2. Impacts of Indonesian Forest Fire

Forest and Land Fires in Indonesia: A Serious Threat to the Conservation of Biodiversity

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Abstract

Wildfires, as an excess of traditional slash and burn agriculture or land-use conversion activities during the dry seasons in every year, have been warned since long time as a potential threat to the biodiversity. The potential threat of wildfire to the biodiversity was greatly proved in the last 20 years. In the last 20 years, the dry seasons were associated with five periods of strong ENSO (El Niño Southern Oscillation), which caused much more severe and longer dry seasons in many areas of Indonesia, and devastating much more widely forest and land fires. The wildfires during the strong ENSO periods in 1982-1983; 1986-1987, 1991, and 1994 damaged about 3.5 million ha, 100,000 ha; 500,000 ha and 4,866,500 ha lands, respectively. The official figure for total area burnt in 1997-1998 was 931,250 ha. However, the recent findings reported that the total area burnt during 1997-1998 wildfire was 9.5 million ha. Burnt lands were including traditional ladang, shifting cultivation areas, transmigration lands, estate lands, logging concession areas, secondary forest and natural forests, spread mainly in Sumatra (Riau, Jambi, South and Lampung provinces) and in Kalimantan (East, Central and West provinces). The principal fire causes were due to the burning method on land-use conversion for commercial crops, and to the slash and burn agriculture practices. The land and forest fires have caused a spectacular damaged and loss on the biodiversity, directly (such as: wildlife species death or injury by fires, ecosystem and habitat destruction) and indirectly (such as: destruction of soils, nutrient and food), and also due to its "downstream" effects to the biodiversity (such as: increasing sediment and reducing solar radiation). The wildfires were also stroke natural forests within the conservation areas where the biodiversity were stored.

Key Words: Biodiversity, Conservation, Dry season, Forest and land fires, Impact, Indonesia

Introduction

Following an intense ENSO (El Niño Southern Oscillation) episode in 1982-1983 and 1997-98, many areas of Indonesia have been experiencing very intense dry season that causes severe drought, devastating wildfires, and hazardous haze. The drought and wildfires in 1982-1983 damaged 3.5 million hectares of forest and agricultural lands of Each Kalimantan alone, with an estimated loss of standing timber and growing stock that worth more than five billion US dollars.

In 1994, more than 5 million ha lands including traditional **ladang**, shifting cultivation areas, transmigration lands, estate lands, logging concession areas, secondary forest and natural forests were burned down. In 1997, forest fires were spread widely in Sumatra areas with 2308 hot spots, Kalimantan (1534 hot spots) and Java & Bali (87 hot spots). As in 1982, the forest fires in 1994 and 1997 also made the Government of Indonesia lose billions of dollars of valuable materials and uncountable amount for invaluable materials.

The impact of the big forest fire in 1997 not only stroked Indonesia but also other countries, such as: Malaysia, Singapore, Brunei, Thailand and the Philippines. Haze from the land and forest fires covered all Southeast Asian countries and forced the countries to close some of their airports for many days. Into a large extent, the large fire also was believed to contribute into global warming and public health through particle and air pollution, such as: aerosols, ozone and carbon releasing.

The present paper intends to overview the recent information on impacts of forest and land fires on the biodiversity, including research needs.

Indonesian biodiversity

Although Indonesia only covers 1.3% of the total world land, it is accounted to possess about 17 % of the total living species on earth; about 11 % of flowering plants, 12 % of mammals, 15 % of the total reptile and amphibian, 17 % of bird species, 37 % of fish species (KLH, 1993). Estimated number of species of each big group taxon is presented in Table 1.

Table 1 Estimated numbers of species of each taxon group of Indonesia and the world.

Taxon Group	Indonesia		World
	Minimum	Maximum	Estimation
Bacteria, Blue Algae	225	300	700
Fungi	4,280	12,000	47,000
Algae	1,000	1,800	26,900
Moss & crust	1,500	1,500	16,600
Ferns & Lycophyta	1,250	1,500	11,300
Gymnospermae	100	100	530
Angiospermae	25,000	30,000	220,000
Protozoa	1.500	3,500	30,800
Insects	1,000,000	5,000,000	30.000,000
Other Arthropoda	30,000	50,000	300,000
Mollusc	2,000	6,000	50,000
Other Invertebrates	5,000	10,000	66,000
Fish	7,000	8,500	19,000
Amphibian	1,000	1,500	4,200
Reptiles	600	2,000	6,300
Birds	1,300	1,600	9,200
Mammals	515	800	4,170
Total	1,082,270	5,131,100	30,818,100

Source: Sastrapradja *et al.*, (1989) and KLH (1993)

This huge diversity were supported by the geographical location of Indonesia, which lies in the center of wet tropical area, and also the condition of its area, which consists of island spreading over the equator, with different seasonal wet and dry climates. Asia and Australia continents have enriched the Indonesian biodiversity with Gondwanaland and Laurasia elements. Bio-geographically, the Indonesia area is divided into two big regions, namely Indo-Malaysia and Australasian life-groups, separated by imaginary "Wallace" line, with a transitional life zones in between.

Most of the Indonesian biodiversity consist of Malaysian component, with a high degree of endemism (Table 2). About 50% of 25,000 flowering plant species (including 10,000 tree species) are endemic at family level (FAO, 1982; KLH, 1993). The biodiversity are conserved mainly in some protected areas distributed in Indonesian islands (Table 3).

More than 303 protected regions have been determined, covering the size of 16.02 million ha or about 8.2 % of the total Indonesian land. Beside that, 23 marine conservation regions have been appointed, and 200 sea shores and other sea regions have been proposed (MoF/FAO, 1991; KLH, 1993). Furthermore about 185 other locations with sizes over 3 million ha, have been recommended to be protected regions, in relation to their functions as water absorbing areas and in possession of high biodiversity (Collin *et al.*, 1991). During the period from 1992-1995, at least 7 new national parks have been appointed (MoF, 1996). Although great biodiversity exploitation has been carried out during the last decade, Indonesia is still ambitious to appoint at least 18.8 million ha of protected regions up to year 2000.

Table 2 Endemic species by island group.

No	Island	Percent of endemic species			
		Birds	Mammals	Reptiles	Plants
1	Sumatra	2	10	11	11
2	Java	7	12	8	5
3	Borneo	6	48	24	33
4	Celebes	32	60	26	7
5	Sunda lesser	30	12	22	3
6	Maluku	33	17	18	6
7	New Guinea	52	58	35	55

Source: KLH (1993)

Table 3 List of protected regions all over Indonesia up to August 1990.

Kinds of protected regions	Number of location	Total ha/region
Nature Reserves	154	3,379,955
Game Reserves	44	2,138,200
Recreation Parks	54	95,000
Marine Recreation Parks	13	379,465
Grand Forests Parks	4	97,000
Hunting Reserves	13	455,091
Marine Nature Reserves	10	2,407,065
National Parks	34	10,054,914
Total	326	19,006,690

Source: MoF/FAO (1991). MoF (1996)

Land and forest fires in Indonesia

Goldammer and Seibert (1989, 1990) have studied the evidence of ancient wildfires in East Kalimantan with ^{14}C-dates of soil charcoal. They concluded that, wildfire had occurred between ca. 17,510 and ca. 350 BP. Goldammer (1997) also reported that those fires were associated with period of drought caused by ENSO complex. Winarso (1999) summarized

the history of ENSO and wildfire in Indonesia since 1888 (Table 4). Table 4 indicates that although the period of drought caused by ENSO were reported since then, but the forest fires as the impacts of severe drought were not well documented before 1982. Some papers have indicated the occurrence of forest fire in Sabah in 1914-1915 (Cockburn, 1974, cited by Goldammer 1997), in East Kalimantan in about 1914 (Goldammer, 1997), but no detail information on the burnt areas.

The forest fire in Indonesia became a very important issue since 1983 when many forest areas in East Kalimantan were burnt down after a long dry period. The 1982/1983 land and forest fires in East Kalimantan was believed as a great disaster in the tropical regions. Lennetz & Panzer (1983) reported that about 3.5 million ha of land and forests suffered great damages from the fires. The damaged forests were included: 800,000 ha of primary forest, 1,400,000 ha of the logged over forests, 750,000 ha of secondary farming land and other community living areas, as well as 550,000 ha of peat swamps and peat forest (Ministry of Forestry 1992). According to the Ministry of Forestry and Estate (1991) decrease of forest area due to normal forest fires between 1982 and 1990 is estimated around 100,000 ha/year.

Table 4 History of ENSO (El Niño Southern Oscillation) in Indonesia (after Winarso 1999).

Year	ENSO	Areas	Severity	Wildfire Location	Burnt Areas (ha)
1888	Strong	S	Severe	?	?
1896	Strong	S	Not Severe	?	?
1902	Weak	S and E	Severe	?	?
1911	Weak	Localized	Not Severe	?	?
1914	Strong	E	Severe	?	?
1818	Weak	S and E	Moderate	?	?
1930	Weak	E	Moderate	?	?
1940-41	Strong	E	Not Severe	?	?
1940s-50s	No records				?
1961	No	S and E	Severe	?	?
1963	Weak	S and E	Severe	?	?
1965	Strong	S and E	Severe	?	?
1967	No	S and E	Moderate	?	?
1969	Weak	South	Moderate	?	?
1972	Strong	S and E	Severe	?	?
1976-77	Strong	S and E	Severe	?	?
1982-83	Strong	Widespread	Severe	East Kal	3,500,000
1986-87	Strong	South and East	Moderate	All Kal	100,000
1991	Strong	Widespread	Severe	Sum, Kal, Java	500,000
1994	Strong	Widespread	Severe	Sum, Kal, Java	4,866,500
1997-98	Strong	Widespread	Severe	Sum, Borneo	9,5000,000

S: South E: East

A great disaster again stroked Indonesia in 1994 when severe dry season was followed by wildfire. The 1994 wildfire burnt down 4,8665,500 ha land categories, included: 2,800,000 ha farmland; 1,500,000 ha shifting cultivation; 300,000 ha transmigration land; 221,000 ha plantation; 20,500 ha reforested land; 17,000 ha timber estates, and 8,000 ha natural forests.

Up to now, there was no an exact figures on the burnt areas of the 1997/1998 forest fires in Indonesia. The official figures (Department of Forestry) and NGO presented different figures of the width of 1997/1998 forest fires in Indonesia (Table 5). The area burnt figured in Table 5, were believed underestimated, since the fires were extended up to 1998. The 1997/1998 forest fires were much more severe, much more widely spread, and caused impact were also much wider than of 1983 or 1994 forest fires. Fig. 1 and 2 illustrates the severity of forest fires in a peat swamp area in Central Kalimantan in September 1997 and the distribution of hotspots in three main islands in Indonesia (see also Table 6).

Recently, ADB (1999) estimated that the 1997/1998 forest fires damaged about 9.5 million hectares land and forests, spread mainly in islands of: Sumatra (Riau, Jambi, South and Lampung provinces); Kalimantan (East, Central and West provinces), and Irian Jaya (Table 7).

Table 5 Data of the width of Forest Fires according to Department of Forestry and Estate (in 1997), Poskobar Walhi (April-September 1997) and WWF.

No	Land Type	Burnt areas		
		Dept. of Forestry	POSKOBAR WALHI	WWF
1.	Protected Forests	21,963	-	-
2.	Production Forests	163,444	587,000	-
3.	Conservation regions		45,000	-
	a. Nature Reserves	17,238	-	-
	b. Tourist Forests	1,415	-	-
	c. National Parks	54,331	-	-
	d. Great Forest Parks	653	-	-
	e. Hunting Parks	202	-	-
4.	City Forest	5	-	-
5.	Research Forests	4,441		-
6.	Plantations	119,877	798,000	-
7.	Peat Land Project	-	260,000	-
8.	Transmigration Areas	-	30,000	-
9.	Community Farms	-	3,000	-
	Total	383,869	1,714,000	5,000,000

Table 6 Number of hotspots relative to vegetation types (February-October 1997).

No	Vegetation types	Σ
1	Swamp forests	1202
2	Lowland rain forests	1047
3	Scrubs, grass land, gardens	356
4	Mangrove forests	40
5	Mountain rain forests	32
6	Inland waters	24
7	Lowland monsoon forests	3

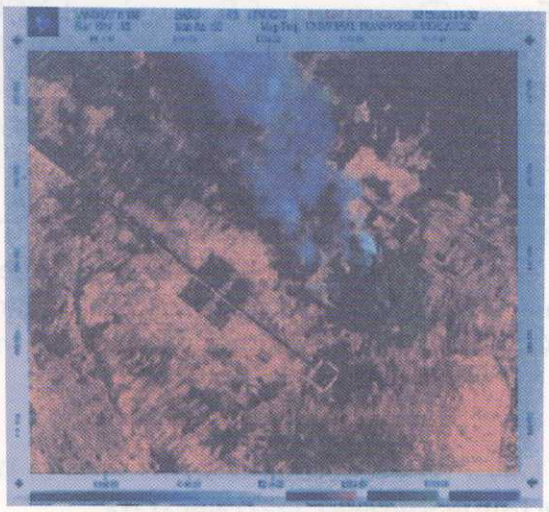

Fig. 1 Forest fires in a peat swamp area in Central Kalimantan in September 1997.

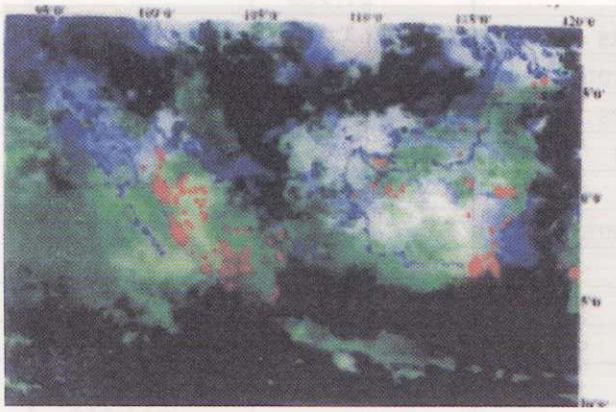

Fig. 2 Distribution of hotspots in Indonesian islands (NOAA & HIMAWARI) 8 November 1997, 08.00 AM.

Table 7 Spatial damage by fire in 1997-1998 (in ha, after ADB, 1999).

No		Kaliman-tan	Sumatra	Java	Sulawesi	Irian Jaya
1	Montane forest					100,000
2	Lowland forest	2,375,000	200,000	25,000	200,000	300,000
3	Peat and swamp	750,000	300,000			400,000
4	Dry scrub & grass	375,000	200,000	25,000		100,000
5	Timber Plantation	116,000	72,000			
6	Agriculture	2,839,000	668,000	50,000	199,000	97,000
7	Estate crops	55,000	60,000		1,000	3,000
	Total	6,500,000	1,500,000	100,000	400,000	1,000,000

Triggering factors of land and forest fires in Indonesia

Long term climate variability (glacial versus non glacial climates) and short term climate oscillations caused by the El Niño - Southern Oscillation (ENSO) event have repeatedly created conditions that make even rainforests vulnerable to wildfires. In the rain forest biome these prolonged droughts drastically change the fuel complex and the flammability of the vegetation. Once the precipitation falls below 100 mm per month, and periods of the two or more weeks without rain occur, the forest vegetation sheds its leaves progressively with increasing drought stress. In addition, the moisture content of the surface fuels is lowered, while the downed woody material and loosely packed left litter layer contribute to the build up and spread of the surface fires. Aerial fuels such as desiccated climbers and lianas become fire ladders potentially resulting in crown fires or torching of single trees. Peat swamp forests represent another fuel type. Increasing precipitation deficit and lowering of water table in the peat swamp biome will progressively dry out the organic layers, and increase the flammability of organic matters deposited in the peat forests.

Lightning is considered as one of the natural causes of forest fires. Tropical region has more number of days with lightning (200 days) per year, compared to the regions with medium climate (60-80 days) (Koramek 1964). Although lightning can cause fire, however it is very seldom to make forest fires, because lightning generally occurs in rainy season. Human activities are generally the most potential cause of forest fires.

People through their various activities, directly or indirectly, are considered to be the most dominant factor as the sources of fires. The main factor as the cause of forest fires is the burning of forest in the process of land clearing. Land clearing by burning the forest is a low cost method compared to that by cutting down the trees; this is commonly done on the peak of the dry season. This land clearing by burning has been practiced not only in small scale by indigenous people but also in the large scale for transmigration and plantation areas.

Indigenous people traditionally have been exposed to the patterns of safe forest and land burning which has been passed on from generation to generation. A traditional mechanism exists within the whole social structure, which serves as a background for the farming activities. All that results in a harmonious relationship, in tune and in balance with the environment. Control mechanism has been executed through religious beliefs or a conviction that people should not be unkind to the environment. Therefore land clearing by burning the forest is only limited to subsistent farming and rotations in farming are carried out on their inherited lands.

However, forest burning method for preparing the lands for new settlements and plantation are also practiced by many companies and individual migrants for their own farm lands. They put their priority on economic aspects and accumulation of land ownership, making it difficult to control during land clearing and burning. Other than forest burning habits in the process of land clearing, there are many other human activities that can be noted as the causes of forest fires. The activities may result from disappointment, hatred, revenge or conflicts with other parties (such as the authority or a company), inappropriate use of fire particularly in forest areas or for other purposes. Considering that even a petty reason may cause a fire disaster, the above reasons can not be neglected. Several minor causes of a fire accident are: negligence (such as: uncontrolled organic waste burning; using of fire in fishing, honey hunt, fire wood collecting, hunting, grass cutting, charcoal making, hiking, camping and its activities in the forests area, and cigarette buts); and outburst of disappointments.

Loss of wildlife species due to forest fires

Directly, fires have killed many wildlife species. Indirectly, fires have decreased the richness of species by decreasing the quality of habitats for different kinds of wildlife. In the meantime, wildlife species which have been effected by land and forest fires until now have not been exactly known, especially about their population status, their behavior, and their propagation in the new locations where they evacuate.

The size of damage or loss caused by fires will be affected by different factors, such as the intensity and frequency of the fire pattern. In general there are 3 forest fire patterns, i.e.: surface fire, crown fire, and ground fire. Surface fire generally happen in the grassland or homogenous forest, while crown fire usually occur in the "*pamah*" (lowland forest) which is covered by liana epiphyte, such as rattan, and other climbing trees. A special case may be a underground fire beneath the forest floor of peat swamp forests or lowland forest where coal seaming deposited. This was the most crucial disaster in recent forest fires in Central Kalimantan and East Kalimantan. Since, recently, due to the limited sources of mineral soils, shallow peat swamp forests had been drained and converted into agricultural lands in a very spectacular rate, such as for palm oil plantations and for new settlements areas. Unfortunately, many of them were unsuccessful, creating major land degradation and biodiversity loss, while on the other hand, little is known on the natural biodiversity, natural function and values of peat swamp forests.

Forest fires have effected the flora and fauna diversity in the forest. Many plant species are not resistant to fires, such species may loss during the fires. Mixed forest of Dipterocarpaceae at the Wanariset, East Kalimantan is known as one of the richest tropical forests in tree species (Kartawinata *et al.*, 1981, Whitmore, 1984). About 90% of tree species in research plots in the area were permanently died during 1982/1983 forest fires, and in research plots (the same forest type) at Lempake (East Kalimantan), also only about 20% of species were still found alive after fires.

About 366 orangutans were returned to nature in Wanariset, and after the 1997/1998 fires only 19 orangutans were found. In the meantime Wanariset Rehabilitation Center had received more than 140 orangutans for being checked-up their health condition and recovered after fires. While in East Kalimantan about 120 old orangutans and 60 juveniles were supposed dead from fires. The protected forest of Sungai Wain in East Kalimantan, which was home of around 100 rehabilitated orangutans was also damaged by fires. The fate of those orangutans in that forest is not known.

About 50,000 ha of 198,000 ha Kutai National Park were burnt down by 1997/1998 fires, whereas this national park was important habitat of around 2000 orangutans and a number of orangutan had been driven away from the habitat for looking their food. The life of orangutan group is not stable and the number decreasing compared to those before the fires. The decrease of their juveniles and elder orangutans is about 38% in each group.

Kalimantan (home for at least 600 bird species with unique characteristics and even endemic) will become a life and death battle for various bird species due to loss of their good habitat. As result of the great fires, there will not be any fruits in the near future, and it means there will be food shortage for the birds. Birds are found in weak condition and difficult to breathe because of haze. Birds, which have been driven from their habitat become disoriented, flying without any direction, even crashed themselves on the windows of the houses nearby.

Direct effect of forest fires is estimated to have killed all species of small snake lizards and turtles, because of their disability to escape from fires. Amphibian species, which are able to jump on trees, were also killed. Even iguana species was unable to escape from fires

although they can move fast. Crocodiles and several other species, which can live in deep water, such as lake and big rivers, have chances to survive.

Long term effects of forest fires on the existence of amphibians and reptiles are especially on their damaged habitat, loss of place to lay eggs, water contamination, and decrease in food resources. The small number of insect population in the forest after fires will have great effect on the life of herpetofauna, which cannot move far.

The escaping animals from the habitat by the fire apparently were captured by the villagers and sold in the markets. These conditions appeared because the people experienced the economic crisis that hit Indonesia. Forest fires that drove away the animals from the forest apparently had stimulated people to trade wildlife to improve their economic conditions.

Since forest and land fires almost occur every year, causing material losses, bring damages to the environment and the biodiversity, therefore, land and forest fires can be one of serious threats to the sustainability of forest and natural biodiversity as a whole. The repeating occurrence of land and forest fires, will not only speed the decrease of soil fertility, but also decrease the wildlife population inside forest ecosystem as well as outside environment around the forest. Soil structure will be damaged due to the opening soil surface. In the next rainy season, ash and soft soil grains will float away in the water to become mud, which finally will be deposited at the river estuaries. Beside, decreasing the water quality, the sedimentation process will occur more rapidly in the area which often suffer from fire.

The 1997/1998 forest and land fires in Indonesia had cleared away more than 17 national parks, and these are threats to the wildlife. The intact of sea habitat, in particular the coral reefs with the diversity of fishes and other animals, indirectly will also be threatened by the downstream effects of land and forest fires. Forest fires will decrease the potential of the ecosystem functions, such as: water purification, water cycle management, air purification, carbon fixation, and erosion prevention. This is related to the changes or even the loss of vegetative composition, which will usually be replaced by pioneer species.

Research on the effect of wildfire on biodiversity

From the 1982-1983, 1986-1987, 1991, 1994 and 1997-1998 experienced wildfires, it had been noted that wildfire greatly affect the conservation of biodiversity; directly, by burnt down the wildlife; indirectly, by changes the habitat condition, changes local microclimate, and by destroying food or nutrient sources. It was also noted that the wildfires not only affect the biodiversity beyond the burnt areas, but also in the stream by means increasing sedimentation rate due to increase of soil erosion rates in the upper stream; and affect the physiological activities of wildlife due to reduction of solar radiation. Although those wildfire effects have been noted since 1982, how much was biodiversity damaged, which species was affected directly and indirectly, and to what extend the remaining biodiversity was effected and how they could recover were still not much studied quantitatively.

Goldammer (1997) has summarized the research of wildfire in Indonesia. He concluded that researches were largely concentrated on fire effect on ecosystem properties and ecosystem stability. Furthermore, he proposed the interdisciplinary research, such as coupling of ecological, atmospheric and climate researches. Although conducted studies largely concentrated on fire effect on ecosystem properties and ecosystem stability, but those were still not enough to answer the above questions.

Based on the recent discussions, it was realized that there were some lack of data on the effects of wildfire on the loss, distribution, population, evolution, adaptation, and behavior

of the biodiversity. Since the present faced problems on the effect of wildfire on the biodiversity were very broad, it was also suggested that the above fields should be prioritize on the present crucial objects of some categories, such as:

- By taxon: (endangered, endemic and commercial species);
- By forest types: (lowland or peat swamp forests);
- By conservation region: (Kutai National Park, Tanjung Puting National Park, Berbak National Park and Kerinci Seblat National Park); and
- By provinces: (Kalimantan: Central Kalimantan, East Kalimantan and West Kalimantan; Sumatra: South Sumatra, Riau and Jambi).

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Wildfires in East Kalimantan: Fire Sources and the Effects of Fire Disturbance on Lowland Dipterocarp Forests

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Abstract

Two of the world's largest forest fires occurred in East Kalimantan during the exceptional droughts of 1982-83 and 1997-98, which were both related to strong El Niño Southern Oscillation (ENSO) events. In addition to the fire risk posed by human activities during a drought, long-lasting fires in coal seams constitute a natural fire risk that intensifies the danger of fire in East Kalimantan. Notwithstanding the fact that these burning coal seams act as natural fire sources during dry spells, the number of forest fires actually ignited by the burning coal seams is considerably less than the number of fires due to human activities. The process of recovery in burned forests has been monitored in the Bukit Soeharto Education Forest (BSEF) of Mulawarman University since 1988. In lightly disturbed stands (LDS), a top canopy composed of dipterocarp trees remained. Heavily disturbed stands (HDS), however, were dominated by a few pioneer species, namely the *Macaranga* spp., which was established after the 1982-83 fires. The number of tree species in a unit area was higher in the LDS than in the HDS during the monitoring period. Tree density was lower in the LDS, and altered only slightly between 1988 and 1997, whereas the tree density of the HDS increased until 1990, but then decreased after 1991. The basal area of the HDS stand increased until 1991 and then became constant. By 1997, the basal area of the HDS was much less than that of the LDS. The fire of 1998 resulted in high tree mortality in both the LDS and the HDS. The percentage of trees killed by the fire was 43% in the LDS, and 91% in the HDS. The number of species in the LDS and the HDS was reduced by 77% and 57%, respectively. To conserve the remaining forests and to rehabilitate forests that have burned, it is imperative that the number of forest fires be reduced.

Key Words: Bukit Soeharto Education Forest, Coal seam burning, dipterocarp forest, El Niño Southern Oscillation (ENSO), Forest fire, Impolite grassland, Macaranga, Stand dynamics

Introduction

In East Kalimantan, the effects of fire disturbance on the lowland dipterocarp forest have been severe, despite the context of a tropical rainforest climate. The Bukit Soeharto Education Forest (BSEF) of Mulawarman University is located on low hills in the coastal area of Kutai Province, East Kalimantan, which has a tropical rain forest climate. This area is known to be drier than other parts of the island of Borneo (Whitmore 1984; Mackinnon *et al.* 1996; Walsh 1996). In East Kalimantan, an unusually prolonged and severe drought lasted from June 1982 until April 1983. It was linked to a strong El Niño Southern Oscillation

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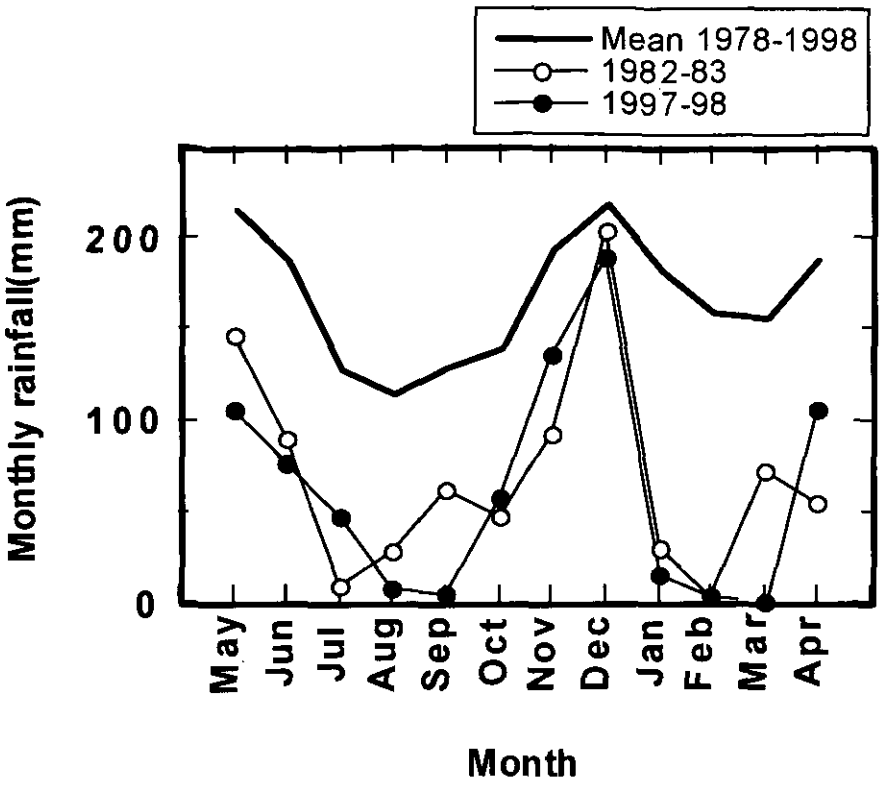

Fig. 1 Monthly rainfall at Samarinda, East Kalimantan, Indonesia. The thick line represents average monthly rainfall 1978 to 1998. The line with open and closed circles represents monthly rainfall in 1982-83 and 1997-98, respectively. After Toma (1998).

(ENSO) event (e.g. Goldammer *et al.*, 1996). There were two rainless periods, one from July to October 1982, and the other from January to April 1983. Another strong ENSO event occurred in 1997 and extended into 1998. Again, there were two rainless periods in East Kalimantan during this ENSO event (Fig. 1; Toma 1998; Toma *et al.*, 2000a). The first ran from July to October 1997, and the second from January to April 1998. During these rainless periods of 1982-83, and 1997-98, huge areas of rain forest in East Kalimantan were affected by drought and by drought-related fires (Mori, 2000).

The first part of this paper reports on the 1997-98 fires in the BSEF. It then addresses the important issue of how forest fires start, so that appropriate fire prevention measures may be implemented. In this regard, the sources of fires are investigated, including the natural coal seam fires that pose a fire risk peculiar to East Kalimantan. The subsequent section summarizes the stand dynamics of burned forests in the BSEF. A long-term monitoring study has been conducted in burned stands that previously experienced different intensities of disturbance (Toma *et al.*, 1997; 2000b). The recovery process for the burned forest following the 1982-83 fire, and the effect of the drought and fires of 1997-98, are described. Tree community data, knowledge of previous history, and information about the influence of disturbance on tree communities are all important sources of knowledge in the development of effective and appropriate forest management. The present study is part of the Tropical Rain Forest Research Project sponsored by the Indonesian Ministry of Education and Culture, and the Japan International Cooperation Agency.

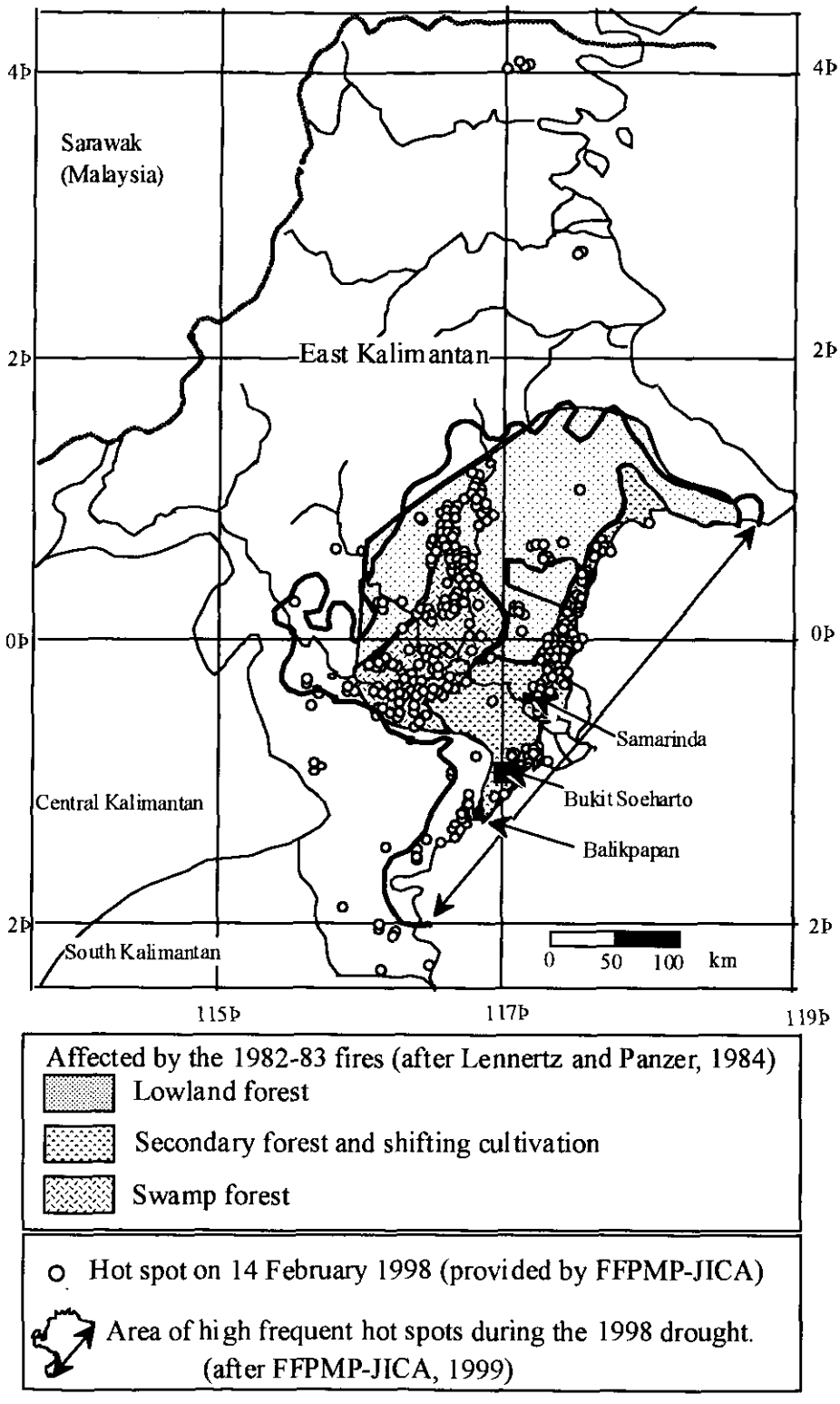

Fig. 2 Fire affected areas in East Kalimantan, Indonesia

The 1997-98 fires

The area of burned forest land in East Kalimantan, as reported to the Ministry of Forestry and Estate Crops, was 26,000 ha in 1997 and 520,000 ha in 1998. However, the distribution of hot spots reported by a NOAA satellite between February and April 1998 (Fig. 2) showed that the land area affected by the fires in 1998 in East Kalimantan was similar to that affected by the great forest fires of 1982-83, ca. 3.6 million ha (Lennertz and Panzer, 1984). The wildfires during the drought in 1997 did not invade the well-developed forests of East Kalimantan, but they were burned by the fires during the drought of 1998. The fires in the forested area of East Kalimantan started at the end of January 1998 (Toma, 1999).

The BSEF is surrounded by bushes, which are the result of slash-and-burn agricultural practices. The flames in a bush fire are large and vigorous, and the fire spreads rapidly. Once a bush fire starts, it is difficult to control. In mid-February 1998, the bush areas surrounding the BSEF started to burn; mostly as a result of human activities. At the end of February, a wild fire coming from the south of the BSEF reached the main forest road in the BSEF, and within a week it had spread into the main area of field research (Toma 1999; Mori, 2000).

Most fires in the BSEF were of the type that is known as "surface fire". In this type of fire, only the litter layers on the forest floor burn, and the fire progresses slowly along the ground. Usually, the progression of a surface fire can be stopped, simply by clearing the litter layers from a strip beyond the fire, as little as 1 m or less in width. However, the 1998 fires in the BSEF were difficult to control in this fashion because a lot of fires started simultaneously.

After the first fire, a large amount of fallen leaves and branches from dead and weakened trees accumulated on the forest floor. Large logs on the ground and exposed coal seams had been ignited by the surface fires and burned continuously. These fires spread to the accumulated organic matter on the forest floor, multiplying the number of fires in progress. The initial fires therefore acted as sources for further fires, and this occurred repeatedly until normal rainfall recommenced in late April 1998.

Sources of wildfire

There are many causes of wildfire in Indonesia, and most are related to human activities. Wildfires may start from fires used for land preparation at commercial plantations, and from slash-and-burn agricultural practices. They may also be the result of illegal logging practices or the result of simple carelessness. The slash-and-burn technique of land preparation for agriculture is the most common source of wildfire in Indonesia. Given normal levels of rainfall, such fires do not spread very widely from the targeted area of land preparation. In times of decreased rainfall, however, the fires can easily and rapidly spread to the surrounding area.

In addition to the fire risk posed by human activities, there is also a natural fire risk that is peculiar to East Kalimantan, posed by long-lasting fires in coal seams. Coal seams near the surface are found extensively in the low hills along the east coast of Kutai province, East Kalimantan (Goldammer *et al.*, 1996). Once an exposed coal seam is ignited, it is difficult to extinguish, and such fires can be a source of wildfire in periods of drought. The area affected by fire in 1998, however, was much more extensive than usually occurs in instances of coal seam fire distribution. Indeed, coal seam fires are often the result of large-scale forest fires, rather than the cause of them.

Before the 1998 fire, there were burning coal seams at 15 places, or thereabouts, in the BSEF. Most of them were thought to have been ignited by the fires of 1982-83. The 1998 fire increased the number of locations at which burning coal seams were found to more than 60 (Makihara, 1998), and they were then the cause of repeated fires.

The risk of forest fire lessened with the return of normal rainfall levels, even though most of the coal seam fires continued to burn. Since these fires pose a forest fire risk in any future period of drought, their suppression and control is very important for the conservation of the forest. This can be achieved by using great quantities of water, and most of the coal seam fires in the BSEF have, in fact, been extinguished (Makihara, 1998). It has proved impossible to extinguish some of the larger coal seam fires, but their progression has at least been halted (Makihara, 1998).

Stand dynamics of burned forests

The recovery process of burned dipterocarp forest has been monitored in the BSEF. In the course of this process, the mixed dipterocarp forest - the original vegetation of the BSEF - has changed to a mosaic of the remaining dipterocarp stands, and secondary stands that are dominated by a few pioneer species. Human activities and forest fires were the cause of this change. Before the BSEF was designated a protected forest in 1979, the forest had been logged sporadically by the local inhabitants, and selectively by timber companies (Matius and Okimori, 1991). The BSEF was also affected by the large forest fires of 1982-83, the effect of which differed from stand to stand, and was dependent on the intensity of past logging activities. The more logging activity there had been in the past, the heavier was the fire disturbance (Matius and Okimori, 1991). In a lightly disturbed site, the top canopy was composed of the remaining dipterocarp trees. A heavily disturbed site, however, was dominated by a few pioneer species, namely the *Macaranga* spp. The recovery process in the BSEF following the fire disturbance of 1983 has been monitored since 1988, both in lightly disturbed stands (LDS) and heavily disturbed stands (HDS) (Toma *et al.*, 1997; 2000b). All trees greater than, or equal to, 10 cm in diameter at breast height (dbh) have been enumerated annually. Both types of stand were burned again by the 1998 fires.

The HDS were characterized by a smaller number of tree species per unit area than the LDS. Even in the HDS, a number of species has survived. Most species are represented by a few individual examples, both in the LDS and the HDS. The proportion of species represented by one individual in the LDS and HDS in 1997 was 63% and 79%, respectively. The death of a tree in a species that is represented in a stand by only one individual results in the extinction of that species in the stand. The number of species in the LDS and the HDS decreased to 77% and 57% of the number that existed before the 1998 fires (Toma, 1999).

Between 1988 and 1997, the HDS changed markedly in comparison to the LDS in terms of basal area (BA) and tree density (Fig. 3). In 1988, five years after the fire of 1983, the tree density of the HDS was already higher than that of the LDS, and it continued to increase until 1990. After 1991, the tree density in the HDS started to decrease, but in 1997 it was still higher than that of the LDS. The BA of the HDS increased rapidly until 1991. After this point, the increase ceased. The BA of the HDS was much less than that of the LDS in 1997, 14 years after the fire of 1983.

The drought of 1997 and the fire of 1998 (Fig. 4) caused drastic changes in the stands being monitored (Toma, 1998; Toma *et al.*, 2000b). The depletion of tree density in the HDS between August 1997 and January 1998 was due to the death of the *Macaranga* trees, which was caused by the drought of 1997. The high tree mortality in both the LDS and the HDS between January and April 1998 was caused by the fire of February 1998. Drought

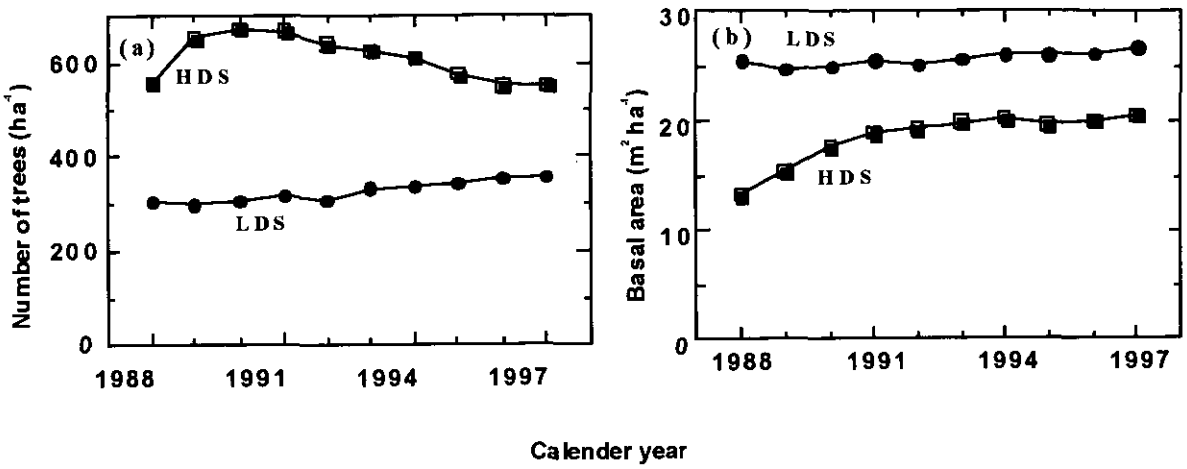

Fig. 3 Trends in a) tree density and b) basal area in the monitored stands. Modified from Toma *et al.* (1997). LDS, and HDS are the lightly, and heavily disturbed stands, respectively.

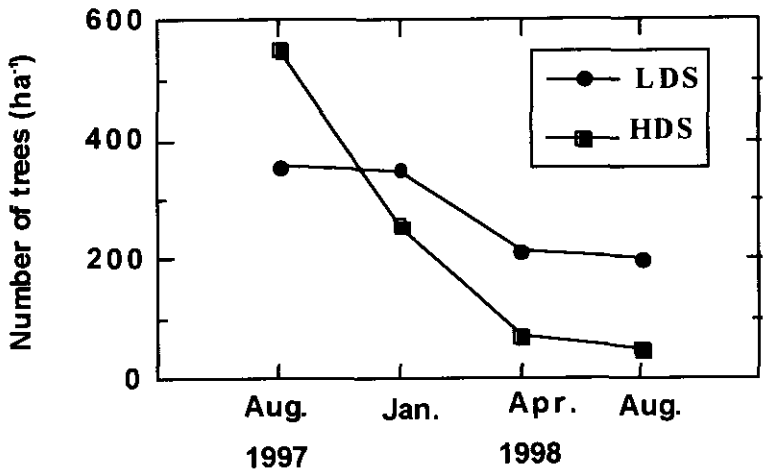

Fig. 4 Changes in tree density in the monitored stands by effects of the droughts and fires from 1997 to 1998. LDS, and HDS are the lightly and heavily disturbed stands, respectively both of the stands suffered forest (surface) fire at the end of February to early March 1998. *Modified from Toma (1998).*

and fire destroyed a number of trees in both the LDS and the HDS. The percentage of dead trees in relation to the total number of trees before the fire was 43% and 91% in the LDS and the HDS, respectively.

Conclusion

A period of fifteen years - from 1983 to 1998 - was too short for the burnt forests to recover fully, and thus all the forest burnt by the 1998 fires was already much more degraded

than the forest burnt by the 1983 fires. Forest degradation by fire happens very quickly, but the recovery of burnt forest takes a long time. It is imperative that the occurrence of forest fires be reduced as soon as possible.

In East Kalimantan, drought is frequently followed by fire. The prevention and management of further forest fires is vital in order that the process of forest rehabilitation can proceed. The 1998 fires burned both natural and plantation forests. Without effective fire prevention, the rehabilitation process will never be given enough time to reach completion. It is to be expected that severe droughts and wildfires will occur again in the near future, and that partially rehabilitated areas will be burned again. It is our conclusion that "Plant-and-burn forestry" is to be avoided.

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