EFFECTS OF A FIRE OF TROPICAL RAIN FOREST ON SOIL EROSION

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I INTRODUCTION

Forest fire alters hydrologic and geomorphic factors related to soil erosion through burning of litter and organic matter as the upper portion of soil as well as vegetation(Swanson 1981). That is to say, the fire exposes forested land and soil to impact of raindrops and also the fire increases surface runoff of the land surface through alternation of soil properties and reduction of infiltration rate of soil. As a result of these, erosion rate of soil after the fire may increase compared with that before the fire.

These are common phenomena for all the forest fires in the world. The extent of the effect of the fire on the soil erosion, however, may differ from place to place, depending on scale and intensity of the fire, soil properties, hydrology, topography, geology, vegetation and so on.

The purpose of this study is to assess the effect of the fire on rainsplash and sheet erosion on a large scale forest fire in 1982 to 1983 in Kutai National Park, East Kalimantan, Indonesia. This fire was caused by a long spell of dry weather without rain for 11 months and the damaged area is estimated to be about 35,000km^2 (Wirawan 1985).

II METHODS

1. Overview of the research area

The research area is located in Kutai National Park, which lies between the equator and 0°35´ north latitude and between 117°00´and 117°30´east longitude, 50 to 100km north of the capital city Samarinda of East Kalimantan, Indonesia(Fig.1). Kutai area as national park of Indonesia was established in Octover,1982. A part of the park was logging area by PI KAYUMAS TIMBER untill then (Wirawan 1985). Therefore, the forestry road for logging is distributed in the park.

The geology of the research area is Tertiary formation, composed of sandstone, mudstone and their alteration of strata with

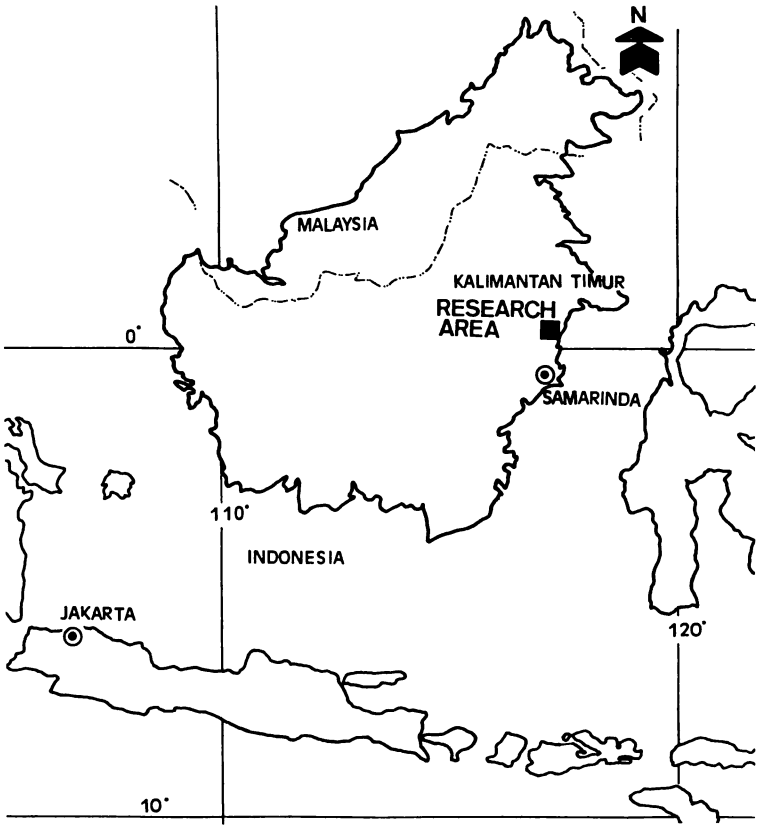

Fig.1. Location of the research area.

intercalation of thin lignite, coal and others. Although the park is located in the low land area, the peak of which is 397m, the topography abounds in ups and downs, and ridges are relatively sharp.

The forest vegetation in the park is well known tropical rain forest in the world dominated by dipterocarp species. The vegetation is different between the unburnt area and the burnt area. The trees over 60m high are grown in the unburnt area. On the other hand, the greater part of the high tree forest was burned down and/or was dead at standing state by the fire. Now, after 3 to 4 years since the fire, the vegetation is in the recovery process and the primary vegetation is grown up in the burnt area.

2. Field survey

a. Measurement of rainfall

Daily rainfall and sometimes hourly and 10-minute rainfall were measured at four camp sites of km 9, 24, 37 and 45 in the park during July 20 to September 8, 1986(Fig. 2). Two plastic cups of 10.2cm in inside diameter and of 12cm in depth were used for measuring rainfall. A piece of sponge was set in the bottom of the

cup to prevent splash of raindrops.

b. Measurement of infiltration rate of soil

This experiment was done in the erosion survey plot. A simple plastic equipment of 10.6cm in inside diameter was used for measuring the infiltration rate of soil. The method of measurement is as follows. First, the equipment was put into soil to 45mm deep. Then 400cc(45mm) water was gently poured into the equipment so as not to disturb the soil surface and the time untill infiltration of the poured water was measured.

c. Measurement of erosion depth

21 survey plots of 10.5m long and 10m wide for measuring the depth of erosion by rainsplash and sheet erosion were set for a comparison of the erosion rate between the burnt area and the unburnt area around three camp sites of km 24, 37 and 45 in the park (Fig. 2, Fig. 3). All the plots are located in the slope 10 to 20m apart from the ridge in order to equalize the hydrologic condition.

The plot was subdivided into 70 parts at intervals of 1.5 and 1.0m in the longditudinal and transverse direction, respectively. Lowering value of the ground surface against exposed tree roots as datable references were measured at each corner point of the subdivision plots(Fig. 4).

d. Observation of soil sections

30 soil pits of about 1m deep were made in and/or just out the erosion survey plots, in the burnt area and the unburnt area around the three camp sites of km 24, 37 and 45, and the soil section was observed at each pit.

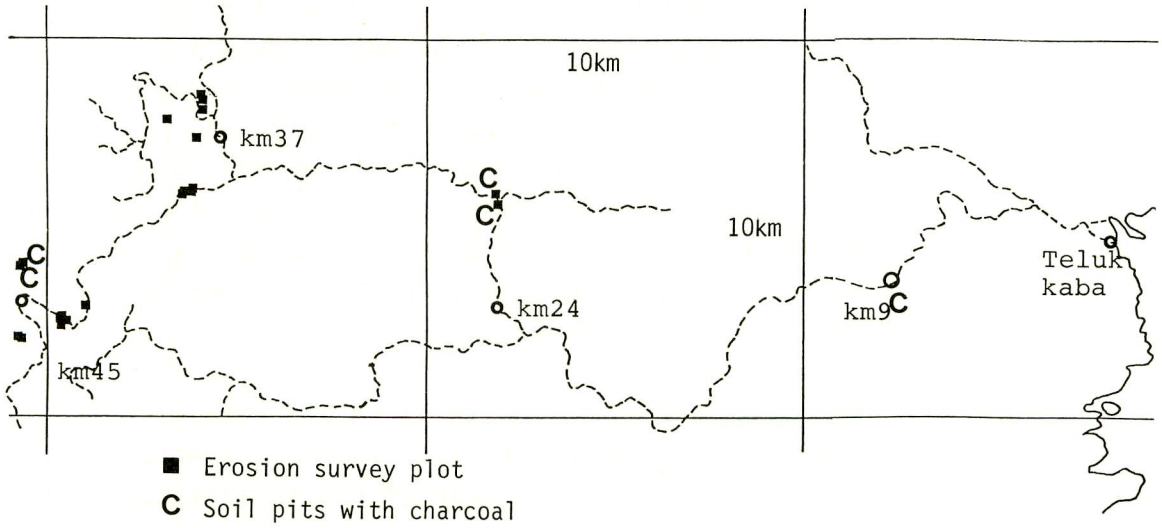

Fig. 2. Location of the erosion survey plots.

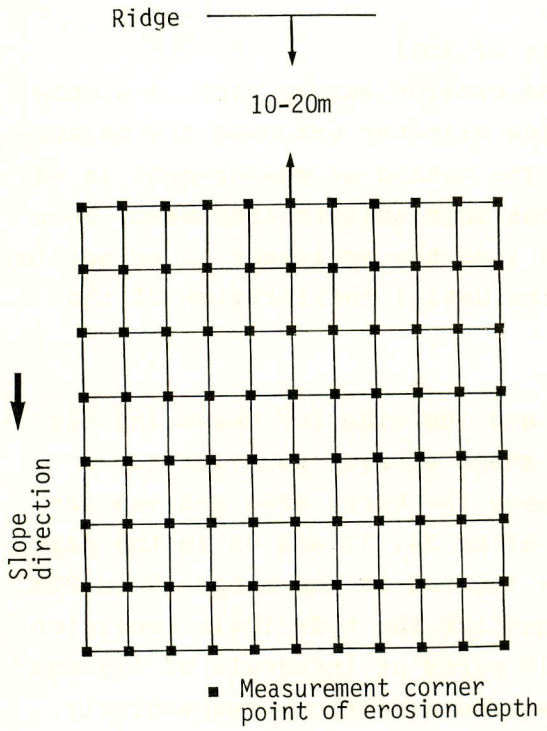

Fig. 3. Erosion survey plot.

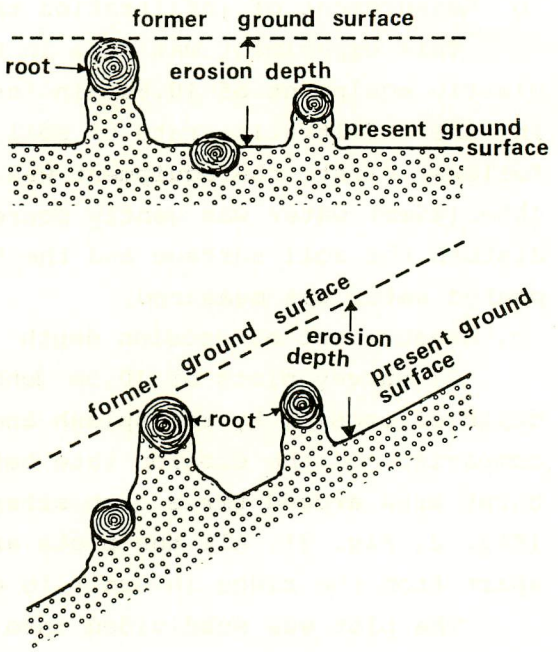

Fig. 4. Measurement method of depth of erosion by exposed tree roots.

III RESULTS AND DICUSSION

1. Rainfall

Rainfall is an important factor of soil erosion. The intensity of rainfall rather than the total is related for soil splash and sheet erosion. The rainfall recorded in the past around the park, however, is daily rainfall only(Table 1). The highest daily rainfall is definitely not large in comparison with that of Japan.

Table 2 is a summary of characteristics of the rainfall measured by a simple method during the research period of July 20 to September 8, 1986. An intence rainfall with maximum hourly rainfall of 69.5mm and 10-minute rainfall of 13mm, which is shower in the tropics, took place during the period.

2. Infiltration rate

Table 3 shows a comparison of the infiltration rate of the soil between the unburnt area and the burnt area. There is significant difference at 1 percent level between mean of the infiltration rate of the unburnt area and that of the burnt area. The infiltration rate is low even in the unburnt area because of the soil with thin

Table 1. Rainfall characteristics of Kutai National Park

(after Wirawan 1985)

monthly and annual means of rainfall (P in mm); highest rainfall value per day in each month (Pd in mm)

Station	P/Pd	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Sengata(1949-1980)	P	172	188	233	192	182	168	133	213	175	169	199	262	2337
11-17 raindays/month														
148 raindays/year	Pd	99	66	108	81	70	115	66	135	95	62	85	77	--
Bontang(1963-1980)	P	187	181	201	165	197	157	103	143	119	128	169	220	2108
6-8 raindays/month														
75raindays/year	Pd	146	105	161	146	142	199	103	139	87	150	149	127	--
Santan(1973-1980)	P	175	201	209	207	165	198	135	112	171	187	210	260	2285
13-19 raindays/month														
187 raindays/year	Pd	123	95	101	109	82	140	80	48	86	77	164	114	--
Muara Wahau(1929-1980)	P	176	147	189	247	263	214	155	155	158	174	252	252	2353
6-11 raindays/month	Pd	149	112	117	160	120	170	132	193	110	120	172	126	--
101 raindays/year														
Batu Ampar(1971-1980)	P	231	211	280	252	246	224	100	203	175	280	265	287	2740
9-16 raindays/month														
152 raindays/year	Pd	65	118	145	117	86	95	75	85	44	134	95	105	--
Muara Ancalong(1927-1980)	P	199	196	252	248	203	161	121	103	128	150	228	275	2325
5-10 raindays/month	Pd	154	164	174	149	149	175	145	174	228	140	139	178	--
95 raindays/year														

Table 2. Rainfall characteristics during the period of the research from July 20 to September 8

	Rainfall (mm)	Remarks
Period total rainfall		
July 20 31	108.5	
Aug. 1 31	86.1	
Sept. 1 8	16.5	
July 20 Sept. 8	211.1	
Maximum daily rainfall	69.5	Km 37, July 25,1986
Maximum hourly rainfall	69.5	Km 37, July 25,1986
Maximum 10 min. rainfall	13.0	Km 37, Aug. 7

Table 3. A comparison of infiltration rate

Forest	Sample No.	Infiltration rate(mm/hr) Range	Mean
Unburnt natural forest	43	0.7 -- 135	34.8
Burnt forest and secondry forest	23	1.1 -- 60	18.5

A_o and A horizon or lack of their horizons. On the other hand, the infiltration rate of the burnt area is considerably lower than that of the unburnt area. This may be caused by burning of litter and organic matter, reduction of soil aggregate, sediment movement by soil erosion and so forth.

3. Soil erosion

a. Types of erosion in the research area

Types of erosion observed in the research area are rainsplash, sheet, rill wash and gully erosion, landslide and so on. Rainsplash erosion is spattering of soil particles resulting from impact of raindrops. Sheet erosion is pick up and washout of soil by passing of sheetflood over a smooth slope. Rill wash erosion is removal of soil by flowing water from a small channel. Gully erosion is an advanced stage of rill wash erosion and removal of soil and other

materials from larger channels than rill. The above four types were conspicuously observed on the road surface, cut and bank slope of road and new landslide scars.

Landslide is small scale slide of shallow topsoil. This type was observed on channel bank scoured by gully erosion and on steep hillslopes in the burnt area and even in the unburnt area.

b. Erosion rate

Fig. 5 shows a comparison of the erosion rate caused by rainsplash and sheet erosion between the unburnt area and the burnt area. The erosion rate was obtained by dividing mean of depths of erosion which were measured at each corner point of the erosion survey plots by the period. The period is 4 years since the fire (1982-1983) for the burnt area, 10 years since the beginning year 1973-1974 of logging by PI KAYUMAS TIMBER for the logging area and 100 years which is a lifespan of tree as an individual for the unburnt tropical rain forest. The period of 100 years is lough value.

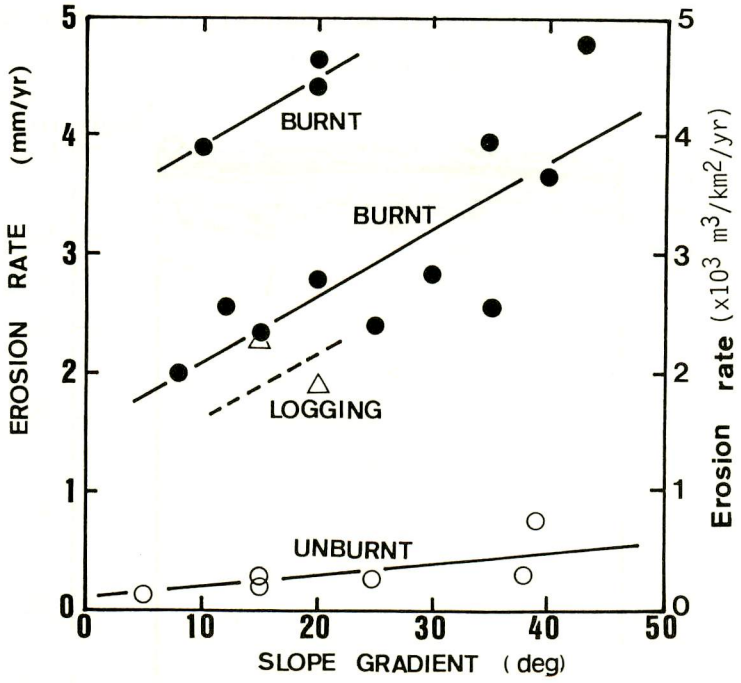

Fig. 5. A comparison of erosion rate caused by rainsplash and sheet erosion between the unburnt area and the burnt area.

The erosion rate linearly increases versus the slope gradient for both the unburnt area and the burnt area. In this figure, 3 data of the upper part were obtained at the erosion survey plots along

the forestry road in which the ground surface is disturbed by logging. The erosion rate of the burnt area and also the logging area is about ten times larger than that of the unburnt area except for three data. In other words, the erosion rate is 0.13 to 0.35mm/yr for the unburnt area and 2.30 to 4.65mm/yr for the burnt area and the logging area. The forest fire and also the logging accelerate the erosion rate of soil.

4. Field observation of soil

a. Characteristics of soil

Fig. 6 shows a typical and representative soil columnar section in the research area. According to the field observation, the soil sections are characterized by the followings. First, both A_0 and A horizon are thin at most of the soil pits and some soil sections are lack their horizons even in the unburnt area as well as in the burnt area. This may be due to speedy decomposition of litter, erosion and sediment movement of A_0 and A horizon by rainsplash and sheet erosion and so on. Next, C horizon shows colour tone of red and reddish brown by weathering in the tropics. Furthermore, tree roots of the tropical rain forest are densely distributed in A_0 and A horizon and are poor in B horizon.

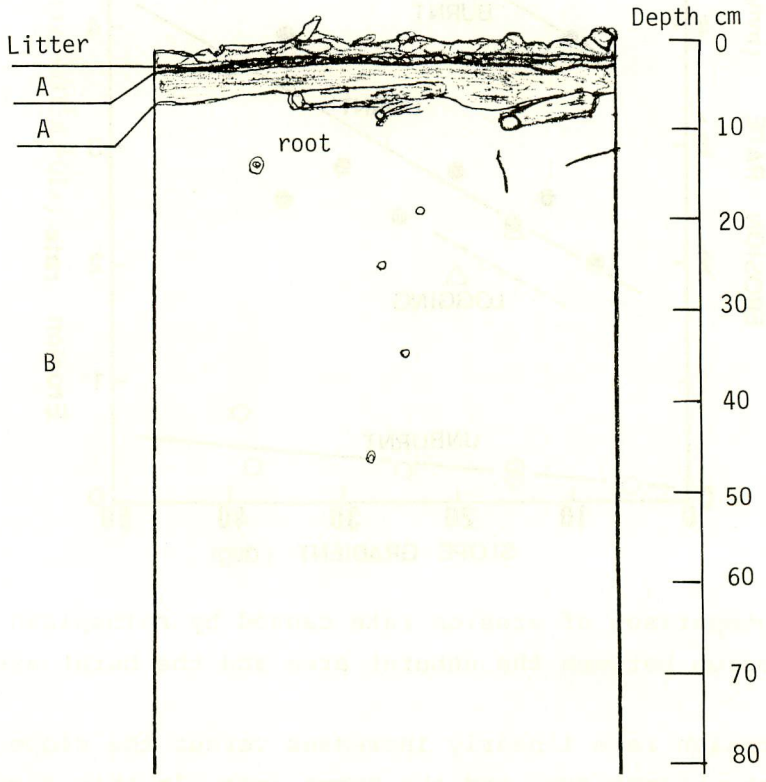

Fig. 6 Typical soil section in the research area.

b. Charcoal layer in soil sections

Old charcoal layer was found out at the upper part of soil section of some soil pits made around km 45, 24 and 9. This suggests existence of old forest fires and also occurrence of intence rainsplash and sheet erosion just after a fire.

Fig. 7 shows a typical example of representative soil section with charcoal at the soil pit made around the camp site km 45. AB-soil horizon which is sediment transported from the upper slope, is divided into two layers, lower part including much old charcoal and upper part without charcoal. The lower part may be sediment by intence rainsplash and sheet erosion on exposed land without vegetation cover during several years just after an old fire, and the upper part may be sediment on recovered forest land after a period since the old fire. The charcoal was observed in an area of 4m by 10m including the soil pit just near the erosion survey plot No.14(Fig. 2), in the unburnt area. And also, around km 45 the charcoal was observed at another place, about 100m apart from the erosion survey plot No.14. Based on the erosion rate of 0.31mm/yr in the unburnt forest area, the period of deposition of the upper sediment layer is about 200 years.

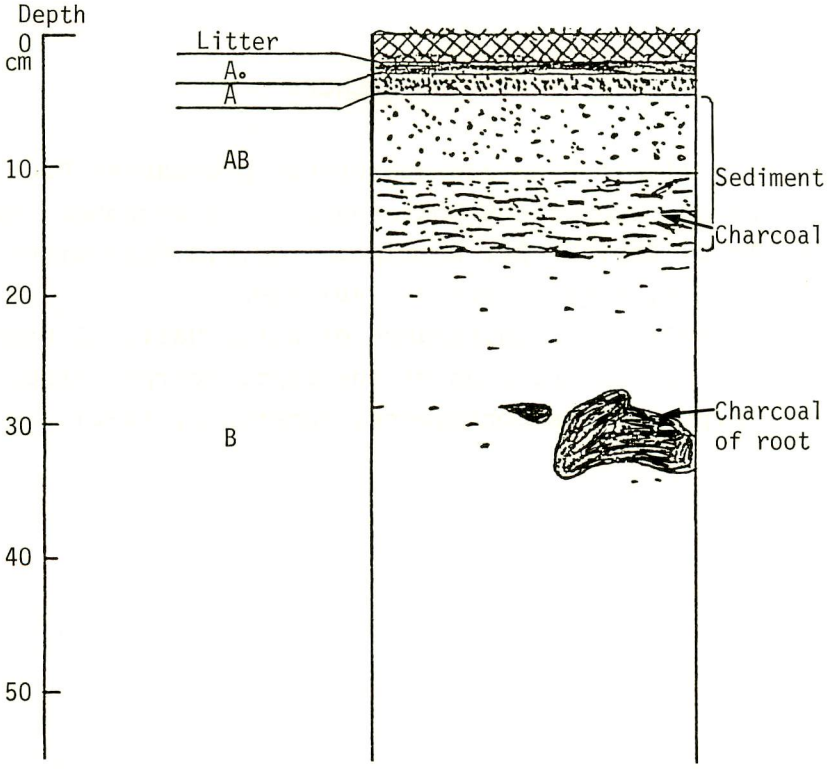

Fig. 7. A typical example of soil section with charcoal.

IV SUMMARY

The effect of the forest fire on the erosion by rainsplash and sheet erosion was mainly examined based on the field survey in Kutai National Park. Lowering values of the ground surface(depth of erosion) against exposed tree roots as datable references were measured at each corner point of the erosion survey plot and the erosion rate(mm/yr) was calculated. The erosion rate is different between the unburnt area and the burnt area. The erosion rate of the unburnt area is small, being 0.13 to 0.35 mm/yr. On the other hand, the erosion rate of the burnt area is 2.30 to 4.65 mm/yr. The forest fire accelerates the rate of erosion on the ground surface. This reason may be burning of the vegetation cover and the soil organic matter including litter, increasing susceptibility of soil to rainsplash and sheet erosion, occurrence of the overland flow due to low infiltration rate on the slopes and so forth. The old charcoal layer was found out in the soil composed of sediment from the upper slope around the camp sites of km 45, 24 and 9. This suggests existence of old forest fires in Kutai National Park and also occurrence of intence rainsplash and sheet erosion just after a fire.

V REFERENCES

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