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THE 1997 LAND-FIRE AND HAZE IN CENTRAL KALIMANTAN: ITS POSSIBLE IMPACT ON AQUATIC ECOSYSTEM IN THE REGION

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Abstract
In 1997, the greatest forest fire occurred in Indonesia. The fire was caused by a combination of traditional shifting cultivation practice, land use change and the prolonged dry season due to the El-Nino phenomenon. Central Kalimantan region was the worse region affected by the fire. In this region the fire occurred mostly in lowland area that mainly consist of peatland. There was evidence that the fire contributed to the occurrence of the acid rain in the region. The rain water pH dropped considerably from 5.88 in 1993 to only 4.61 in 1997. This acid rain could affect the acidification of aquatic ecosystem in the region. However, there have been also many scientists reported that the forest fire could, inversely, affected the alkalization as well as the eutrophication process to the aquatic ecosystem. The extremely high production of fly ash or total particulate matter from the last 1997 forest fire in Central Kalimantan and the location of the fire that spread our all over the southern part of the region, might also contribute to the alkalization and eutrophication of certain aquatic ecosystem. Since there has been no a specific research conducted, so the future co-operative research program on this issue is urgently needed.

Keywords: Forest fire, aquatic ecosystem, acidification, alkalization, eutrophication

Introduction
During the year of 1997, there was an extensive and large scale of land and forest fire all over Indonesian main islands. The fire started from early August 1997 and continuously, uncontrolled, spread out until the end of April 1998. Approximately 3,000,000 ha of land was on fire in Indonesia last year, where Kalimantan and Sumatera islands were the most affected islands. Among the region which was on fire, the Central Kalimantan province could be categorised as the worse area. This classification was based on the duration and the size of the area on fire. The impacts of forest fire has been analysed widely such as such impacts on human health, social and economic, as well as such impact on wildlife especially on terrestrial ecosystem. However, there has been less information on such impact on aquatic ecosystem especially on aquatic biota.

This paper attempts to discuss the possible impact of the land-fire and its haze production to aquatic ecosystem particularly in the Central Kalimantan region. The issue was chosen due to the specific ecological characteristic of the region and the intensity of the fire. Firstly, this paper will look at the general ecological characteristics of the Central Kalimantan province. Then, it will describe the relationship between such ecological factors and the occurrence of the fire. Thirdly, there will be a discussion on the possible impacts of the fire to the aquatic ecosystem in the region. At the end, this paper will attempt to suggest some possible future co-operative research project that

could be conducted in the region related with the impact of land fire and haze to the aquatic ecosystem in Central Kalimantan.

Ecological Characteristics of Central Kalimantan

The Borneo Island which is the second biggest island in the world occupied by three countries namely Indonesia, Malaysia and Brunei. Indonesia occupies the largest proportion, located in the southern part of the island. This Indonesian side is usually called the Kalimantan, which is divided into four provinces namely the West, South, East and Central Kalimantan. The province of Central Kalimantan which covers an area of 152,600 km^2 (Central Bureau of Statistics of the Republic of Indonesia, 1998) was the worse region on fire in 1997 (Fig.1).

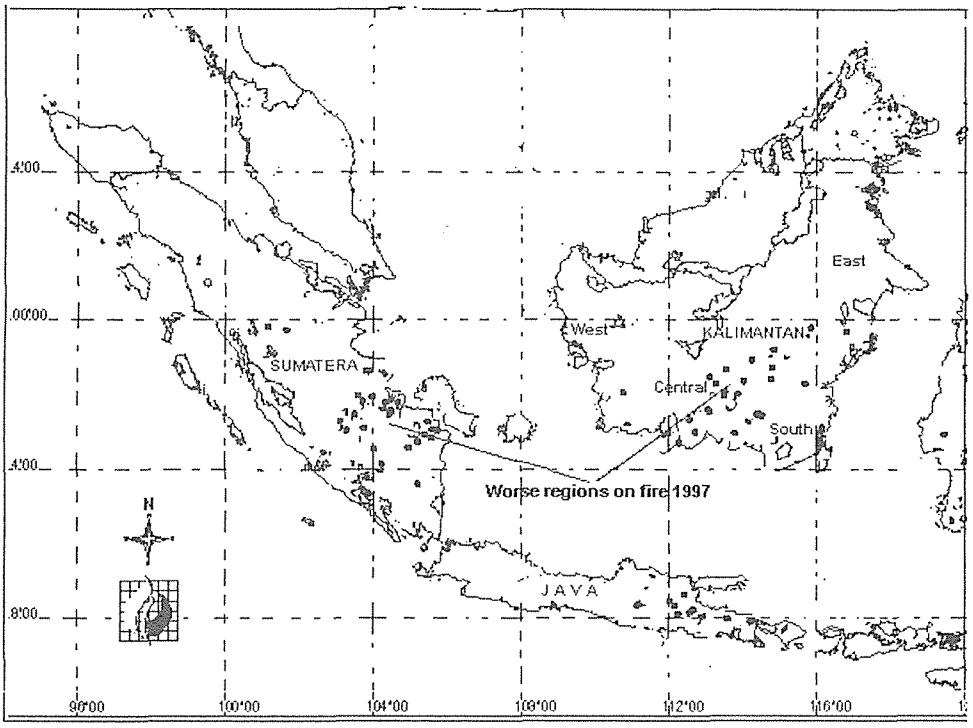

Fig. 1. Part of Indonesian map, showing two regions heavily affected by the land fire and haze in 1997 (modified from satellite image produced by the Environmental Impact Management Agency - Bapedal, Indonesia)

Ecologically, this province can be categorised into two major ecological conditions: dry upland tropical rain forest in the northern part, and large extensive tropical peatswamp forest in the southern part of the province. From hydrological point of view, this dry mountainous or upland tropical rain forest in the northern part has its function as a source of water storage for 11 main big rivers that flow toward southern part of lowland area of the province and, due to the topographical condition, support the formation, occurrence and stability of extensive wetland ecosystem including peat swamp forest in the region.

Relationship between Ecological factor and the Occurrence of the Fire

The relationship between ecological condition and the last 1997 land and forest fire in this region could be analysed from two different points of view. Firstly, the long term of deforestation practise either in upland or low land forest leads to the changing of hydrological balance especially changing of surface run-off in high altitude areas. This increase of surface run-off, will lead to the occurrence of an extreme water level fluctuation in rivers and inevitably will also affect the whole wetland area in the down stream of the river. During wet season the southern part area will undergo flooding condition and, conversely, during dry season the water table in this wetland area will be extremely very low. A research conducted by Takahashi (1997) indicated that during normal climate condition the different between water table during wet and dry season in peatland area could be up to 1 meter as the case during the period of 1993 to 1995.

During 1997, an extreme climate condition occurred in Indonesia. Due to the El-Nino phenomenon, most of Indonesian islands exhibited a drier condition since the dry season began earlier than during normal climate condition. From May 1997, there was no rainfall at all in certain Indonesian region including Central Kalimantan. In the prolonged absent of rainfall, and the lack of water discharge from upstream area, as a consequence, the wetland area in down stream would undergone an extreme dry condition and causing the drop of surface and ground water table up to more than 3 m. As the wetland area of Central Kalimantan consists of peatland, so this type of biomass was extremely vulnerable to fire.

The second argument is the land use change in the region. Among the four provinces in Kalimantan, Central Kalimantan could be categorised as the least developed province. Due the fact that most of lowland area consists of peatland which is un-fertile and inaccessibility, the population density in this province has been remain very low. This 152,600 km^2 area, according to the data in 1997, is only occupied by approximately 1.3 million people with the population density of 9 people per km^2 (Central Bureau of Statistics of the Republic of Indonesia, 1998). Public settlement spread out mainly along the river and coastal area, and only small proportion in the upland area. Originally, most of local people in this province, especially who settled along the river and upland area, are traditional farmers who apply the shifting cultivation system in their agricultural practice. During land clearing stage which is at the end of the dry season, local people usually burn the falling tress and shrub in order to clear their cultivation land and use the ash as a traditional fertiliser to improve soil fertility.

Since last three years, there has been a government policy to, regionally, develop the Kalimantan region. One of the top priority was to costruct a Kalimantan highway in order to link the four provinces in this area. In other three provinces, this highway has been constructed since several years ago, whereas in Central Kalimantan, which is the longest distance, just started in 1997. This long highway was constructed on the lowland area that mostly consist of peatland. In order to utilise the land along the highway, at the same time, the local government also invited many investors to open the land for various types of big scale plantations such as oil palm and rubber. These big companies also applied burning method during their land clearing. Moreover, there was also a giant controversial project to convert one million hectare of peatland to become a rice paddy plantation in this province. This project also practised the same method which is clear cut followed by burning during their land clearing stage. The combination of the above

factors was the most reasonable reason for the occurrence of the largest forest fire in Indonesia especially in Central Kalimantan province in last 1997.

Impacts on Aquatic Ecosystem

The impact of forest fire and haze to the aquatic ecosystem has been studied less than such impact on terrestrial ecosystem, especially in the tropical region. This due to the fact that in temperate region, the current issue on air pollution has been focused more on the emission of various air pollutants such as CO_2, SO_2 and NO_x that are produced mainly from power plants, industries and transportation activities. So, the term of air pollution in the temperate region has been associated with more developed society, whereas in tropical region, conversely, such pollution is more closely associated with activities in less developed countries such as forest fire and shifting cultivation by traditional farmers. Nevertheless, there is a similarity between air pollutant emitted in temperate region and such pollutant which is produced by the forest fire, since the combustion materials consist mainly of plant biomass origin. Therefore, impacts of fossil fuel combustion either from power plant or transportation activities in temperate region to the aquatic ecosystem could also be used as a background information for discussing the possible impact of forest fire and haze to the aquatic ecosystem in tropical region.

There might be two main possible impacts of forest fire and haze to the aquatic ecosystem. The first impact is acidification of aquatic ecosystem due to the acid deposition. The term of acid deposition in tropical region is more appropriately explained as the acid rain which refers to any rainfall that has an acidity level or pH value less than 5.6 (The Indonesian Meteorology and Geophysics Agency, 1997). The main cause of acid rain is the production of sulphur dioxide, nitric oxide and nitric dioxide to the atmosphere either from natural sources such as volcanoes, sea spray, rooting vegetation and plankton; or the burning of fossil fuel such as coal and oil as well as biomass burning. Recently, there has been an increasingly globally concern on biomass burning since this phenomenon has a great contribution to the production of various combustion products such as carbon dioxide, carbon monoxide, methane, nonmethane hydrocarbon, nitric oxide, nitrous oxide and particulate matter to the atmosphere (Levine, 1996). The biomass burning due to forest fire from tropical rain forest has been though is the major cause of acid rain in the region.

Measurement of rainwater quality conducted by The Indonesian Meteorology and Geophysics Agency during 1996 and 1997 indicated that there was a clear relationship between the last 1997 forest fire with the occurrence of acid rain in Indonesia. In 1996 the average pH value of rainfall in Indonesia was 5.46, whereas in 1997 such value dropped very significantly to 4.97. Such value measured in Palangka Raya, the capital city of Central Kalimantan, was only 4.61 which was one of the lowest average value among 26 other provinces in Indonesia (The Indonesian Meteorology and Geophysics Agency, 1997). This 1997 value was considerably lower compared with the pH value of rain water measured in this region in 1993 which was 5.88 (Page 1998). Since Central Kalimantan is a less developed province and there have been no great changes in the intensity of transportation and industrial activities, so the occurrence of acid rain in Central Kalimantan in 1997 could be argued as the consequence of the worse forest fire in the region during that period.

There have been many studies in temperate region concerning the relationship between acid rain and the acidification of aquatic ecosystem. A paleolimnological research conducted by Dixit *et al.* (1993) proved that acid deposition due to metal mining and smelting activity in the Sudbury basin (Canada) between 1960 and 1970 had lead to the pH decline of Whitepine Lake from 6.2 to 5.8. Another paleoecological study by Korsman (1998) proved that forest fire also caused lake acidification in a Northern Swedish by the changing of pH value from 6.9 to 5.6 during 3000 years. This study proved, however, the organic acid deposition due to the changing of vegetation in lake catchment area after the forest fire, was more important factor than acid rain for the acidification of lakes in this region. Several factors that affect the acidification magnitude among different types of aquatic ecosystem in different region could be categorized as: the intensity of forest fire, the type of burning material and also the level of alkalinity or buffer capacity of the aquatic ecosystem. Natural waters with high total alkalinity are usually effective in resisting pH changes (Cole, 1983).

The impact of natural water acidification to the aquatic organisms has been studied widely. A study conducted by Bendell, *et al.* (1995) has been focused on the impact of lake acidity and the abundance of littoral insects. Their study indicated that some insect species would give different response to the lake acidity. The changing of lake acidity would lead to the changing of the number of species, species richness and the species dominant in an aquatic ecosystem. Research conducted by Dixit *et al.* in 1993 also indicated that there was a clear relationship between the decline of lake trout of Whitepine Lake, Canada and the lake acidification. They pound that following lake acidity, the fish mortality was also caused by the leaching of toxic metals especially Al from catchment area caused by acid rain. The introduction of Al to fish tissue will reduce the amount of sodium in the bloodstream of fish and finally causing fish death.

With contrary to the above acidification process, forest fire could also lead to the alkalization of aquatic ecosystem. There have been many studies supporting this hypothesis. Korhola *et al.* (1996) reported that the catchment fire on lake Pieni Majaslampi, Finland caused the pH rise in such naturally acid hill-top lake. The increased of this pH value was mainly caused by the increased clastic mineral and solutional input to the lake. Similar phenomenon also reported by Renberg *et al.* (1993) who conducted a research on several acid sensitive Swedish lakes. Their research indicated that the alkalization process occurred in most of these acid sensitive lake due to forest fire. They argued that burning destroys acid raw humus, and releases base cations and nutrient bound in biomass and organic soil layers, leading to increased base saturation of soils and increased soil pH. Through leaching of the ash, bases and nutrient are also lost from the soil system to the surface waters, where pH and alkalinity may increase.

The alkalization could also closely associated with the eutrophication process of an aquatic ecosystem. As mentioned above, pH increase was caused mainly by the release of nutrient to the water surface which is mostly originated from ash and soil erosion in the catchment area. The 1997 forest fire in Central Kalimantan occurred mainly on southern part of the province that consist mainly of peatland area. Since the type of tropical peatland in Central Kalimantan is woody peat, so the burning of this biomass will produce a considerable amount of particulate matter to the atmosphere. The permitted level for total particulate matter is 260 $\mu g/m^3$ air for 24 hours. Data collected by The Indonesian Meteorology and Geophysics Agency in 1997 indicated that

the production of total particulate matter in Palangka Raya was extremely higher than the above permitted level, as can be seen from following table:

Table 1. Data of Suspended Particulate Matter during 1997 measured in Palangka Raya. Source: The Indonesian Meteorology and Geophysics Agency, 1997.

No.	Date (1997)	Concentration ($\mu g/m^3$)
1.	July	91.75
2.	August	363.72
3.	September, 16	1,881.93
4.	September, 22	4,819.07
5.	September, 27	3,237.10
6.	October, 1	4,217.87
7.	October, 3	1,472.30
8.	October, 25	1,843.22

The above data shows that during period of August until the end of October 1997, there was a considerable amount of particulate matter released to the atmosphere in Central Kalimantan. Since during forest fire the rainfall was totally absent, so it was very likely that this particle will fall to the earth surface as a dry deposition. When it falls in the dry form, this dry ash could be argued as a similar form to the ash that has been used by local people as a traditional fertiliser. So, it might contain several nutrient elements which some of them could be categorised as essential nutrients for plant growth such as nitrogen and phosphorous. When this ash fall on to the water surface, it will introduce the nutrient to the aquatic ecosystem and theoretically will contribute to the eutrophication process of the ecosystem.

After the forest fire, similar process of nutrient enrichment could also occur from the erosion of the catchment area that was on fire. Korhola *et al.* (1996) also reported this phenomenon. They found that a slight eutrophication process occurred in a naturally acid hill-top lake of southern Finland that was eroded from its catchment area. Since most of lakes in Central Kalimantan are the oxbow types lakes, so the catchment area of these lakes mainly consists of alluvial soil that was deposited from the river during the lake formation. Therefore, the burning of this catchment area will lead to the release of nutrient from this relatively fertile soil and will also accelerate the eutrophication process in the lake.

The impact of alkalization and eutrophication of natural waters has been widely recognised. Renberg *et al.* (1993) identified that the pH increase in Swedish lake was closely associated with the changes of dominance diatom flora. Before the alkalization, most studied lakes were dominated by acidophilous and benthic species such as *Frustulia rhomboides* agg., *Branchysira* spp, and *Aulacoseira* spp; whereas after the alkalization the lakes were dominated by more alkaliphilous flora rich in plankton such as *Cyclotella* spp, *Asterionella formosa* and *Aulacoseira ambigua*. Similar impact of lake alkalization was also reported by Korhola *et al.* (1996). From their research in several lakes of Finland, it was noted that the increase in diatom production was clearly

correlated with the eutrophication of the lakes due to forest fire. Although the data of diatom production was not clearly presented, this research informed that the accumulation of essential elements of Mangan and Phosphorus were the most important elements causing the eutrophication.

In addition, there might be also other possible indirectly impacts of forest fire to natural waters such as changing of water balance, loading of toxic substances and sedimentation rate as well as the creation of new aquatic habitat. However, due to the unavailable data, such impacts will not be discussed in this paper.

Possible Future Co-operative Research project

Having discussed the possible impacts of forest fire and haze to the aquatic ecosystem in Central Kalimantan, this paper will attempt to address a general conclusion and possible future collaborative research programs related with limnology of Kalimantan. From ecological point of view, the last 1997 forest fire in Central Kalimantan could have a significant impact on aquatic ecosystem in the region. The types and magnitude of the impact will chiefly depend on the types of biomass origin, fire location and its relative distance to a particular aquatic ecosystem, and also the characteristic of each natural water body before affected by the fire.

There has been no a specific research conducted on this issue. A long-term study is needed in order to investigate the impact. In the field, the research could be focused on a comparative limnological study for understanding different feature of each type of aquatic ecosystem and define how it might response to the next possible forest fire in the region. In the laboratory, a laboratory microcosm method could be applied in order to experimentally investigate the role of forest fire in controlling the growth, mortality, and production of a specific or various types of aquatic organisms. This laboratory experiment could be simulated in an ecological modeling in order to understand what might be the real consequences of forest fire to the aquatic ecosystem dynamic.

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