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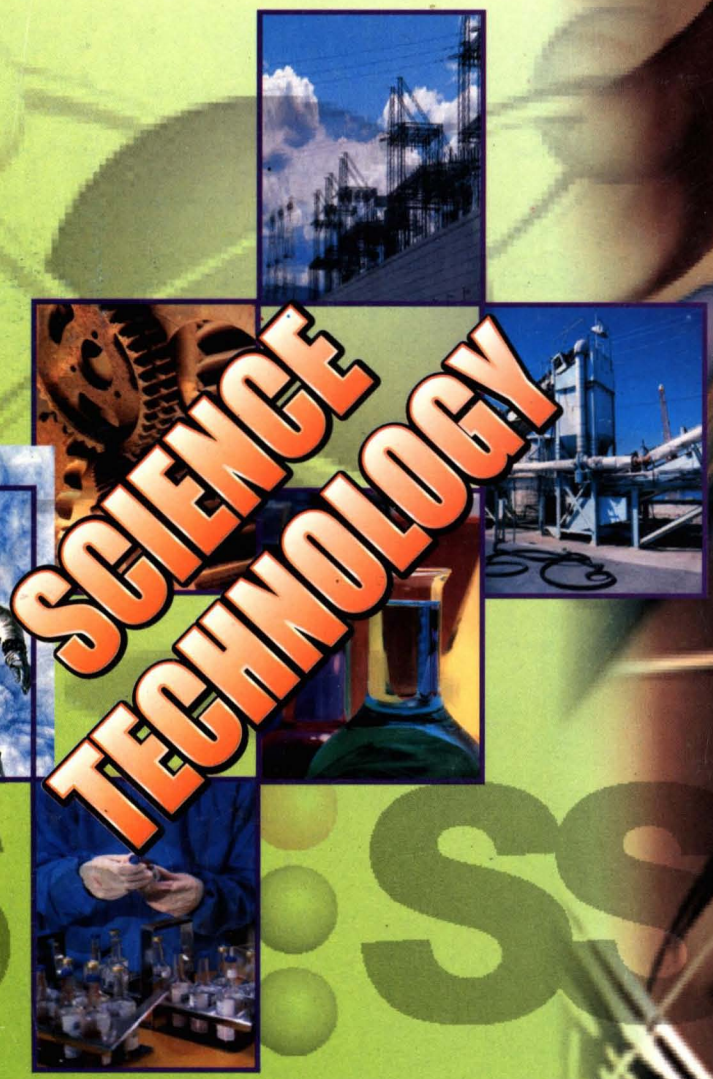

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Fluvial Sediment Yield in the Sungai Bebar Peat Swamp Forest: A Summary of Source, Concentration and Transportation

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ABSTRACT

In a natural environment, sediments in river play an important role in elemental cycling in the aquatic environment. Sediments are responsible for transporting a significant proportion of many nutrients and contaminants. They also mediate their uptake, storage, release and transfer between environmental compartments. Most sediment in surface waters derives from surface erosion and comprises a mineral component, arising from the erosion of bedrock, and an organic component arising during soil-forming processes. However, over sediment flux may result changes on water quality and flow regimes. This paper addresses the impacts of land development on sediment yield in the Sungai Bebar Peat Swamp Forest (SBPSF). Hydrometeorological conditions and sediment yield produced from Sungai Bebar catchment were investigated in the month of February and April 2005. Mean annual rainfall and runoff were calculated at 2244 mm and 1367 mm, respectively. These results are within the predicted by HP No 12 where PE is between 1000-1500 mm year^{-1}. Meanwhile, hydrometeorological and flow conditions play a crucial role in sediment transport within the Sungai Bebar/Serai system. Sungai Serai contributes 81.2 percent of total sediment load to the Sungai Bebar. All together, the total monthly sediment yield for Sungai Bebar is 3.06 kg/km^2 or 36.7 kg/km^2/yr^{-1}. The volume is lower compared with Sungai Serai which shows higher sediment yield as estimated at 13.2 kg/km^2 or 158.4 kg/km^2/yr^{-1}. This study suggests both long and short terms management and conservation approaches to minimize the impacts.

Keywords: *Sediment yield, sediment transport, river flow, hydrometeorological, peat swamp*

Introduction

In a natural environment, sediments play an important role in elemental cycling in the aquatic environment. As studied by many researchers (i.e. Bruijnzeel 1990; Wan Ruslan 1996; Mohd Ekhwan 2004), sediments are responsible for transporting a significant proportion of many nutrients and contaminants. They also mediate their uptake, storage, release and transfer between environmental compartments. Most sediment in surface waters derives from surface erosion and comprises a mineral component, arising from the erosion of bedrock, and an organic component arising during soil-forming processes. However, over sediment flux may result changes on water quality and flow regimes. Factors such as channel slope, relief, basin size and seasonality of rains play a very important role in determining the amount of sediment transport out of a catchment system particularly in the tropics. Recent estimations budget sediment flux from rivers to oceans of about 18 x 10^9 tons year^{-1}. The specific aim of this paper is to evaluate the recent sediment transport and yield in the upstream of Sungai Bebar Pahang. This paper also discusses the hydrometeorology conditions of the study area, the rainfall-discharge relationships and its influence on the sediment yield originating from the upland Bebar-Serai River catchment.

Study Area

Over the last 20 years, the Peat Swamp Forest (PSF) areas were reduced significantly due to development pressure. Most of the areas were converted to agriculture, aquaculture, housing and new industrial zones. In Peninsular Malaysia for example, the PSF remains to about 200 000 ha or 75 percent of the total wetland area, mostly concentrated at the State of Pahang, Selangor, Perak and Johor.

In general, Malaysia has about 1.45 million ha of peatlands with Sungai Bebar Peat Swamp Forest (SBPSF) is the largest intact virgin PSF area (160, 000 ha). Over half of the area (87 045 ha) is located within four production forest reserves namely Pekan, Nenasi, Resak and Kedondong (UNDP/GEF 2001). Started in June 2002, the SBPSF was chosen as one of the three selected sites for the UNDP/GEF peat swamp forest project to demonstrate the conservation and sustainable use of PSF's and associated wetland ecosystems.

Sedimentological speaking, the peat in SBPSF is estimated to have been formed at an average of about 0.3cm per year about 2000-2500 years ago as a result of in situ vegetation decomposition (Che Aziz & Kamal Roslan 2005). The peat deep is estimated to be about one to 1.5 meter indicating shallow peat layer compared with those in the west coast, Sabah and Sarawak which estimated > 2 meter depth (Adzmi & Suhaimi 2005).

The acidic water of Sungai Bebar, the main river tributary flows within the PSF registered a pH of 4.0-4.5 (Shuhaimi & Lim 2005). The overall water quality index (DOE-WQI) of SBPSF is considered as Class II where treatment is necessary. The SBPDF also supports many services for the local Asli Jakun community at Kampung Runchang resettlement particularly for fishing and hunting (Faridah, et al 2005) (Figure 1).

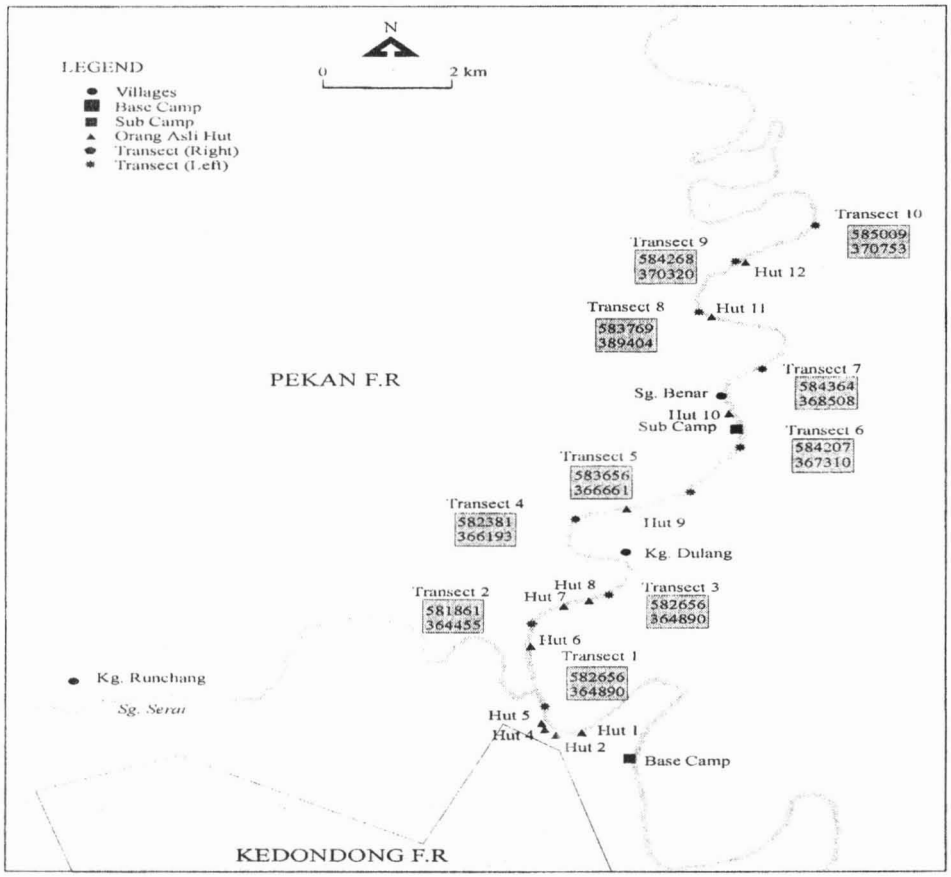

Fig. 1: The SBPDF showing the survey transects and Kg Runchang resettlement

Methodology

In this study, the sediment sampling was conducted within short-term period. Sampling was carried out twice covering a period of two weeks. The first measurement was carried out during the Biodiversity Expedition on February 2005 which represents dry condition while the second one was engaged during the rainy one week intensive field study on April 2005.

Particle size distribution and concentration not only vary in the vertical section, but may also vary considerably across a river section. Therefore, measuring suspended sediment concentration must take into account these variations. This becomes especially important when suspended sediment concentration is being measured for the purpose of calculating sediment load and yield in a river.

For determining suspended sediment load, it is necessary to consider all particle sizes (sand + silt + clay). In this study, the suspended sediment concentration (SSC) was obtained using *Equal-discharge-increment method.* The mean discharge-weighted SSC is obtained by taking the average of the concentration values C obtained for each interval i.

$$SS_c = \frac{\sum_{i=1}^{n} C_i}{n} \qquad \text{.....[1]}$$

The discharge-weighted sediment load (SSL), in kg per day, for the river cross-section is obtained by multiplying the concentration, C, in ppm (mg l^{-1}) by the discharge, Q, in m^3 s^{-1} of each equal-discharge- increment, i, and summing for all increments.

$$SSL = \sum_{i=1}^{n}(C_i Q_i) x 0.0864 \quad \text{.....[2]}$$

Meanwhile, the hydrometeorological data were obtained from Muadzam Shah Meteorological Station (MSMS). This meteorological station was equipped with a U.S Class A white galvanized iron evaporation pan located about 63 km from the field study and considered as the nearest meteorological station from the study area. The daily and monthly rainfall data were abstracted directly from the climatological records whiles the potential Evapotranspiration (*PE*) and runoff (*r*) were calculated using the equations below.

$$PE = 1.63N\left[10\frac{T}{I}\right]^{a} \quad \text{.....[3]}$$

Where N = a factor to correct for unequal day length, T = monthly mean air temperature, and I = summation of monthly heat index. Using this equation, it is assuming that *PE* in open water areas and wetlands are equal to reference *PE* during the calculation period. The runoff then was calculated using the equation:

Runoff (r) = Precipitaion (P) – Potential Evapotranspiration (PE).....[4]

During the field survey, water samples were taken at selected points. Noted that the sediment sampling and cross sectional area stations were covered both Sungai Bebar and it tributary- the Sungai Serai. During the field study, it is believed that much sediment flows from Sungai Serai before entered to Sungai Bebar near Transect 1.

Results and Discussion

Generally, the climate of study area is typical of the equatorial climate of Peninsular Malaysia, which is characteristic by moderate average annual rainfall, temperature and humidity. Hydrologically, the catchment is representative of the upstream site of Sungai Bebar Peat Swamp. This site as categorized by the hydrological Procedure No 12 (DID, 1976) as W_3 with precipitation (*P*) – potential evapotranspiration (*PE*) is between 1000 mm to 1500 mm per annum.

Rainfall

The mean monthly rainfall patterns of MSMS show a double peaked distribution. The wettest months are from September to December coinciding with the North East Monsoon Season while the driest are recorded in the Inter-monsoon period of May and August. Annually, December and February were the wettest and driest months with rainfall recorded at 466mm and 76 mm, respectively. These seasonal variations influence the water level fluctuations in Sungai Bebar peat swamp. During flood season, many low-lying at left-right bank were inundated during the wet spell which can extend for several weeks (Figure 2).

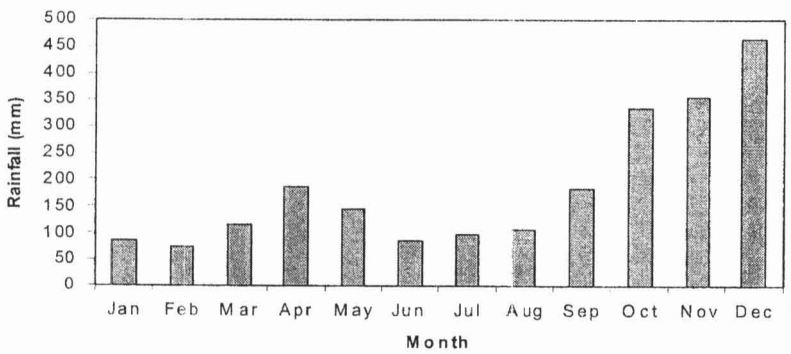

Fig. 2: Monthly Rainfall of Sungai Bebar Catchment *(Source: MSMS 1990 -2000)*

Evapotranspiration

The average monthly and annual potential evapotranspiration (PE) were calculated using equation [3]. It can be seen that during the wet months (November and December), PE are lower due to overcast sky (less energy available in the form of solar radiation for the evapotranspiration process and increased humidity. Conversely, the PE during the dry months is much higher (Figure 3).

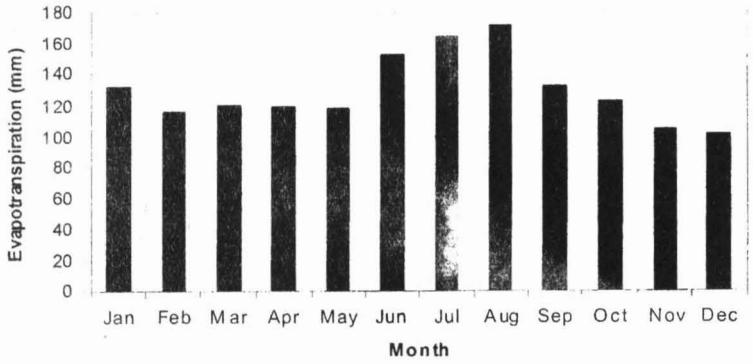

Fig. 3: Mean Monthly PE for the Study Catchment *(Source: MSMS 1990 -2000)*

Runoff

Runoff at the study catchments was calculated from the equation [4]. The mean annual runoff was 1367 mm which is within the predicted by hydrological Procedure No 12 where PE is between 1000-1500 mm year^{-1} (Figure 4). May shows exceptional where runoff was higher than rainfall. Possibly, groundwater storage in the upstream peat swamp contributed to this higher runoff.

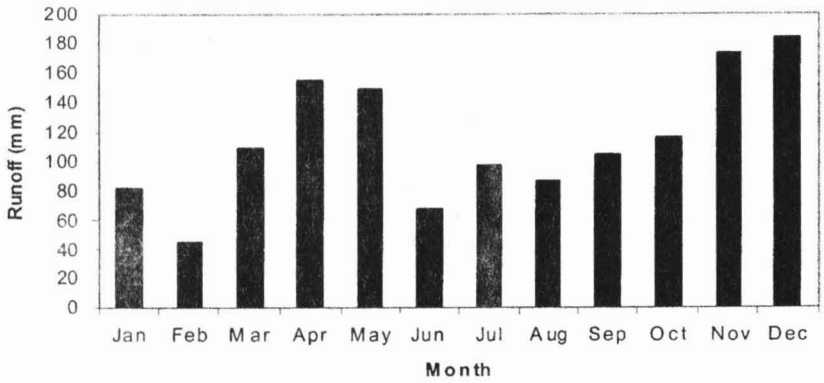

Fig. 4: Mean Annual Runoff of the Study Catchments *(Source: MSMS, 1990 -2000)*

Suspended Sediment Concentration

Table 1 summarizes SSC as calculated using equation [1]. The maximum SSC for both rivers were observed during the storm day recorded on the 4rd April 2005. Meanwhile, minimum SSC was recorded on 3nd April 2005 for Sungai Bebar and Sungai Serai, respectively.

Table 1: Summary mean SSC (mg/l) for Sungai Bebar and Sungai Serai

Descriptive statistics	River	
	Sg. Bebar	Sg Serai
Mean	104.2	128.3
Maximum	132.5	718.4
Minimum	0.32	11.2
Std. Dev	116.23	121.26
N	9	7

Sediment Load

The total sediment load (kg/km^2) was calculated using equation [2] and plotted in Figures 6a and b. The result shows that sediment load varies reflecting the influence of rainfall. In total, Sungai Serai contributes 81.2 percent of total sediment load to the Sungai Bebar. Highest concentration was found during the rainy day (4/4/05) which carried about 44.3 percent from total load.

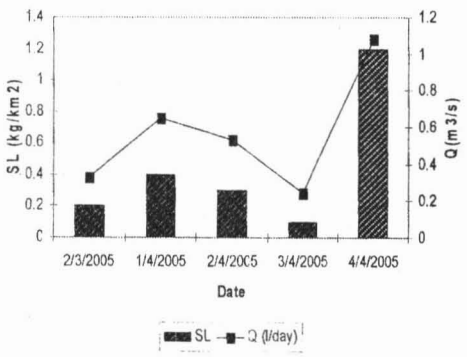

Fig. 6(a): Variation daily SL for Sungai Serai

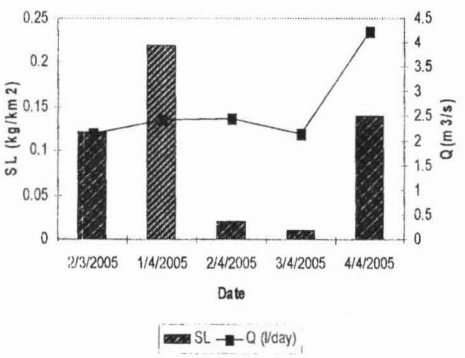

Fig.6 (b): Variation daily SL for Sungai Bebar

Monthly Sediment Yield

The result indicates that total monthly sediment yield for Sungai Bebar was estimated at 3.06 kg/km^2 or 36.7 kg/km^2/yr^{-1}. However, as expected, Sungai Serai shows higher sediment yield. Monthly yield estimated was 13.2 kg/km^2 or 158.4 kg/km^2/yr^{-1} and again it reflecting the influence of rainfall occurrence.

Source of Sediment

Reflecting the trend of sediment yield produced throughout the study period reveals some major challenges to conservation efforts of SBPSF. The challenges include widespread land conversion to agricultural and aquaculture, unsustainable timber extraction and potential forest fire. In recent years, intensive development of SBPSF to agriculture and aquaculture were resulting increased on sediment production and decreasing the PSF coverage. In the SBPSF, high amount of sediment from Sungai Serai was due to agriculture activity. This activity can be seen about three kilometers before entering Kampung Runchang. In fact, even the southern part of SBPSF also surrounded by oil palm plantations. In a case of SBPSF, although the sediment production is reflecting the influence of rainfall occurrence, human activity as discussed above also was observed contribute to high loading of sediment within the catchment. This study could provide an insight into a problem of sustainability in the catchment and probably provide good information for a better management of the SBPDF in future time.

Conclusion

Sediment yields for Sungai Bebar catchments are relatively low compared with other forested catchments. Sungai Serai, although small in terms of Q but producing high volumes of fresh sediment in its channel. Sediment transport in particular is closely related to hydrometeorological and flow conditions. This variability in the sediment loads urge the need for a long term monitoring as well as proper gauging to evaluate total sediment yield over year.

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