fuel load changing from pre-burn in January and April were 41.27 percent and 39.96 percent, respectively, thus the fuel load value showed significantly different to pre-burn value (t=3.057, p=0.038 and t=4.119, p=0.015, respectively), because the accumulation of grass in January and the accumulation of litter in April after no fire in last year.

The dry leaves became fallen down in February (the dominant fuel type changed from grass in January to litter in February). Therefore, the dominant fuel type in twelve months post-burn showed similar to pre-burn condition. Most of the percentages of fuel bed properties changing after one year in January burn plots were no significant differences. Although low fire intensity could reduce the fuel, one year (twelve months) after a burn, fuel load was roughly 70 percent of its pre-fire state.

CONCLUSION AND RECOMMENDATION

The study of the effect of burning fire on fuel bed properties in dry deciduous dipterocarp forest at Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province was concluded as followings:

1. The average of fuel depth in pre-burn conditions ranged from 26.15 cm to 42.64 cm. The burning fire consumed most fuel types reducing it from average pre-burn depth of 35.57 cm to 28.51 cm and 18.39 cm in an immediate and one-month post-burn, respectively. After burning, the average fuel depth was reduced in the first month, and gradually increased in the subsequent month. Fuels exhibited the highest level in terms of depth during rainy season (July to October). The recovery of the fuel depth to the first state was in nine-month after burning. The results of percentage of fuel bed properties changing from the pre-burn condition in an immediate post-burn indicated that the higher fire line intensity than other burn months (76.91 kW.m-1; Himmapan, 2005), fuel height/depth in February decreased from pre-burn (33.20 percent) and these value were significantly different among the burn months. While compared to pre-burn condition, the average fuel height/depth in an immediate post-burn showed significant difference (t=2.299, p=0.031). Similar to the average fuel height/depth in twelve months post-burn was also significant different to pre-burn condition, due to the high fuel accumulation after there was no rain in year 2002.

2. The average fuel moisture contents in pre-burn condition were 54.28, 58.74, 31.17 and 59.02 percent in January, February, March and April, respectively. Fire reduced fuel moisture content. The average fuel moisture content in an immediate post-burn was lower than pre-burn 46.13 percent. Thus, the percentage of fuel moisture content changing was highly significantly different to pre-burn (t=3.884, p=0.001). After one year, the average fuel moisture content was still lower than in pre-burn condition, but it was not significantly different. Compared among the burn month (January to April), the fuel moisture contents were not significantly different. However, the fuel moisture content varied due to the season.

3. Almost all fuel types were found in every month. The average coverage of gross fuel in each month (January to April) was also over 80 percent. The average fuel coverage reduced to 55 percent or 38.19 percent changing from pre-burn in an immediate post-burn. The ash covered all the plot instead of other fuel types, the total coverage after in an immediate post-burn was not shown significant difference

to pre-burn. Dead fuels as litter and twigs tended to decrease, while grass and undergrowth increased during the rainy season. Although the fuel coverage of each month's burn varied due to the presence of rain and the fuel recovered rapidly, the coverage in twelve months post-burn was significantly higher than pre-burn state (t=-3.371, p=0.003).

4. The fuel loads in pre-burn conditions ranged from 5.15 t ha^{-1} to 8.10 t ha^{-1}. After burning, the fuel loads of each fuel type varied with the season. Dead fuel as litter and twigs was reduced, while grass was also reduced due to the growth of trees during rainy season. Then, fallen leaves increased during the summer season and eventually became litter. Because the high fuel moisture contents and the low fire intensities, fuel consumption was relatively low. The average gross fuel reduced from 6.86 t ha^{-1} to 3.47 t ha^{-1} in an immediate post-burn or about 50 percent less than that of the pre-burn value. Grass was the greatest fuel load reduction, while twig was the lowest fuel load reduction. Although fire burned litter in every burn months, dry leaves fell down from the tree increased the fuel load. The percentages of fuel load changing from pre-burn in January and April were 41.27 percent and 39.96 percent, respectively, thus the fuel load value showed significantly different to pre-burn value (t=3.057, p=0.038 and t=4.119, p=0.015, respectively), because the accumulation of grass in January and the accumulation of litter in April after no fire in last year. However, there were significantly different among the burn months. Moreover, the results indicated that in one year (twelve months) after a burn, fuel load was roughly 70 percent of its pre-fire state.

5. The important value index provides an indication of the dominant fuel type. It was shown that in the pre-burn, grass was the dominant fuel type in January, while litter was the dominant fuel type in February, March and April. It's mean that the litter was the main fuel burned by the forest fire in dry deciduous dipterocarp forest in the dry season. Litter became dominant in the first few months after that. Tremendous growth of the undergrowth after rain had driven it became the dominant fuel type in every burn months at the six months of post-burning conditions. Most fuel types were reduced by burning. Live fuels such as undergrowth and grass accumulated rapidly during rainy season, while dead fuel such as litter accumulated rapidly during summer. After burning the dominant fuel type varied as the season change.

6. As fuels are permitted to accumulate fires increase in severity and damage and are much more difficult to control, while, prescribed burning conditions must be carefully monitored to achieve a desired result while minimizing loss of other natural resources. Agee *et al*. (1979) has shown that apart from the configuration in the fuel bed, the time of year is also an important determinant of flammability. Moreover, dry deciduous dipterocarp forest is maintained by fire. The study indicated that twelve months after a burn; fuel load was roughly 70 percent of its pre-fire state, therefore, the prescribed burning is important for Huai Kha Khaeng Wildlife Sanctuary. The best period for prescribed burning should concern to other issues such as effect of burning on the growth and the survival rate of vegetation, effect on soil and the smoke composition from burning fire. The study effect of fire on vegetation indicated that the increment of diameter at the base of seedling in this area was 0.44 cm $year^{-1}$ and seedlings which the diameter at base of lower than 2.55 cm was immediately killed after burning (Himmapan, 2005), thus the prescribed burning in this area should be done in 5-6 years period. Because after February, the fire intensity and flame height were higher and could damage the small saplings and seedlings more than the period during the beginning of dry season (November to January), the suitable period for prescribed burning was before February. The benefits of prescribed burning is not only for reducing the risk of damaging high-intensity wildfires, but it also for promoting new forage species for wildlife management.

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