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EFFECT OF LOGGING ON SEDIMENT YIELD IN A HILL DIPTEROCARP FOREST IN PENINSULAR MALAYSIA

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BAHARUDDIN KASRAN. 1988. **Effect of logging on sediment yield in a hill dipterocarp forest in Peninsular Malaysia.** Investigations on suspended sediment yield were made from three small forested catchments before and after logging in Bukit Berembun Forest Reserve, Negeri Sembilan, Malaysia, over a period of six years from 1980. Both catchments (BC1 and BC3) were logged using normal 'san-tai-wong' method, but BC3 with close supervision and additional prescriptions, such as a proper road construction and alignment and construction of cross drains on steep logging roads. BC2 remained as control catchment. After logging, the suspended sediment yield increased by 97 and 70% from BC1 and BC3 respectively, as compared to before logging. The highest weighted suspended sediment concentration also increased from 386.0 to 844.5 *mg/l* from BC1 and 158.3 to 318.2 *mg/i* from BC3. Hence supervised logging could reduce sediment in forest waterways considerably.

Key words: Small catchment – hill dipterocarp forest – logging – sediment yield.

Introduction

Forest logging in Peninsular Malaysia is now mainly confined to the hilly areas, especially the hill dipterocarp forests. Logging in these areas has created a number of environmental problems (Daniel & Kulaisingam 1974). Results from one study carried out in a logged-over forest in Peninsular Malaysia showed that stream discharge during the peak flow carried 8 – 17 times higher sediment load than it was before logging (Chong 1985). Another local study indicated that the suspended sediment concentration discharge from a logged-over catchment was 1,595 *mg/l* compared to only 114 *mg/l* in an unlogged catchment (Salleh *et al.* 1981).

There is however, still a serious lack of information on soil erosion from hilly areas of Peninsular Malaysia. It is in this context that the Forest Research Institute Malaysia initiated a forest catchment study at Bukit Berembun Forest Reserve, Negeri Sembilan. The purpose of this study is to quantify the hydrological consequences of logging activities in the hill forest. This paper highlights some of the results on the amount and pattern of suspended sediment transported before and after logging, based on data collected from January 1980 to December 1985.

Study site

The study was conducted at Bukit Berembun Forest Reserve in Kuala Pilah, Negeri Sembilan, Malaysia (2^{o} 46'N latitude and 102^{o} 06'E longitude, Figure 1). The study area consists of three samll catchments, which are named Berembun Catchments 1, 2 and 3 (BC1, BC2 & BC3). A description of the physical and climatic features of the catchments is given in Table 1.

Table 1. Physical and climatic features of Bukit Berembun catchments

Catchment No.		BC1	BC 2	BC3
Physical features				
Area *(ha)*		12.9	4.2	29.7
Elevation:	Highest	251.5	222.6	292.7
(m.a.s.l.)	Mean	192.8	179.5	217.0
	Lowest	167.7	167.7	168.1
Mean slope (%)		27	21	24
Soil (Major series)			Rengam/Berserah	
Drainage density *(km/km²)*		7.4	6.0	4.5
Morphology				
(i)	Form factor	0.36	0.30	0.34
(ii)	Circulatory	0.63	0.57	0.55
Climatic features				
Annual rainfall		2121 *mm*		
No. of rain days		163 days		
Air temperature:				
(i)	Mean maximum	32.2°C		
(ii)	Mean Minimum	21.0°C		
Relative humidity		84.2%		
Windrun		16.5 *km/day*		
Evaporation (US "A type")		3.5 *mm/day*		
Sunshine		4.8 *h/day*		

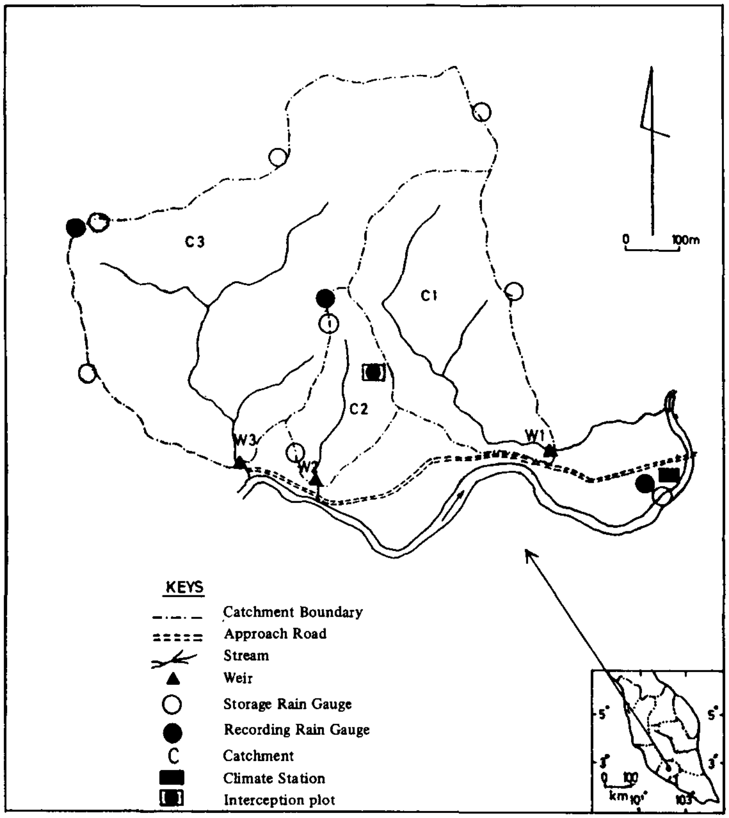

Figure 1. Forest catchment plot layout in Bukit Berembun Forest Reserve

The geology of the area is predominantly of undifferentiated granitic rocks of acidic nature, believed to be of the Upper Triassic formation. The soil texture ranges from coarse to fine sandy clay with Rengam and Berserah being the major soil series.

The forest can be classified as Red Meranti-Keruing type (Wyatt-Smith 1963). The vegetation is dominated by Keruing (*Dipterocarpus* spp.) and Meranti (*Shorea* spp.). Abdul Rahim *et al.* (1985) classified it as a Red Meranti-balau forest type by virtue of a large presentation of Balau kumus (*Shorea laevis*).

Materials and methods

A gauging station consisting of 120° V-notch weirs, water level recorders and sediment traps were constructed at each catchment. Water samples during peak flows and base flows were taken to estimate the amount of the suspended sediment yield.

Water samples were taken at the downstream of the weir using the grab sample method during high and low flows; the high flow is carried out on storm events whilst the latter sampling is on a weekly basis. It was not possible to use depth-integrating or point-integrating sampler due to the shallowness of the stream flow, particularly during base flows. Water samples were analysed in the laboratory for suspended a concentration following the procedure outlined by Drainage and Irrigation Department (DID 1977). The residue remaining on the filter paper was oven dried at 105°C for 24 *h*, cooled in a dessicator and weighed.

The total amount of suspended sediment load was calculated by multiplying the weighed suspended sediment by the instantaneous stream discharge during samplings. The suspended sediment load values in *kg* were then plotted against instantaneous discharge on log.-log. paper to give a sediment rating curve (DID 1977, Rieger *et al.* 1982). From the curve an equation was developed to predict the amount of suspended sediment yield from the catchment:

$$SY = aQ^b$$

where SY is suspended sediment load in *kg*. Q is stream discharge in *l/s, a is* constant and b is the slope of the curve on log. paper.

Eight storage rainfall stations were located randomly in the catchments to measure the areal rainfall in the study area; three of them were equipped with tipping-bucket recording gauges. Rainfall measurements were taken on a weekly basis for a period of six years from 1980 to 1985. Stream discharge was continuously measured at the weir using a water level recorder which was serviced weekly during the study period.

The two catchments BC1 and BC3, were logged using the traditional "san-tai-wong" method but with different logging specifications. "San-tai-wong" method is the system used for extracting logs that consists of winch lorries (a locally adapted lorry with a carrying capacity of 10,000 to 12,000 *kg*) and crawler-tractor or wheeled-skidder. BC1 was logged employing the "san-tai-wong" logging method but without supervision, while in BC3, the same method was employed but under close supervision and additional prescriptions, which included a proper road construction and alignment, and construction of cross drains on steep logging roads. Two cutting limits were prescribed for BC3, that is 60 and 90 *cm* diameter breast height (dbh) for non-dipterocarps and dipterocarps, respectively. For BC1 only 60 *cm* for all species was prescribed. BC2 was left as control. Logging was carried out in the experimental catchments from July to September 1983.

Results and discussion

The annual rainfall distribution for Berembun catchments during the study period from July 1980 to June 1985 is shown in Table 2. The three catchments received the highest rainfall in 1980/81. The lowest rainfall was recorded in 1982/83 water-year for all catchments.

Table 2. Annual rainfall *(mm)* at Bukit Berembun catchments

Catchments	BC1	BC2	BC3
1980/81	2465	2608	2611
1981/82	1822	1714	1822
1982/83	1442	1462	1453
1983/84	2410	2518	2403
1984/85	2019	2108	2060
Average	2032	2982	2070

The monthly rainfall distribution in Bukit Berembun catchment on a six-year period from 1980 to 1985 is shown in Figure 2.

Results show that weighted suspended sediment concentration discharge from the three Berembun catchments varied from 3.7 to 844.5 *mg/l* (Table 3). Most of the suspended sediment was flushed and transported during storm flows. During pre-logging calibration period, the highest weighted concentration suspended sediment discharges for BC1 and BC3 were 386.0 and 158.3 *mg/l*, respectively. After logging, the maximum weighted suspended sediment concentrations were higher, 844.5 and 318.2 *mg/l* from BC1 and BC3, respectively. The higher suspended sediment transported by surface wash after logging was probably mainly derived from the detachment of soil particles over bare land surfaces of the logging roads and skid tracks. Ruslan and Manan (cited by Hamilton & King 1983) reported that the erosion rate on newly constructed and used skid roads was 154.8 *t/ha/y* and no erosion occurred in undisturbed forest. Salleh *et al.* (1981) found that the large values of suspended sediment in logged over catchment could be attributed to the intensity of road usage.

Suspended sediment concentration values for the precalibration period from Berembun were relatively higher compared to that from Sungai Tekam Experimental Basin in Pahang, Peninsular Malaysia, which ranged from 21 to 82 *mg/l* (DID 1986). However, after deforestation the maximum suspended sediment concentration of Sungai Tekam Experimental Basin was 18,808 *mg/l*, which is about 23 times higher than the post-logging suspended sediment concentration of the present study. The large difference in concentration is probably largely due to the different methods of logging employed: clear-cutting in the former while selective logging was employed in the latter.

The equations to predict the suspended sediment load before and after logging for each catchment were developed. Table 4 shows the minimum and maximum values of the constants (a & b) used in this equation. Using daily stream discharge from each catchment, the total monthly suspended sediment yield could be determined. Figures 3, 4 and 5 show the total monthly suspended sediment yields from BC1, BC2 and BC3, respectively.

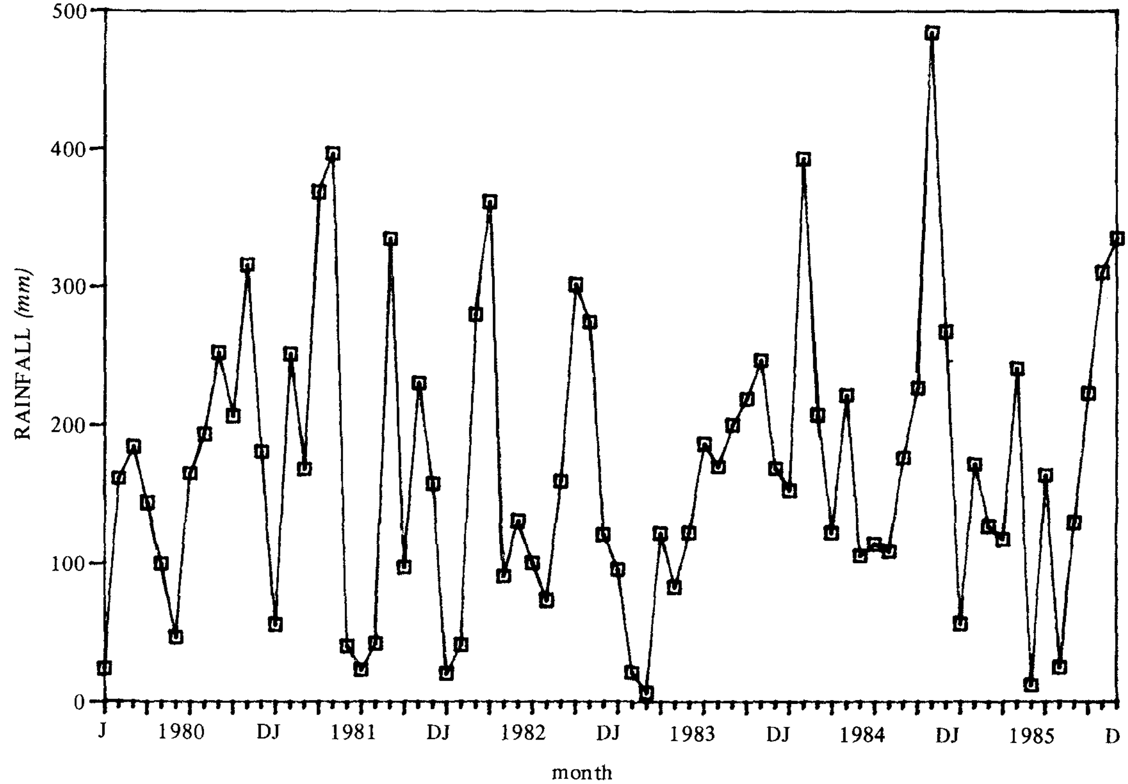

Figure 2. Monthly rainfall distribution at Bukit Berembun catchments from January 1980 to December 1985

Table 3. Suspended sediment concentration *(mg/l)* and annual suspended sediment yield *(kg/ha/yr)* from Berembun catchments

Catchment	Before logging					After logging			
	Suspended Sediment Concentration (Range)	Suspended Sediment Yield				Suspended Sediment Concentration (Range)	Suspended Sediment Yield		
		1980/81	1981/82	1982/83	Mean		1983/84	1984/85	Mean
BC1	4.0 – 386.0	170.0	140.4	99.5	136.6	2.7 – 844.5	315.1	223.1	269.1
BC2	4.0 – 217.0	301.5	207.8	90.6	200.0	4.2 – 187.7	216.3	164.1	190.2
BC3	3.7 – 158.3	97.5	61.6	46.8	68.6	4.7 – 318.2	137.1	96.8	117.0

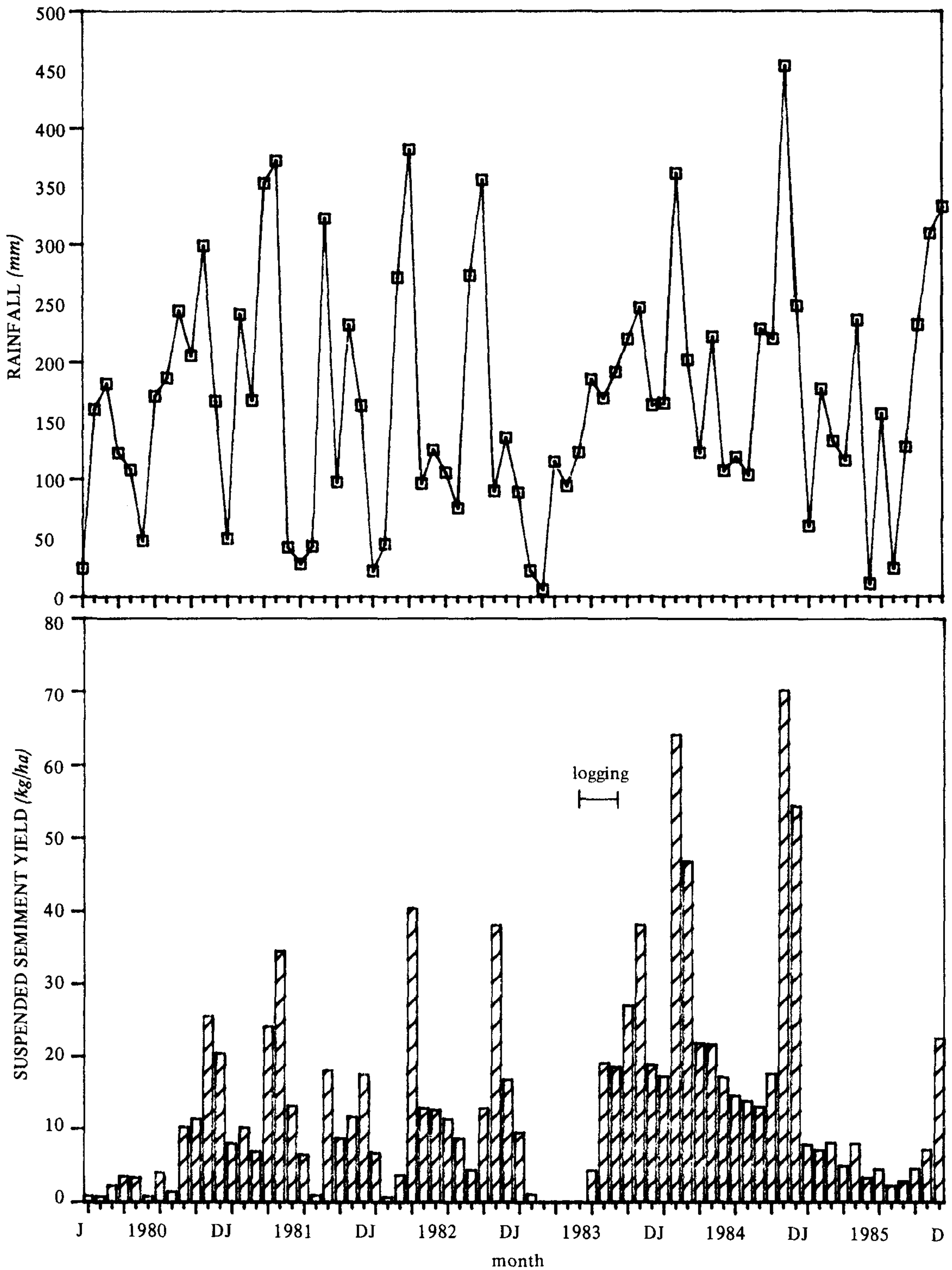

Figure 3. Monthly suspended sediment yield of Berembun catchment 1 (BC1)

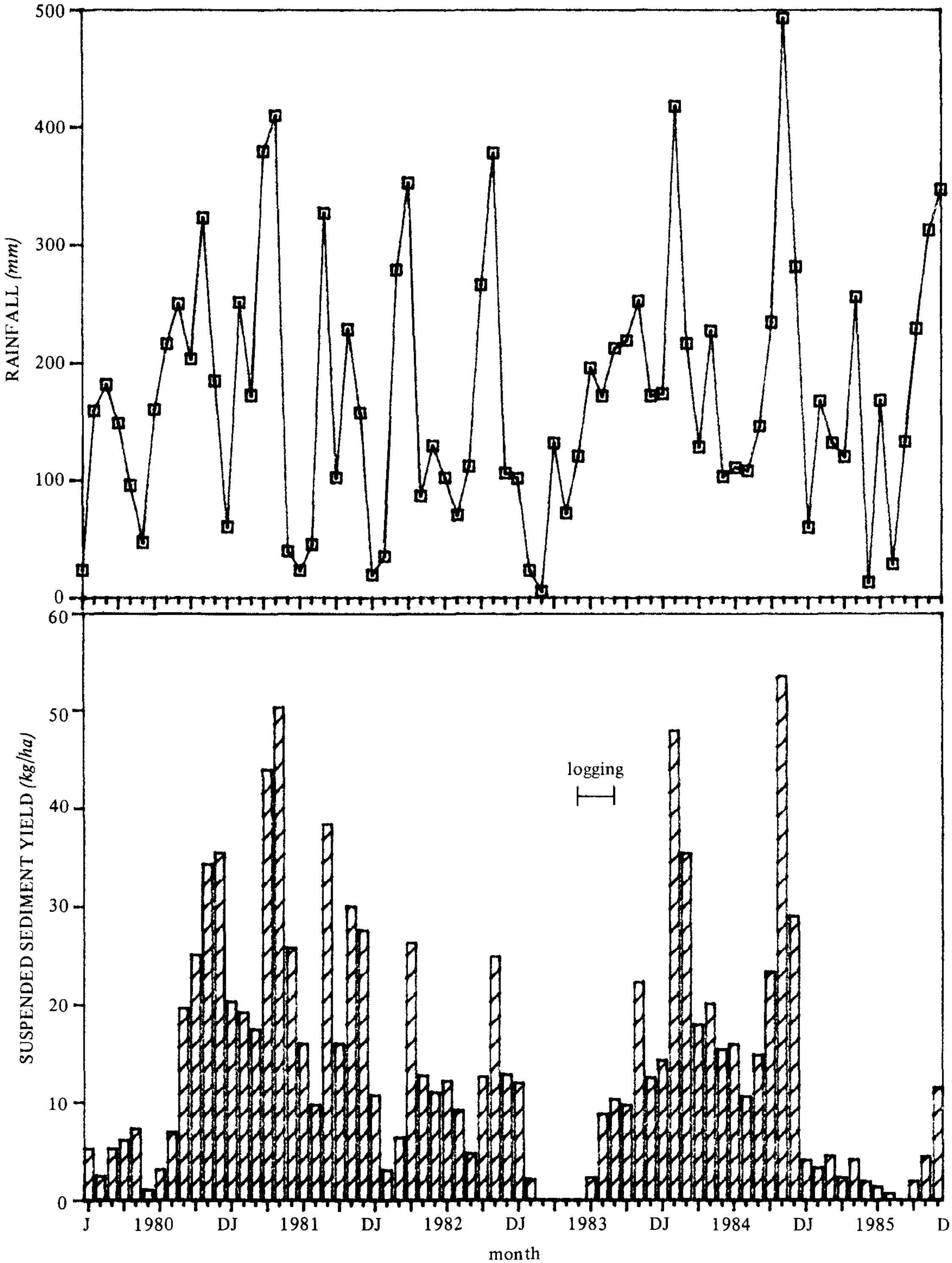

Figure 4. Monthly suspended sediment yield of Berembun catchment 2 (BC2)

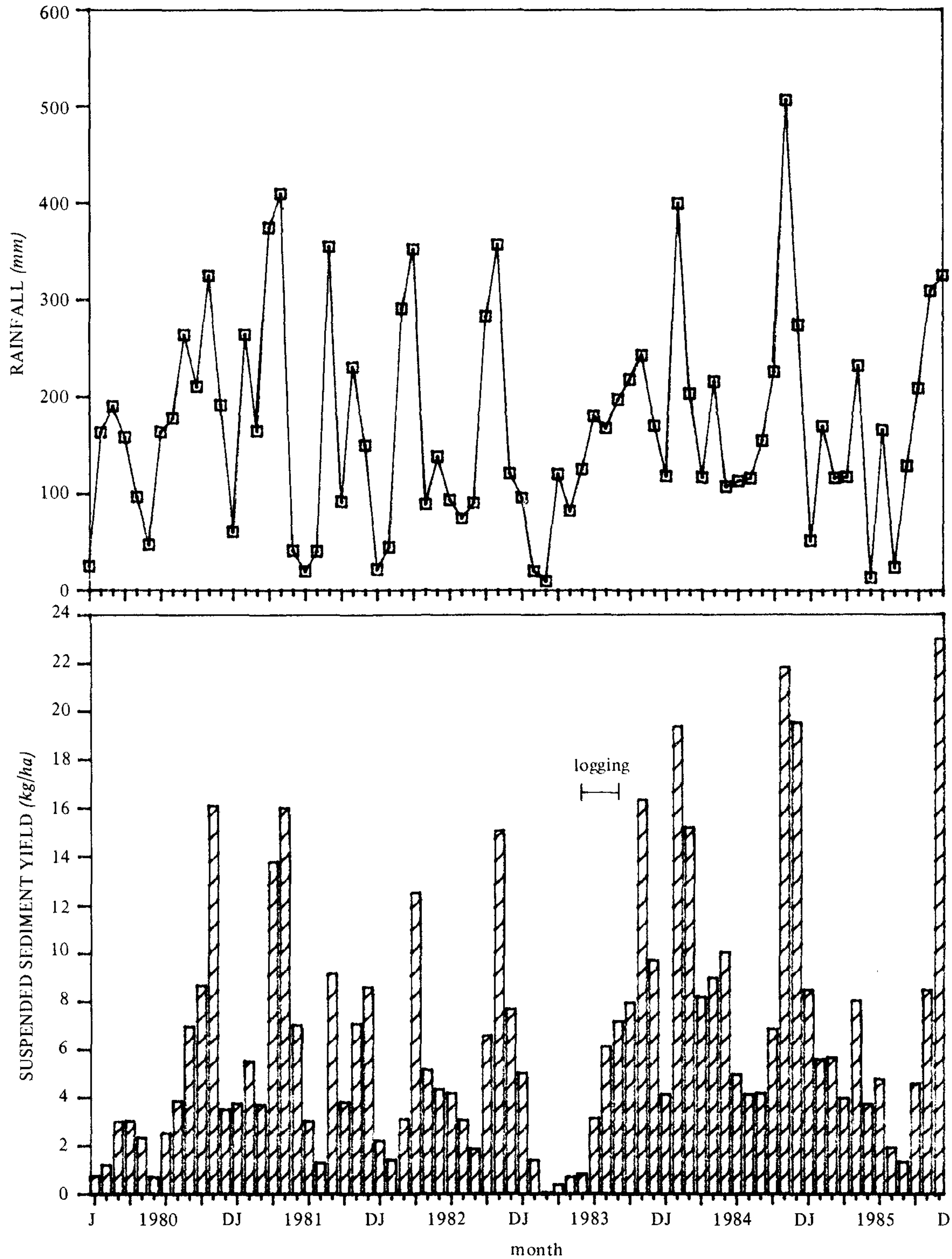

Figure 5. Monthly suspended sediment yield of Berembun catchment 3 (BC3)

Table 4. Minimum and maximum values of a, b, r-square and n for the rating curves for each catchments

Catchments	Logging condition	a		b		r-square		n	
		min.	max.	min.	max.	min.	max.	min.	max.
BC1	Before	0.701	1.092	1.775	1.874	0.96	0.98	9	63
	After	0.973	1.534	0.900	1.704	0.74	0.90	26	52
BC2	Control	0.681	1.296	0.878	1.751	0.67	0.96	26	68
BC3	Before	0.490	0.865	1.482	1.585	0.91	0.95	17	82
	After	0.625	1.510	0.817	1.428	0.59	0.83	26	54

The total suspended sediment yield from BC1 was significantly higher especially in the first year after the completion of logging (Figure 4). In this particular catchment the highest monthly suspended sediment yield before logging was only 41.1 *kg/ha* (April 1982), whereas after logging the highest yield was 71.3 *kg/ha* (November 1984). The second highest yield after logging was 65.1 *kg/ha* in February 1984, although the amount of rainfall for the month was less than that in April 1982. The maximum values from BC3 were 16.1 and 23.1 *kg/ha* before and after logging, respectively. The highest suspended sediment yield from BC2 (control catchment), during the same study period was 50.3 and 53.6 *kg/ha* before and after logging of the neighbouring catchments, respectively. No significant difference in suspended sediment yield before and after logging was observed from BC2. In both catchments BC1 and BC3 a significant increase was observed in suspended sediment yield after logging activities ($P < 0.01$, $t = -2.77$ & -2.68 for BC1 and BC3, respectively). Generally, the suspended sediment yield produced from all three catchments followed closely the rainfall pattern in the area.

The annual suspended sediment yield for three water-years before logging and two water-years after logging were calculated. The mean annual suspended sediment yield from BC1 before logging was 136.6 *kg/ha/y* and increased to 269.1 *kg/ha/y* after logging (Table 3), a 97% increase. In BC3 the increase was however, smaller, about 70% from 68.6 to 117 *kg/ha/y*. The mean suspended sediment yield from the control BC2 before and after logging was 200 and 190.2 *kg/ha/y*, respectively.

Apparently, the size of the catchment has an important effect on the total sediment yield. This is clearly shown by the three catchments under study. For BC3 (29.7 *ha*). before logging the mean suspended sediment yield was only 68.6 *kg/ha/y*, whereas for BC2 (4.2 ha) the suspended sediment yield was 200 *kg/ha/y*. The latter is about three times higher. This seems to suggest that smaller catchments could have a higher suspended sediment yield than bigger catchments. This could be because larger catchments have a more diversified topography and environments for redeposition of eroded materials (Toebes & Ouryvaev 1970). Records from 1,100 measurements in the United States, for example, show that basins less than 10 km^2 in area have unit sediment yield of about seven times higher than those from catchments of 1,000 km^2 (Toebes & Ouryvaev 1970).

Conclusion

The study shows that the mean annual suspended sediment yield increased significantly after logging. The increase ranged from about 70% in Berembun Catchment 3 (under close supervision and additional prescriptions) to about 97% in Berembun Catchment 1 (logging as in current practice). Reduction in sediment concentrations and thus sediment yield can be achieved through enforcement of the existing regulations in logging, especially with proper road construction and alignment, creation of buffer strips and construction of cross-drains.

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