# PRESCRIBED BURNING IN AN *Acacia mangium* PLANTATION IN SOUTH SUMATRA, INDONESIA

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## ABSTRACT

Poor maintenance of forest plantation, i.e., inadequate weeding and pruning, increases fuel load in the forest floor resulting in an increased high risk of fire invasion, especially in the dry season. This high fuel load should be reduced in order to prevent fires. One possible solution is prescribed burning. Prescribed burning can be conducted if there is no damage to trees and the value of the wood does not decrease. This burning may also reduce the natural regeneration of bad quality seedling in the forest floor in the second rotation cycle of *Acacia mangium* plantation. Research shows that, at 3 ton/ha of fuel load and an 8 cm fuel depth, prescribed burning can be conducted successfully. No trees die, and no damage or natural regeneration is recognized after the fire.

*Keywords* : *Acacia mangium*, burning, fire, fuel, plantation

The role of plantation forests in Indonesia is very important, especially for conservation purposes. It is believed that high yielding plantations will meet higher wood demand while maintaining or reducing the areas of natural forest harvested (Seabright, 1995). Planted forests are an important element of land use. Planted forests can fulfill many of the productive role of the natural forest. When they are adequately planned, planted forests can help stabilize and improve the environment (ITTO, 1993).

One of the reasons why industrial forest plantations in Indonesia are valuable is the high demand for raw materials, especially for pulp and paper, which has increased the ability to help meet demand yearly. For pulp, the 1997 projected supply capacity increased 4.6 million ton/year. In 1998, the estimate is 5.2 million ton/year, and in the year 2010 capacity will increase to 11 million ton/year. To guarantee sustainability of the raw materials, a new million hectares of industrial forest plantation needs to be established. Without this, the natural rain forest will be destroyed. Many factors, however, affect the success of forest planting, one of those is forest fire (Saharjo, 1997).

Fire is still a critical factor in managing industrial forest plantation in Indonesia, especially for *Acacia mangium*. The daily increase of fire damaged areas, especially in the dry seasons, and destruction of young *A. mangium* plantations would not happen if fuel load in the plantation was reduced & tree maintenance was improved (Saharjo & Watanabe, 1996). If nothing is done, entire plantations are quickly destroyed. In heavy fuels, wildfires are particularly destructive and severe damage results to timber and soil. The reduction of destructive wildfires in commercial *Eucalypt* forest can be achieved by burning to reduce fuel accumulation over wide areas (McArthur, 1962). One possible solution therefore to reduce fuel load in the *A. mangium* plantation is prescribed as it was done in *Eucalypt* forest in Australia, *Pinus* forest in USA, Canada, and France but it is not familiar in Indonesia.

Prescribed burning is carried out now for many purposes (Gill & Bradstock, 1996). It may be used to reduce accumulated fuel (McArthur, 1962; Raison *et al.*, 1986; Birk & Bridges, 1989; McCaw *et al.*, 1997), protect wood products, water supplies, animal production and heritage items, control weeds, maintain biodiversity and improve human safety, eliminate undesirable species, microbial activity of forest soil (Ahlgren & Ahlgren, 1965; Harvey *et al.*, 1976; Hauke-Pacewiczowa & Trzcinska, 1980; Herr *et al.*, 1994) and more (Whelan, 1995).

Fires occur when flammable fuels are exposed to firebrands. Fire prevention can be accomplished either by removing the source of the firebrand or by removing the fuel it may ignite. The alternative chosen is influenced by the values threatened by fire. The need for controlling or eliminating fire risk increases as fuel hazards and values increase. Swain (1978) has shown that fires separated by intervals shorter than the age of first reproduction in a particular species cause a reduction of that species in the ensuing forest. Frontal-fire intensity gives the heat output of the flame front and is important in determining mortality. Van Wagner (1973) correlated frontal-fire intensity with scorch height of surface fires. Scorch height can then be related to the risk of mortality in individual species (Peterson & Ryan, 1986). It becomes a truism to the fire control planner that high fire risk must not be permitted in any area which has both high fuel hazards and high destructible values (Brown & Davis, 1973).

The objective of this research is to clarify the possibility of prescribed burning being conducted in the *A. mangium* plantation and its effects on tree mortality and available fuel after fire.

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## STUDY SITE AND METHODS

### Study Site

Research was carried out from August until December 1997 in a newly established *A. mangium* plantation, planted in the years, 1991/1992, 1992/1993, 1993/1994, and 1994/1995 at 2 m x 4 m spacing. This belongs to PT. Musi Hutan Persada, a joint venture on an industrial forest plantation company between Barito Pacific Group (a private company) and PT INHUTANI II (State-owned company under the Ministry of Forestry and Estate Corps) in South Sumatra, Indonesia. The company is planning to develop a 300,000 ha plantation in order to support a pulp mill with a capacity of 450,000 tons/year, consuming 2 million $m^3$ of wood with an 8 year rotation.

The mean rainfall is approximately 2,800 mm and monthly rainfall ranges from 92 mm in July to 278 mm in February. According to the Schmidt & Fergusson system (1951), the climate of this area belongs to rainfall type A($0<Q<0.143$). Mean maximum temperature is 32.6°C in August, mean minimum air temperature is 22.3°C in December and mean relative humidity is about 85 %.

### Methods

One quadrate of 150 $m^2$ (10 m x 15 m) each were set up for the four different ages of plantation (1991/92, 1992/93, 1993/94, 1994/95). In this quadrate, trees diameter and height, seed storage in the soil surface and under the soil surface, fuel load, and fuel moisture samples were collected and measured.

A fuel load of 3 ton/ha and fuel bed depth of 8 cm was used as a limiting factor because it can create flame temperatures in the soil surface around 150°C and a flame length of no more than 1 m at the lowest part of branches, this lowest branches resulted from weeding or pruning (Saharjo, 1997). The main requirement for prescribed burning in *Eucalypt* forest (McArthur, 1962) is that flame height do not exceed 1 m and fire intensity 500 kW/m. At 150°C, *A. mangium* seeds in the forest floor will die, so-called seed lethal temperature (Saharjo & Watanabe, 1997b). This limiting flame temperatures was used in order to reduce the possibility of natural seedling to regenerate, because the seed was not in a good quality as it shown in the growth performance. If the flame temperature was less than 150°C, it has been predicted that million of bad seedlings will occupy the space in the forest floor and it will become weedy as happen in the second rotation (Saharjo, 1997). Then, fuel loads consisted of grass and shrubs (dead and live), and litter fall as much as 45 kg (3 ton/ha) were spread out into the quadrate while another rest fuel was delivered out of it and fuel bed depth was set at 8 cm.

*Trees Diameter and Height*

All trees diameter and height in the quadrate at four different ages of plantation was measured. Tree height was measured with tree height equipment, while diameter was measured at dbh (1.3 m above the ground) using a Vernier caliper.

*Estimation of Seed Storage*

a. In the soil surface (0 m)

Four subplots of 1 m x 1 m in the 150$m^2$ quadrate were established in the forest floor in each plantation year in order to measure seed storage. The seeds were collected and counted.

b. Under the soil surface

Seed storage was measured using a ring sample of 400 $cm^3$ in volume (surface area was 100 $cm^2$ and ring height was 4 cm). This ring was used to take seed at the 0-5 cm and 5-10 cm under the soil surface at different plantation years. Five samples were taken in every quadrate. The seeds in each ring was collected, counted and brought to the laboratory to determine germination percentage.

*Seed Germination*

Seeds taken from all 4 stands at depth 0-5 cm and 5-10 cm were sown in germination boxes in order to asses variation in seed germination. The medium used was sand which has been dried for 8 hours and allowed to cool overnight. Each of the four germination boxes was half filled with sand and then placed in a green house. Seed were stored in a hot water at 85°C for 1 minute and soaked in fresh water for 24 hours before sowing. 251 seeds were used for germination test in the first box, 175 seeds in the second, 167 seeds in the third and 113 seeds in the fourth. The germinated seeds were monitored for two weeks after treatment. The viability of seed stored in the soil was high, averaging 92 % in seed collection from a depth of 0 - 5 cm depth to 95.8 % in seed from 5 -10 cm depth (Saharjo, 1997).

*Estimation of Fuel Load*

In each quadrate 150$m^2$ at four different ages of plantation, five subplot of 1 m x 1 m were chosen for the estimation of fuel load and moisture content. Fuel load was estimated by collecting all the materials dead and a live in the subplot. These materials were then brought to the laboratory for measuring weight and moisture content. Fuel moisture content was measured based on dry weight calculation, and placed in an oven for 24 hours at 105°C.

*Experimental Burning Procedure*

Burning was conducted in the quadrate at four different ages of plantation with a 45 kg of fuel load (dead and live) in the afternoon between 13.00 pm and 16.00 pm. In Manitoba and Saskatchewan research (Williams, 1960), the burn must be made on a day when the humus layer has a moisture content ≤ 20 %. Matches were used as a source of fire. Fires were set on the sides of the quadrate at the same time and allowed to propagate naturally. Burning was done until mostly of fuel burnt. In this experimental burning, fire temperature, rate of the spread of fire and flame length were estimated.

*Estimation Flame and Fire Characteristics*

Flame temperature at 0 m and 1 cm under the soil surface was estimated by using "Tempilaq" (temperature indicating liquid), which melts at a specified temperature and provides estimates of maximum temperatures. Each liquid was set in an aluminum pipe 2 cm in diameter and 30 cm long (Saharjo, 1995). The temperature censors were placed in the vegetation at two locations.

Rate of the spread of fire was estimated by measuring the average distance perpendicular of the moving flame front per minute. A stopwatch and measurement tape were used.

Flame length was estimated by measuring the average distance between the tip of flame and the surface fuel. Tree height equipment and counter was used.

Crown scorch was estimated by measuring the percentage of canopy whose leaves were dark soon after burning. Tree height equipment was used.

Fire intensity is the product of the available heat of combustion per unit area of ground and the rate of the spread of fire. It was calculated by using Byram's equations (Chandler, *et al.*, 1983), FI: 273 $(L)^{2.17}$, where FI is fire intensity (kW/m) and L is flame length (m).

*Fuel Left and Fuel Load After Burning*

Soon, after burning, all fuel left in the quadrate was collected and measured to determine how much fuel was left after burning. Meanwhile, the performance of fuel load in the forest floor is monitored monthly to determine how much of fuel load accumulated.

*Fire Effects and Natural Seedling*

The effects of fire on the trees and natural regeneration of seedling in the forest floor in every quadrate of four different ages of plantation is monitored monthly to determine how many trees die and how many natural seedling emerge.

*Statistical Analysis*

A completely random design of variance was used to test for differences among tree growth parameter, diameter, and height and fire behavior parameter, flame length, rate of the spread of fire, and fire intensity, based on the following model (Steel & Torrie, 1981):

$$Y_{jk} = \mu + \tau_j + \varepsilon_{jk}$$

where;

- $Y_{jk}$ = tree growth and fire behavior for plantation *j* in the *k* replication
- $\mu$ = mean of the treatment population sampled
- $\tau$ = treatment
- j = plantation year
- k = replication
- $\varepsilon_{jk}$ = random component

To detect a significant differences in tree growth and fire behavior parameters ($P \leq 0.05$), the Duncan test was used (Steel & Torrie, 1981).

## RESULTS AND DISCUSSION

Diameter of trees (Table 1) in the quadrate ranged from 10.3 cm to 15.8 cm, and height from 10.7 m to 19.4 m.

**Table 1.** Plantation year, diameter and height of trees in the quadrate.

| Plantation year | N / ha | Diameter (cm) | Height (m) |
|---|---|---|---|
| 1991/1992 | 1250 | 15.8 ± 4.2b | 19.4 ± 3.6c |
| 1992/1993 | 1250 | 11.7 ± 7.26ab | 14.8 ± 2.3b |
| 1993/1994 | 1250 | 10.3 ± 2.0a | 12.4 ± 0.4a |
| 1994/1995 | 1250 | 11.2 ± 2.1a | 10.7 ± 1.6a |

* Means are significantly different when standard error is followed by different letters ($P \leq 0.05$)

Seed storage (Table 2) in the forest floor varied from 5.0 seeds/m$^2$ in the 1994/95 plantation to 215.3 in 1991/1992. Seed storage under the soil surface varied from 90.0 to 850.0 seeds/m$^2$ at 0-5 cm, and 0.0 to 700.0 seeds/m$^2$ at 5-10 cm. Germination percentage of seeds taken both from the soil surface and under the soil surface was quite high, ranging from 80 – 90 %. It was evidence that seeds on and under the soil surface was in a good condition with high percentage of germination.

**Table 2. Seed storage in the forest floor and under the soil surface.**

| Plantation year | Seed storage in the forest floor (per $m^2$) | Seed storage under the soil surface (per $m^2$) | |
|---|---|---|---|
| | | 0 - 5 cm | 5 - 10 cm |
| 1991/1992 | 1250 | 15.8 ± 4.2b | 19.4 ± 3.6c |
| 1992/1993 | 1250 | 11.7 ± 7.26ab | 14.8 ± 2.3b |
| 1993/1994 | 1250 | 10.3 ± 2.0a | 12.4 ± 0.4a |
| 1994/1995 | 1250 | 11.2 ± 2.1a | 10.7 ± 1.6a |

* Means are significantly different when standard error is followed by different letters ($P \leq 0.05$)

Fuel load (Table 3) varied from 13.7 ton/ha in 1993/94 to 25.1 ton/ha. Fuel load in 1993/94 was lower than in other areas because this place was monitored and maintained by the Research and Development section belong to the company that monitor and evaluate the condition of plantation regularly. If these fuel loads burn directly, it is estimated that all the trees will die, as happened in 1994 (Saharjo & Watanabe, 1996).

Flame length as an indicator of fire intensity ranged from 0.74 m in 1991/1992 to 0.93 m in 1994/1995. The highest fire intensity was in 1994/1995, with 224.3 kW/m and a maximum fire temperature of 170°C. Fire intensity will directly influenced scorch height and therefore determine how much of the plant canopies are consumed, killed or untouched by the fire (Whelan, 1995). Glitzenstein *et al.*, (1995) found that mortality in the largest size class (≥ 20 cm dbh) of long leaf pine savannas was significantly correlated only with fire line intensity. Crown scorch height varied from 5-6 m in 1993/94 to 9-10 m in 1992/1993. Flame temperature in the surface soil did not have any effect on seed under the soil surface, because the penetration heat is less than 38°C, and the seed is still dormant. The germination of *A. mangium* (Adjers & Srivastava, 1993) is significantly poor if the seed is not heated to more than 80°C.

Three months after the fire, no trees died and no natural regeneration of seedling was observed in the forest floor. Fuel load mainly dominated by litter fall again to cover in the plantation, however, ranging from 2.6 to 5.3 ton/ha (Table 4). In *Eucalyptus pilularis* (Birk & Bridges, 1989), four years after fire there was no difference between the fuels in control and burned stands (20 ton/ha), with repeated burning, however, particularly at 2-years interval, the understory of woody shrubs was replaced by a larger of grass. This means that prescribed burning can control chance outbreaks of wildfire at heavy fuels and it should be conducted regularly at least three months before dry season. In uneven-aged stand of Ponderosa pine (Kalabokadis & Wakimoto, 1992) reported 6.5 to 9.0 % of the overstory trees with diameter ≤ 12 cm and > 3 m tall killed. Worst condition in *Quercus chrysolepis* stand reported by Payen & Narog (1992) that prescribed burning caused mortality approximately 50 % in diameter ≤ 15 cm and < 10 % in larger classes.

**Table 3. Weather condition and fire behavior when burning was being conducted.**

| | Plantation year | | | |
|---|---|---|---|---|
| | 1991/1992 | 1992/1993 | 1993/1994 | 1994/1995 |
| Weather conditions | | | | |
| Air temperature (°C) | 30 | 33 | 35 | 33 |
| Relative humidity (%) | 80 | 80 | 75 | 80 |
| Wind speed (m/s) | 1.7 | 1.6 | 1.7 | 1.8 |
| Fire behavior | | | | |
| Fuel moisture (%) | 5.5-30.0. | 12.2-43.9 | 11.6-31.2 | 3.5-49.5 |
| Pre-fire fuel (kg) | 20.2±0.5b | 23.2±0.3c | 13.7±0.4a | 25.1±0.3d |
| Post-fire fuel (kg) | 45.0 | 45.0 | 45.0 | 45.0 |
| Fuel bed depth (cm) | 1.9 | 2.5 | 1.2 | 0.5 |
| Rate of the spread of fire (m/min) | 1.4±0.2a | 1.5±0.2a | 1.6±0.2a | 1.7±0.2a |
| Flame length (m) | 0.74±0.06a | 0.78±0.04a | 0.85±0.04b | 0.93±0.03c |
| Flame temperature (°C) | | | | |
| 0 m (soil surface) | 149-159 | 139-149 | 149-159 | 149-170 |
| 1 cm under soil surface | < 38 | < 38 | < 38 | < 38 |
| Crown scorch height (m) | 8 - 10 | 9 - 10 | 5 - 6 | 8 - 10 |
| Fire intensity (k W/m) | 136.9±23.9a | 151.1±16.5a | 183.1±21.1b | 224.3±15.8c |

* Means are significantly different when standard error is followed by different letters ($P \leq 0.05$)

Table 4. The effect of fire on tree mortality and available fuel three months after fire.

| | Plantation year | | | |
|---|---|---|---|---|
| | 1991/1992 | 1992/1993 | 1993/1994 | 1994/1995 |
| Trees mortality | 0.0 | 0.0 | 0.0 | 0.0 |
| Available fuels (ton/ha) | 5.3±0.2b | 2.6±0.1a | 2.7±0.2a | 5.3±0.2b |

* Means are significantly different when standard error is followed by different letters ($P \leq 0.05$)

Burning consumed at least 85-90 % of fuel load in the quadrate. This means such an area will become safe for a while, until fuel load accumulate again. High consumption of this fuel load mainly was caused by a low fuel moisture content, and fine fuels dominated by litter, dry leaves and small branches. The most readily available fuels for a forest fire are the dry surface layer of litter on the forest floor, small dead branch wood and the cured grass. Dead leaves or other loose litter on the ground constitute a highly flammable surface layer (Brown & Davis, 1973). The composition of fuel load (dead and live fuel) in the quadrate obviously affects the rate of the spread of fire and flame length. Fuels with higher moisture content require more heat than dry fuels to raise them to ignition temperature (Anonymous, 1970) and more intense fire. This means that more heat energy is needed to burn it. Thus, burning in 1994/95 quadrate reached the highest maximum flame temperature (170°C) and fire intensity.

One of the reasons why prescribed burning should be conducted in the *A. mangium* plantation is to reduce the high available fuel stored in the plantation. This results from poor maintenance activities, i.e., inadequate weeding and pruning and low material decomposition. Table 3 shows that all the plantations have more available fuel than should be permitted, 3 ton/ha. This means that all the plantations have a high risk of fire invasion, and trees will easily be destroyed. This happened in 1994 (Saharjo & Watanabe, 1996), where 20,000 ha of *A. mangium* plantation of 120,000 ha planted destroyed in only three months. The risk is also increased by the potential for arson around the plantation

After prescribed burning, no trees were damaged and no natural seedling was found in the forest floor. This means that the procedure for burning can be based on the previously stated rule. Three months after the fire, fuel load increases again in the quadrate. It seems this fuel load is dominated by falling leaves and old branches. Therefore, it becomes important for maintenance activities to be conducted at three month interval in order to prevent accumulation of heavy fuel that will cause wildfires. Regularly fuel reduction burning in *Eucalyptus pilularis* forest (Birk & Bridges, 1989) may increase the probability of controlling chance out breaks of fire.

## CONCLUSION

This research has demonstrated that prescribed burning can be used to reduce high fuel load in the plantation without any damage to the trees. Prescribed burning should be conducted with the following rule: Maximum fuel load at 3 ton/ha, fuel bed depth of 8 cm, fuel moisture content of 5 % - 40 % dominated by dead fuel. Air temperature should be between 30°C and 35°C, relative humidity at 75 - 80 %, and a wind speed of 1.6 - 1.8 m/min. Sunny days are preferable, in the afternoon between 1.00 pm and 4.00 pm and the fire should be put on the side of plot, following the wind direction.

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