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Suspended and Dissolved Sediment Concentrations of Two Disturbed Lowland Forested Watersheds in Air Hitam Forest Reserve, Selangor

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Key words: Disturbed forested watersheds; suspended sediment; dissolved sediment.

ABSTRAK

Kepekatan endapan ampaian dan larutan dari dua kawasan tadahan hutan sudah dibalak yang terletak di Hutan Simpan Air Hitam, Selangor dikaji selama enam bulan. Sampel-sampel air diambil semasa paras air sungai itu rendah dan tinggi. Keputusan-keputusan yang diperolehi menunjukkan bahawa perbezaan kepekatan endapan ampaian di antara kedua-dua tadahan adalah bererti. Kepekatan endapan ampaian berkisar di antara 2 – 1305 mg/l bagi tadahan A, kawasan yang lebih dibalak manakala bagi tadahan B, yang kurang dibalak kepekatan adalah di antara 1 – 292 mg/l. Kepekatan endapan larutan pula berkisar di antara 4 – 136 mg/l untuk tadahan A dan 3 – 90 mg/l bagi tadahan B, iaitu satu perbezaan yang tidak bererti secara statistik. Keputusan-keputusan yang diperolehi dalam kajian ini selanjutnya menunjukkan kesan pembalakan ke atas kepekatan endapan yang bervariasi dengan masa walaupun operasi pembalakan di sesebuah tadahan telah tamat satu tahun lebih awal dari tadahan yang lain.

ABSTRACT

Observations on suspended and dissolved sediment concentrations were made from two disturbed watersheds situated in Air Hitam Forest Reserve, Selangor over a period of six months. Samples were taken during low flows and high flows. Results obtained showed that the difference in suspended sediment concentrations from the watersheds is significant. Suspended sediment concentrations ranged from 2 – 1305 mg/l for watershed A, a relatively more disturbed watershed and 1 – 292 mg/l for watershed B, a less disturbed catchment. For dissolved sediment concentration, the range was 4 – 136 mg/l for watershed A and 3 – 90 mg/l for watershed B, of which the difference is not statistically significant. The findings in this study demonstrate rather clearly the effect of logging on sediment concentrations and variance over time in the two watersheds with logging operations ceasing about a year apart.

INTRODUCTION

The vital role of forest cover in maintaining good water quality has long been recognised. The usefulness of water supply for instance, depends in part on the quality of water, which is often dependent on the sediment concentration (Kunkle, 1974; Anderson, 1981). Man's use of forest land, for timber in particular, has often been the cause for concern not only over the quality of water but also on stream behaviour, water losses from catchment, floods and droughts. Logging operations have always been described as one of the major causes for altering the often near-complicated hydrological processes.

Although there is a growing uncomfortable awareness on the adverse hydrological impact resulting from increased exploitation of hill forests on the principal sources of water supply, extraction of logs in logged-over forests largely in lowland areas is still being carried out. The intensity is however relatively lower. Hydrological information resulting from the latter will remain useful especially so since these forests are still equally important source areas of water supply for domestic, agricultural and industrial use.

This paper reports a study on suspended and dissolved sediment concentrations carried out in two recently logged disturbed lowland forested watersheds. The main aim is to assess the impact of logging on sediment concentrations over time.

MATERIALS AND METHODS

Study Area

Two watersheds demarcated, WA and WB, are tributaries of Sg. Rasau, the main river draining Air Hitam Forest Reserve *(Fig. 1)*. The forest reserve comprises 22 compartments of which WA drains compartments 6, 7, part of 9 and a small portion of a mature oil palm plantation. Compartments 10, 11 and parts of 8, 9 and 16 are located in WB. WA is larger in area covering 7.3 km^2 compared to 4.7 km^2 of WB. Some physiographic characteristics of both watersheds are presented in Table 1.

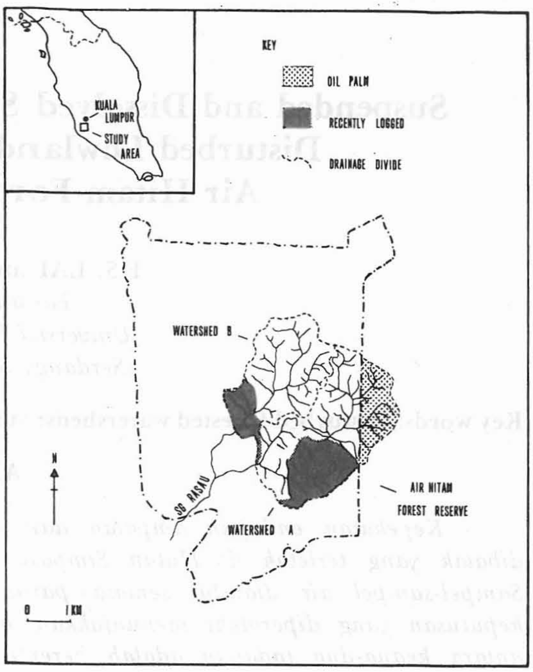

Fig. 1. Location of study area.

Soil and Vegetation

Soil type for both watersheds are similar, comprising the soil series of Serdang-Kedah-Durian association (Zainuddin, 1976). Serdang series occur along places downslope while that of Kedah and Durian are found on the ridges and upper slope region. The local Alluvium Colluvium association occurs in the valley and foothill region.

TABLE 1

Some physiographic variables of the watersheds

Physiographic properties	WA	WB
Area (km^2)	7.3	4.7
Length of main channel (km)	5.2	4.0
Drainage density (km/km^2)	4.11	3.51
Maximum height difference (m)	106	106
Mean slope of main channel	0.004	0.009
Form factor	0.87	0.73
Circulatory ratio	0.52	0.58

According to Ali Riza (1977), the Air Hitam Forest Reserve, previous to logging, was a lowland dipterocarp forest after which it was gradually replaced by secondary disturbed forest species. Three canopy levels could be identified; the emergent canopy level which is dominated by dipterocarpaceae family *(Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Shorea, Parashorea);* the middle canopy which represents the main canopy level is dominated by the former canopy species together with families of *Burseraceae, Gutiferae, Myristicaceae, Myrtaceae* and *Saportaceae;* and the lower-most understorey, which is dominated by species of the two upper storeys.

Forestry Activities

From past records, logging has been the main activity in WA and WB. Log extraction began as early as 1930 and thereafter continuous extraction has been undertaken on a commercial and subsistence basis up to 1983. On record, WA is relatively more disturbed compared to WB; logging operations (including salvage logging) only ceased in July 1983 in WA, a year after operations stopped in WB. About 35.3% and 13.5% of basin area of WA and WB were affected respectively.

Log extraction was carried out by a crawler tractor-Santai Wong system in which a A-16 Komatsu was used. Since the area had been previously logged, the construction of logging roads were minimal and previous logging roads were used in most instances.

Collection od Data

The sampling of stream water for suspended and dissolved sediment concentrations in the study consisted of the use of a USDH-48 depth integrating sampler and a multi-stage sampler comprising 4 one-litre plastic bottles fixed firmly on to a vertical mount at 0.1 m intervals. Each sample container was fixed with two copper tubes, one as the intake and the other as an air exhaust, inserted through a rubber stopper following the specifications of the single-stage sampler U.S. U-59C (U.S. Inter Agency Committee on Water Resources Report No. 13 – cited in Ullah, 1972). The USDH-48 sampler was used to obtain samples during low flow conditions while the latter was installed for sampling storm and high flows in order to improve sediment records.

Steamflow was periodically determined which involved the basic procedures of current metering and measuring known cross-sectional areas of the channel. Each measurement was then made reference to a stage gauge reading in order to facilitate the computation of rating curves for the respective rivers.

Steam water samples were analysed in the laboratory for suspended and dissolved solid concentrations following the procedure outlined in Wang and Ong (1978). However, in order to obtain mineral sediment concentrations, of suspended solids and dissolved solids, the samples were ashed at 600°C for 2 hours to remove organic materials which are non-denudational components (Peh, 1981).

RESULTS AND DISCUSSION

Suspended and Dissolved Sediment

Tables 2a and 2b summarise some of the measures of dispersion of suspended and dissolved sediment data obtained during baseflows and stormflows. From the tables, it is obvious that the suspended sediment concentration produced in WA during stormflows is more than 4 times greater than that of WB with respect to mean values. However, the maximum concentration of suspended sediment produced during stormflows is about 150 times greater than the mean baseflow concentration for WA and 52 times for WB respectively. The importance of storms with respect to sediment discharge is clearly shown.

For statistical tests, the difference in suspended sediment concentration between watersheds is significant ($P < 0.05$). This is expected since WA is more recently logged-over compared to WB. The effect of logging on erosion and subsequent sedimentation in streams is well known (Ow Yang, 1965; Douglas, 1970; Daniel

TABLE 2a
Suspended and dissolved sediment concentrations in mg/l – WA

	Minimum	Maximum	Mean	No. of samples
		Suspended Sediment		
Baseflow	2	20	8.5	32
Stormflow	5	1305	187.3	32
		Dissolved Sediment		
Baseflow	4	136	36.7	32
Stormflow	12	70	29.8	26

TABLE 2b
Suspended and dissolved sediment concentrations in mg/l – WB

	Minimum	Maximum	Mean	No. of samples
		Suspended Sediment		
Baseflow	2	16	5.6	32
Stormflow	1	292	40.7	26
		Dissolved Sediment		
Baseflow	3	90	28.4	32
Stormflow	6	58	22.9	26

and Kulasingam 1974; Kunkle, 1974). The relationship between suspended sediment and discharge is not firm for both watersheds *(Figs. 2a* and *2b)*. An examination on the scattergrams indicates considerable scatter about the line of best fit as explained by the low r^2 values obtained especially for WB. In this regard, inherent potential errors during sampling such as hysteretic effects related to rising and falling stage, exhaustion effects and varying patterns of tributary inflow have some effect on the results (Heidel, 1956; Walling, 1977). For example, sampling done after storms on a few occasions recorded low concentrations although at high discharge levels. The main reason for this occurrence is largely because of 'flushing' of sediments during early parts of stormflows.

However, the sensitivity of WA *(Fig. 2)* to suspended sediment disharge is immediately clear by comparison; due mainly to greater erosion within degraded areas of the watershed. Exposure of forest soils, particularly from logging roads and skid trails, are the main sources of sediment supply. High intensity storms easily dislodge recently exposed soil which are subsequently washed into streams by overland flow.

This action increases the concentration of suspended matter and in its form, suspendend sediment. The role of overland flow in this respect has been noted to be of significance even under forested conditions (Peh, 1980). The area WB, where logging operations ceased a year earlier, records significantly lower suspended sediment concentrations primarily because of recovery with time. Regeneration, especially rapid with the lower plants has been effective in covering previously exposed tracks. Consequent to which, the vegetation serve as energy dissipators to rain drops, improve infiltration as well as hold the soil together.

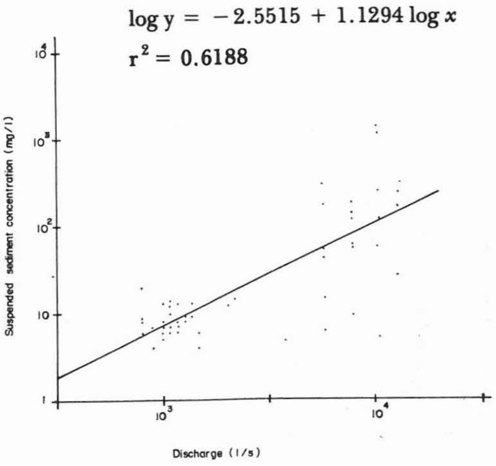

Fig. 2a. Relationship between suspended sediment concentration and discharge for WA.

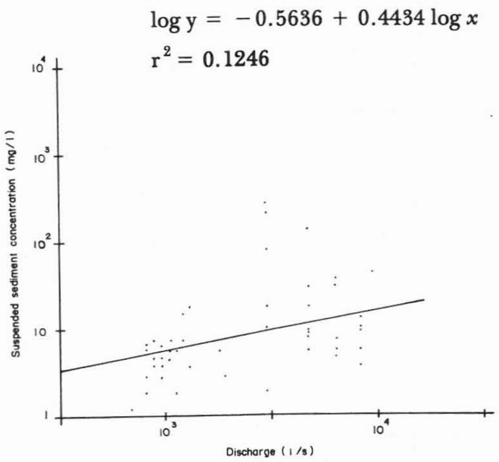

Fig. 2b. Relationship between suspended sediment concentration and discharge for WB.

It will also be important to note that some form of watershed protection was carried out in WA and WB to reduce damage from logging operations. They include avoiding the use of roads and logging near major streams, avoiding major stream crossings and the maximum use of previous logged roads. Additionally, logging intensity was relatively low, averaging 4 to 5 tons/acre. It is certain that these considerations have resulted in lower than expected sediment discharge from the watersheds.

Results from studies conducted elsewhere in Peninsular Malaysia are compared (Table 3). From the table, the range of suspended sediment concentrations seem more varied than dissolved sediment despite different watershed conditions. Compare, for example, results obtained from Douglas (1968). The behaviour stresses the important suspended sediment component in total sediment load during stormflows. The comparison between concentration range is however, limited in view of inherent potential errors involved in sampling mentioned earlier, time period of study and watershed conditions. Taking these factors into consideration, suspended sediment concentrations from watersheds in this study are nevertheless relatively low due mainly to watershed protection measures, comparatively low timber production and time between sampling and logging operations.

Dissolved sediment concentrations however, do not differ significantly between watersheds. The range was 4 – 136 mg/l for WA and 3 – 90 mg/l for WB. The relationship between dissolved sediment and discharge is not significant for both watersheds *(Figs. 3a* and *3b).* Indications that dissolved sediment concentrations can be relatively higher during baseflows than stormflows are, however, largely attributed to dilution effect. Essentially, dissolved sediments are derived from chemical action of water in contact with rocks and soils. Water that is discharged into streams from surface runoff generally contains lower concentrations of dissolved sediments because water that flows over the surface (during storms) reaches the stream quickly and in relatively large volumes. This process can result in lower concentrations of dissolved sediments although the catchment discharge is high (Hembree *et al.*, 1964). It will be important to note that dissolved sediment loads are also dependent on the geology, soil and geomorphology of the basin area. Douglas (1968) for example, in a study in Gombak found that areas with limestone outcrops yield higher dissolved sediment concentrations with discharge than granitic areas because of the solubility of limestone.

TABLE 3

Summary of suspended and dissolved sediment concentrations of selected watersheds in Peninsular Malaysia

Watershed	Location	Suspended Sediment (mg/l)	Dissolved Sediment (mg/l)	Remarks	Source
Upper Sg. Gombak	Selangor	8 (mean)	—	Forested condition	Norris and Chartson (1962) — cited in Peh (1981)
1) Field Centre	Selangor	2.1 – 1609.2	7.5 – 55.0	Forested condition	
2) 12½ Milestone	Selangor	4.2 – 1080.9	10.0 – 82.5	Forested condition	Douglas (1968)
3) Jalan Pekeliling	Selangor	21.1 – 1071.1	17.5 – 95.0	Some mining activities	
4) Sg. Pasir	Selangor	2.1 – 5788.9	20.0 – 110.0	Effects of accelerated runoff from road surface significant	
Sg. Manan Kanan	Negeri Sembilan	2 – 76	80 (mean)	Forested condition	Leigh *et al.* (in press) — cited in Peh (1981)
Sg. Tekam					
1) Basin A	Pahang	21 – 112	19 – 66	Forested condition	Peh (1981)
2) Basin B	Pahang	31 – 110	41 – 72	Forested condition	
3) Basin C	Pahang	28 – 90	25 – 65	Forested condition	
Sg. Tok Pawang	Kedah	17.5 (mean)	—	Forested (control catchment)	Salleh *et al.* (1983)
Sg. Bujang	Kedah	3.1 – 25.4	—	Disturbed Forest	Salleh *et al.* (1983)
Sg. Rasau					
1) WA	Selangor	2 – 1305	4 – 136	Disturbed Forest	Present study
2) WB	Selangor	1 – 292	3 – 90	Disturbed Forest	Present study

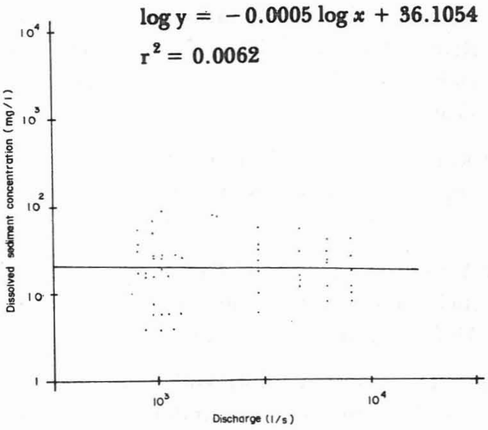

Fig. 3a. Relationship between dissolved sediment concentration and discharge for WA.

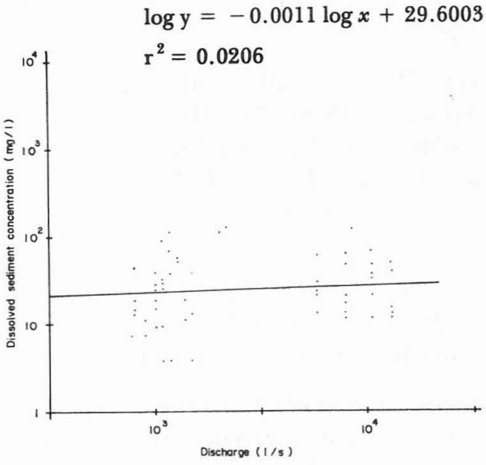

Fig. 3b. Relationship between dissolved sediment concentration and discharge for WB.

Suspended and Dissolved Sediment Loads

The volume of suspended and dissolved sediment discharge can be determined separately by the equation:

$$Q_s = \frac{0.3448}{A_d G} CQw$$

where, Q_s = sediment load in $m^3/km^2/yr$

C = suspended or dissolved matter in mg/l

Q_w = stream discharge in ft^3/s

A_d = drainage area in m^2

G = specific gravity of sediment/rocks in basin area.

Although the rate of denudation, expressed in volume per unit area per year, would provide an importang indication on soil loss from the watersheds, it is not permissible to estimate the annual load in the absence of continuous streamflow records. However, estimations on the maximum and minimum sediment load discharge were computed to demonstrate the differences in the instantaneous denudation rate at the time of sampling; suspended sediment load varies from a low 2.7 $m^3/km^2/yr$ to a high 18375.6 $m^3/km^2/yr$ for WA and 4.7 $m^3/km^2/yr$ to 1828.6 $m^3/km^2/yr$ for WB respectively; dissolved sediment load varies from 5.8 $m^3/km^2/yr$ to 397.4 $m^3/km^2/$ yr to 314.3 $m^3/km^2/yr$ for WA and WB respectively.

The results indicate rather high rates of denudation from the instantaneous suspended sediment samples, especially for WA. By comparison, the maximum limit of sediment production from streams under natural or undisturbed conditions in the humid tropics is in the region of about 100 $m^3/km^2/yr$ (Douglas, 1972 – cited in Peh, 1981) which is clearly below the estimated maximum instantaneous sediment discharge load in the study. It is unfortunate however that long term steamflow records were not available to enable a meaningful estimation and comparison on the total annual sediment loads. Nevertheless, the results obtained will be useful indicators with respect to future changes in the watersheds.

CONCLUSION

The study suggests time difference with respect to logging operations to be of great importance with respect to comparative suspended sediment concentrations and loads after logging operations. The impact on the dissolved sediment component is somewhat lesser in extent. The study also indicates the importance of stream recovery during post-logging periods insofar as suspended and dissolved sediments are concerned. It is within this scope that this study will be continued after a one-year lapse with the primary aim of assessing the extent of further change with time.

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