

## Effects of Forest Fire on Wood: A Biological (Anatomical Study)

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### **Abstract**

The effects of forest fire on wood were studied on fifteen dead and living trees of various tropical species. The wood reacted in the following ways: (1) creating smaller but denser pores than normal in a concentric pattern, (2) changing dimension and numbers of axial parenchyma, (3) producing more axial intercellular canals, (4) forming decay spots in the wood, (5) creating the concentric area of fibres area or forming the vessels late, (6) creating new calluses and the bole losing its cylindrical form, (7) producing abnormal gums in the wood and (8) the bole becoming hollow. These abnormalities decrease physical or mechanical properties depending on how serious the defect is in the wood. Wood deterioration was more strongly influenced by the conditions caused by the forest fire and subsequent attacks by fungi, bacteria and insects than by fire itself. There were various effects depending on the durability and other properties of the wood. The wood was classified into four groups: “merkubung/sengon”, “akasia/medang”, “ulin” and “leda”, according to condition in the field.

### **INTRODUCTION**

In nature, wood is one of the reliable materials for recording data of past events. If a tree survives frequent forest fires, air pollution and other drastic ecological changes, the physical wounds will be recorded in the wood. Reactions among trees vary according to the tree species and/or wounding process. Several times forest fires in East Kalimantan have almost destroyed our forest plantations, leaving just a few living trees in various conditions. Up to now, industrial and governmental managers have hesitated about decisions on how to manage the forest after fire, especially whether or not to cut dead trees. However, the wood will deteriorate in time if the dead-standing trees are left.

The aim of the research was to determine what wood deterioration occurs in the standing tree in a burnt area, and what changes take place in the

fire-damaged structures one year after the fire. Further, to make a timber classification to assist collection of timbers from the field after forest fires.

### **MATERIAL AND METHODS**

The wood samples were taken from Tahura Bukit Suharto Education Forest (BSEF) of Mulawarman University located at 1° S latitude and 117° E longitude and 43 km from Samarinda, East Kalimantan. The climate is hot and wet throughout the year and typical for a tropical rain forest region. The average annual rainfall is 2002 mm and

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average annual total evaporation 1273 mm. The yearly mean air temperatures is 29.9°C for daily maximum and 21.4°C for daily minimum. The mean annual relative air humidity is 93% for daily maximum and 59% for daily minimum. The original vegetation is lowland mixed dipterocarp forest that has been logged sporadically by local inhabitants and selectively by timber companies BSEF became a protected forest in 1979. In East Kalimantan, an unusually prolonged and severe drought lasted from June 1982 until April 1983. It was linked to a strong El Nino Southern Oscillation (ENSO) event. Another strong ENSO event occurred in 1997 and extended into 1998. In the two rainless periods of 1982-83 and 1997-98, huge areas of rain forest in East Kalimantan, including the BSEF, were affected by droughts and by drought-related fires (Kobayashi *et al.* 1999).

Fourteen dead and living trees of various species and diameters in the burnt area were cut down (Table 1). The macro- and microscopic investigation was focused on the cross section and longitudinal surface of the basal part of trunk. The terminology used follows the International Association of Wood Anatomists' Standard (Wheeler *et al.* 1989). All defects caused by biological attack and physical deterioration on the wood disc were recorded, and the percentage of decayed area measured by the dot-grid method. Significant abnormalities were photographed and analysed. Microscopical features were observed on prepared slides 25-30 µm thick and the solid wood samples examined under light- and stereo-microscopes.

## RESULTS AND DISCUSSION

### General Condition and Type of Trees After the Fire

Although the death of trees very much depended on thermal radiation intensity, almost all small diameter trees (up to 10 cm) were highly susceptible to fire damage. The bark peeled and the stem split in some of them. Generally the impact of fire on trees depends on tree height and diameter, type of leaf and bark, and heat resistance of sap- and heartwood. Almost all woody plants

were destroyed in the area. The burned trees could be classified into four groups:

- *Burnt and dead*: These trees were common in the area (Photo 1).
- *Dying*: Many trees were in this condition, shedding their leaves and their branches drying out (Photo 2).
- *Stressed*: After all leaves were shed over some months, then new buds sprout on the branches and the base of tree (Photo 3).
- *Fire-resistant*: This condition was found especially for the tall trees, high wood density, isolated trees. They have thicker bark which contains sclerenchyma and in general have few shrubs and/or litter around them (Photo 4).

### Responses of Wood to Forest Fire

The principal response of wood to thermal radiation is to change vessel formation and fibre dimensions, create more excretion cells, and

Photo 1. Dead trees in the forest



**Photo 2.** Trees shedding their leaves after the fire



**Photo 4.** The fire resistant *Shorea ovalis*



**Photo 3.** Sprouting after fire injury



Table 1. General description of wood anatomy and morphology in burnt trees at Bukit Soeharto National Park

No	Genus/ Family	Ø (cm)	Thick- ness of bark (cm)	Density (g cm <sup>-3</sup> )	Tree condi- tion	Damage type								Remarks	
						Splits	Hollows	Side burnt	Discolou- ration	Blue stain and other fungi	Moulded area %	Decayed	Insect attack		
1.	Meranti merah (I) ( <i>Shorea</i> spp) Dipterocarpaceae	58	0.90	0.56	live	split from heart to cambium	not found	only in bark (light)	at heartwood (not blue stain)	not found	not found	not found	not found	not found	
2.	Meranti merah (II) ( <i>Shorea</i> spp) Dipterocarpaceae	25.5	0.60	0.56	dead	not found	big circle enough	not found	not found	little	-	at all hollow areas	not found	not found	calluses formed
3.	Bangkirai (I) ( <i>Shorea laevis</i> ) Dipterocarpaceae	44	0.85	0.91	live	not found	big circle enough (moat)	only in bark (light), not through inside wood	not found	not found	-	Some at hollow area and split areas	not found	not found	calluses formed from post-fire in 1982 and protecting the wood from fire activity at years 97
4.	Bangkirai (II) ( <i>Shorea laevis</i> ) Dipterocarpaceae	69	0.85	0.91	live	split from pith to heartwood and becoe discolour- ation	circled	really bad (charcoal formed) at opening wood uncovered bark)	at around opening wood part since earlier '82	A little present	-	A little at sapwood post- fire in 1982	not found	not found	calluses formed since first fire, make wood become misshapen
5.	Jabon ( <i>Anthocephalus cadamba</i> ) Rubiaceae	38.5	0.50	0.36	dead	split/crack because of bend when it fell down	not found	bark burnt but not through inside wood	all over wood parts (heartwood and sapwood)	all over wood parts (heartwood and sapwood)	>75% (sapwood and heartwood)	Decay all over wood can be seen after planing	found pinhole	discolouration at heartwood from dark to light brown	
6.	Simpur ( <i>Dillenia exelsa</i> ) Dilleniaceae	26.5	0.75	0.80	live	not found	not found	not found	not found	not found (normal)	-	A little at sapwood	not found	not found	

Table 1. (continued)

No	Genus/ Family	Tree condi- tion	Density (g cm <sup>-3</sup> )	Thick- ness of bark (cm)	Ø (cm)	Damage type							Remarks	
						Splits	Hollows	Side burnt	Discolou- ration	Blue stain and other fungi	Moulted area %	Decayed		Insect attack
7.	Medang ( <i>Notaploche</i> spp./ <i>Litsea</i> spp.) Lauraceae	dead	0.64	1,1	31	A little splitting at heart	not found	in bark parts not bad damage	all over sapwood	at opening bark found white spots in the periphery of wood because of borer	<10% outer sapwood parts	from bark to sapwood	found big gap of pinhole borer at sapwood and	
8.	Akasia ( <i>Acacia</i> <i>mangium</i> ) Leguminosae	dead	0.65	0.35	22.5	not found	not found	not found but having a high water deficiency	at sapwood but heartwood still good	at sapwood around stem	<20% sapwood part	all over sapwood parts	tunnel attack	heartwood still good
9.	Mata buaya <i>Endospermum</i> <i>deaderum</i> Euphorbiaceae	dead	0.50	0.25	24	cracked lines (short) from heart to cambium	not found	not found	dark, heavy brown, black spots	the whole wood/ sporadic (in heart- wood and sapwood) and marked with brown lines	>80% sapwood heartwood	along part from pith to cambium, founded the sapwood totally damaged, marked on after planing	too much pinhole	the wood very susceptible, less than one year, and then die in the field
10.	Leda ( <i>Eucalyptus</i> <i>deglupta</i> ) Myrtaceae	dead	0.79	0.10	21.25	found, in short formed (during drying process)	not found	almost surrounding the stems to sapwood	does not appear	not found	-	a little bit in the burnt area	not found	sapwood or heartwood are very susceptible although the bark was peeled
11.	Sengon ( <i>Paraserianthes</i> <i>falcata</i> ) Leguminosae	dead	0.46	0.35	50	found from heart to cambium split	not found	not found	discolouration in all sapwood surrounding the stems (blackish brown)	fungi attack (not blue stain) causing discolouration, with brownish lines	>75% sapwood and heartwood	all sapwood up to a little at heartwood	much borer making smaller tunnels than in acacia and medang	

Table 1. (continued)

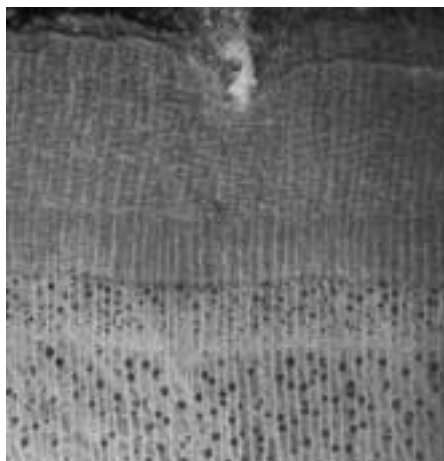
No	Genus/ Family	Tree condi- tion	Density (g cm <sup>-3</sup> )	Thick- ness of bark (cm)	Ø (cm)	Damage type								Remarks
						Splits	Hollows	Side burnt	Discolou- ration	Blue stain and other fungi	Moulted area %	Decayed	Insect attack	
12.	Terap ( <i>Artocarpus elastica</i> ) Moraceae	live	0.60	0.70	41	a little	not found	not found	not found	not found	<5% outer part of sapwood	a little	found at rotten area	
13.	Ulin ( <i>Eusideroxylon zwageri</i> ) Lauraceae	live	1.1	0.80	60	-	-	outer parts of bark	-	-	-	-	-	decreased cell production
14.	Merkubung ( <i>Macaranga gigantea</i> ) Euphorbiaceae	dead	0.45	0.35	50	split vertically and dead	-	extinguish and peeled	all wood from inside to outside	badly	> 75% sapwood and heartwood	rapidly from the bottom of trees	many borers	very susceptible population

produce abnormalities in shape/form of trees. According to macroscopic and microscopic investigations, the abnormalities in wood or trees vary depending on the species and the burning process and the reaction can be generally classified into following responses:

***The wood forms the smaller pores but they are packed more densely than normal wood***

The ability of wood to adapt to their circumstances has been basically decided by the tree's genetic make up. One way to adjust to water deficiency is to have smaller diameter pores in xylem. This may help respiration through stronger transportation by improved capillary power. On the other hand, holocellulose production is reduced much less under water-deficient conditions. Big trees, such as ulin (*Eusideroxylon zwageri*), red meranti (*Shorea* sp.) and medang (*Notaphoebe* sp.), especially can withstand fire and easily compete with other trees in the dry season, because this group has higher crowns and deeper root systems. This phenomenon can be seen also in trees from arid or semiarid areas, e.g. *Bumelia lanuginosa* and *Manilkara* spp. (Kukachka 1980, 1981 in Carlquist 1987) with changing their shape and arrangement of pores. The pores become smaller, denser and clustered with many tracheids surrounding them.

**Photo 5.** The concentric line from abnormal cells, the pores smaller and denser in red meranti (*Shorea* sp.)



**Changes in dimension and numbers of axial parenchyma**

If the trees are stressed, they reduce production of cells and form them more densely. After a while, the new cells become larger and rich in axial parenchyma as there is less competition due to the deaths of surrounding trees and greater availability of nutrients from the burnt trees. This was observed in the large buttresses of *Irvingia* sp. (bongin) (Photo 6).

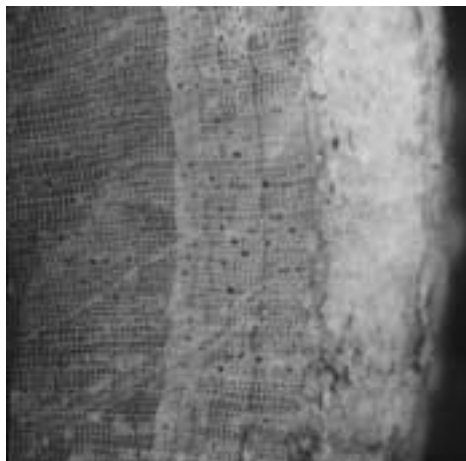
***Producing more axial intercellular canals***

Severe drought stimulated the excretion cells to produce much gum. This could be due to the intensive formation of axial intercellular canals, in the shape of concentric tangential bands. Bangkirai generally produces resin when the axial canals become dense (Photo 7).

***Expanding decay in the wood***

The process of decay begins from lack of water when water content is reduced below the fibre saturation point, especially in sapwood. This condition may let fungi invade the outside parenchyma cells through splits in the bark or lenticels. Fungal enzymes can degrade the cell wall and then the wood deteriorates continuously, e.g. kenuar (*Shorea johorensis*) (Photo 10).

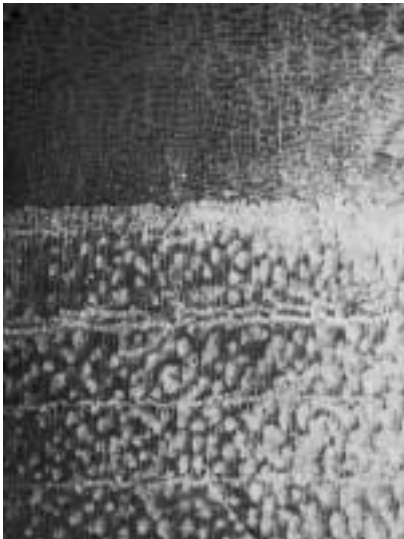
**Photo 6.** Dimension and intensity change of axial parenchyma in bongin (*Irvingia* sp.)



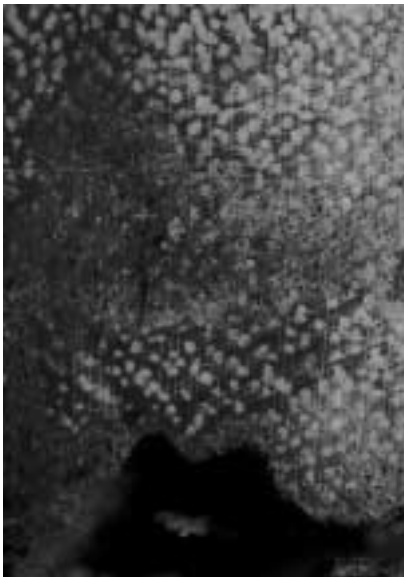
*Creating a ring of fibres or delaying of pore formation*

Trees produced more thick fibres than pore cells to increase the efficiency of water and nutrient uptake. This phenomenon is controlled by gibberelin synthesising enzymes (Guenter and Hartmut 1983). The fibre tissue dominates in tangential lines, e.g. simpur (*Dillenia exelsa*) (Photo 9).

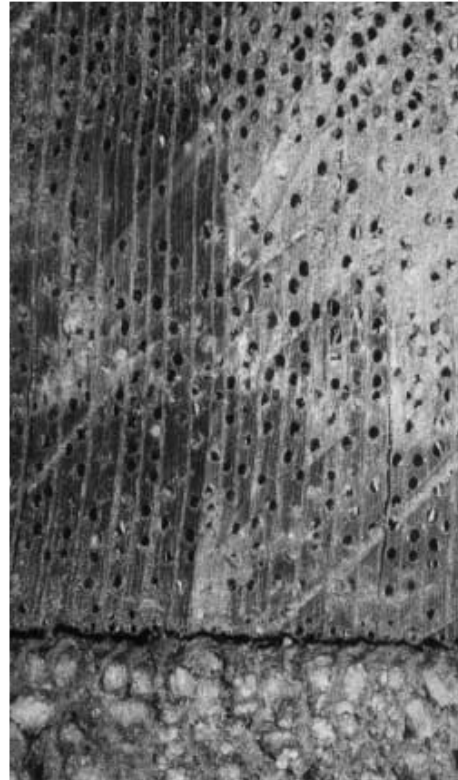
**Photo 7.** The dense tangential line of axial intercellular canals in bangkirai (*Shorea laevis*)



**Photo 8.** Decayed spots in the wood tissue in bangkirai (*Shorea laevis*)



**Photo 9.** Concentrated fibres in a concentric pattern in *Dillenia exelsa*



**Photo 10.** Bole becoming hollow in kenuar (*Shorea johorensis*)



### *Creating new calluses and producing a misshapen bole*

Calluses grow rapidly both sides of damaged bark to cover the wound and this concentrated growth activity results in a misshapen bole (Photo 11).

### *Producing gums and other abnormal components*

A large quantity of gum is needed to cover injuries and contribute to new tissue called the “barrier zone” (Shigo 1989). The cambium takes several years to cover the damaged tissue and a lot of resin or gum is trapped in the wood. An example of gum occurring around the wood causing a ring-hollow pattern in kenuar (*Shorea johorensis*) is shown in Photo 12.

### *Bole becomes hollow*

Sometime calluses cannot quickly close the wound and this condition attracts fungi, bacteria or other pathogens which decompose the wood cells and allow further development of fungal or insect attack. Then the wound becomes deeper and the bole hollow.

## **TYPES OF WOOD DETERIORATION AFTER FIRE**

The research indicated that the state of the wood was largely influenced by post-fire deterioration, such as the effects of fungi, bacteria and insect invasions rather than by fire itself. The effects varied depending on durability and other wood properties. The thin cells and light coloured wood usually have less extractive toxin and this wood was very susceptible to damage. Trees were classified into four groups according the type of post-fire damage:

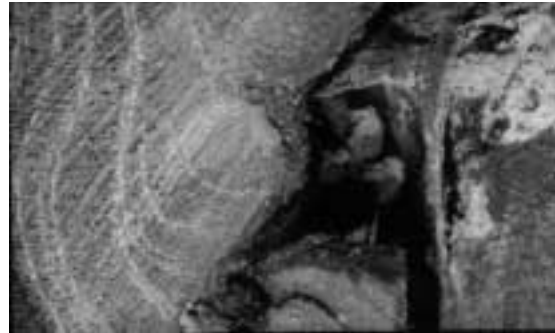
### **Merkubung/Sengon (Type 1)**

This type has low durability. Generally wood density is low and the wood light coloured with no difference between sapwood and heartwood. Cell walls are thin so can be easily penetrated by fungal hyphae. Normally, blue-stain or other fungi can reach more than two-thirds of the bole within

**Photo 11.** The misshapen of bole of bangkirai (*Shorea laevis*)



**Photo 12.** Trapped resins inside wood cells of kenuar (*Shorea johorensis*)



one-year (Photo 13). The stem base in contact with the ground decays severely and the stem is easily blown over. Sengon (*Paraserianthes falcataria*) and some other pioneer species are typical of this group.

### **Akasia/Medang (Type 2)**

In this group, sapwood and heartwood are distinct and have different moisture content and extractives. The sapwood, which has not many extractives, is a good place for microorganism infection when exposed by fire damage but the heartwood is resistant to attack (Photo 14). In this type, one year after fire, the sapwood has already badly decayed while the heartwood is still sound. More investigation of mechanical properties is needed if the heartwood is to be utilised.

**Photo 13.** Fungi rapidly attack the entire disk of merkubung (*Macaranga gigantea*) tree (Type I)



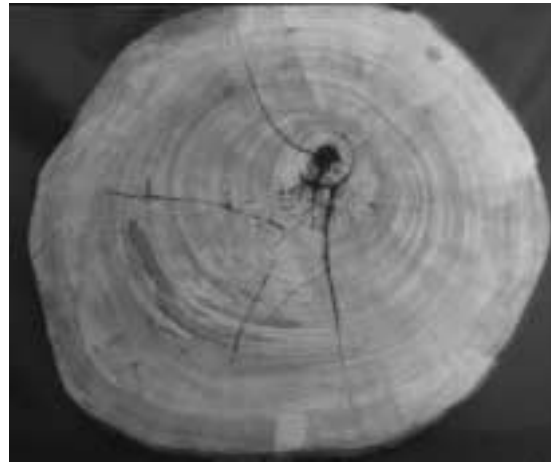
**Photo 14.** Fungi attacking only sapwood and followed by insect borers in heartwood of medang (*Litsea* sp.) (Type II)



### Ulin/Bangkirai (Type 3)

This type has medium and high wood density. The bark is thick and contains much fibre and sclerenchyma. The fire usually only burnt the outer bark, but when exposed to high thermal radiation for a long period the cambium activity stopped for some time. Wood with an abnormal structure is produced. The bark remains on the cambium after its death and there are no places for microorganisms to attack (Photo 15). Ironwood (*Diospyros* sp.) made smaller pores and the cell reproduce slowly. Some other species e.g. meranti batu (*Shorea* sp.) show abnormal growth and produce more gum than usual. One-year after the by forest fire this group had normal wood quality, even in dead trees.

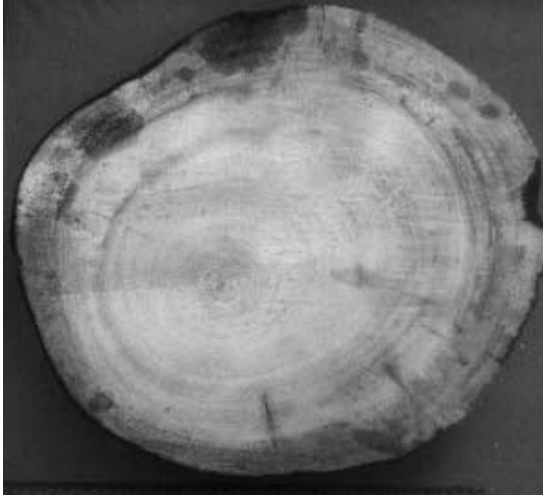
**Photo 15.** High density dark red meranti (*Shorea* sp.) with thick and compact bark which is very resistant to fire and microorganisms (Type III)



### Leda/Palawan (Type 4)

The last group type is leda (*Eucalyptus deglupta*) and palawan (*Tristania* sp.). These trees usually have thin bark, often shed in strips, so sunlight can reach the wood surface. This is a reason wood is durable and more resistant to invasion by fungi and insects (Photo 16). This wood is not good for pulping as the remaining charcoal will cause discolouration.

**Photo 16.** The sound stem disk in leda (*Eucalyptus deglupta*) after fire with only in the outside of the bole charcoaled (Type IV)



## CONCLUSIONS

- The response of wood to thermal radiation is manifested in the formation of vessels, change of fibre dimensions, stimulation of excretion cells and bole shape abnormalities.
- Impact of fire on trees was variable depending on height and diameter of the tree, type of leaf and bark, and resistance of sapwood and heartwood.
- The state of the wood in the trees was more influenced by post-fire deterioration, such as invasion by fungi, bacteria and insects rather than by fire itself. The extent of these influences on wood quality was determined by the durability and other wood properties

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