Short-term sediment yields from small catchment of Sungai Anak Bangi Selangor

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Abstract— Suspended sediment yield from the forested catchment of Sg Anak Bangi was investigated from September to November 2006. Three main data were measured namely the rainfall depth, the suspended sediment concentration and river discharge (Q) at two sampling stations along the river. Twelve rainfall events were recorded with highest rainfall of 36.7 mm was received on October 02 2006, while the lowest rainfall depth was recorded on October 08 2006 (1.9 mm). Almost all the rainfall events occurred within the short and moderate durations (< 7 hours). Meanwhile, the daily Q sampled ranges from 172.8 m^3/day to 6220.8 m^3/day or 172,800 to 6220,800 L/day. The average suspended sediment concentration values recorded for both stations are considered low, with 19.47 mg/l and 25.23 mg/l recorded at Station 1 and Station 2, respectively. When converted to average suspended sediment yield per day, Sg Anak Bangi recorded 75.04 kg/day at Station 1 while at Station 2 was 103.26 kg/day. When converted into per square km, the gross value of suspended sediment yield leaved from Sg Anak Bangi is estimated to be about 27.91 kg/km^2/day or 10,186 kg/km^2/yr^{-1}.

Keywords: Suspended sediment concentration, rainfall, river discharge, concentration, Sg Anak Bangi

Abstrak— Penghasilan muatan sedimen terampai di kawasan tadahan Sg Anak Bangi telah diselidiki bagi tempoh September hingga November 2006. Tiga data utama telah diukur, iaitu kedalaman hujan, konsentrasi sedimen terampai dan luahan sungai (Q) di dua stesen pencerapan di sepanjang sungai. 12 kejadian hujan telah direkodkan dengan hujan tertinggi ialah 36.7 mm yang diterima pada 2 Oktober, 2006 sementara hujan terendah dicatatkan pada 08 Oktober 2006 (1.9 mm). Kebanyakan kejadian hujan berlaku dalam tempoh singkat dan sederhana (< 7 jam). Sementara itu, nilai Q harian adalah diantara 172.8 ke 6220.8 m^3/hari atau 172,800 and 6220,800 L/hari. Purata nilai konsentrasi sedimen terampai yang direkodkan bagi kedua-dua stesen adalah rendah, iaitu masing-masing 19.47 mg/l dan 25.23 mg/l yang direkodkan bagi Stesen 1 dan 2. Nilai ini bila ditukarkan kepada penghasilan muatan sedimen terampai bagi Sg Anak Bangi ialah 75.04 kg/hari di Stesen 1 manakala di Stesen 2 ialah 103.26 kg/hari. Angka ini jika ditakrifkan kepada setiap kilometer persegi menunjukkan anggaran sedimen yang diangkut keluar melalui Sg Anak Bangi ialah 27.91 kg/ km^2/hari atau 10, 186 kg/ km^2/tahun.

Kata kunci: Penghasilan muatan sedimen terampai, hujan, luahan sungai, konsentrasi, Sg Anak Bangi

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 water derives from surface erosion and comprises mineral components, arising from the erosion of bedrock, and an organic component arising during soil-forming processes.

The studies of the impacts of sediment on alluvial rivers have been explored significantly all over the world. Most of the studies concentrate on the impacts of land reclamation on sediment concentration at downstream rivers (Lane, 2004; Mohd Ekhwan, 2003), agriculture activities and increase in sediment load (Subramaniam, 1993), logging activity in hilly forest (Baharuddin, 1988) and sediment-river water quality (Li, 1976). Presently, rivers contribute 95 percent of sediments entering the ocean (Chakrapani, 2005). Most of studies agreed that over sediment flux may result changes on water quality and flow regimes. Estimation on annual sediment productions are varied geographically. Factors such as channel slope, relief, basin size and seasonality of rains play a very important role in determining the amount of sediment transported out of a catchment system particularly in the tropics. For example, Holland (1981) estimates the average budget sediment flux from rivers to oceans of about 18,592.8 billion kg $year^{-1}$. This trend of sediment production may be increase in future times due to rapid economic activities particularly those from development countries. These including land use change, reservoir construction, sediment control programmes and mining activity.

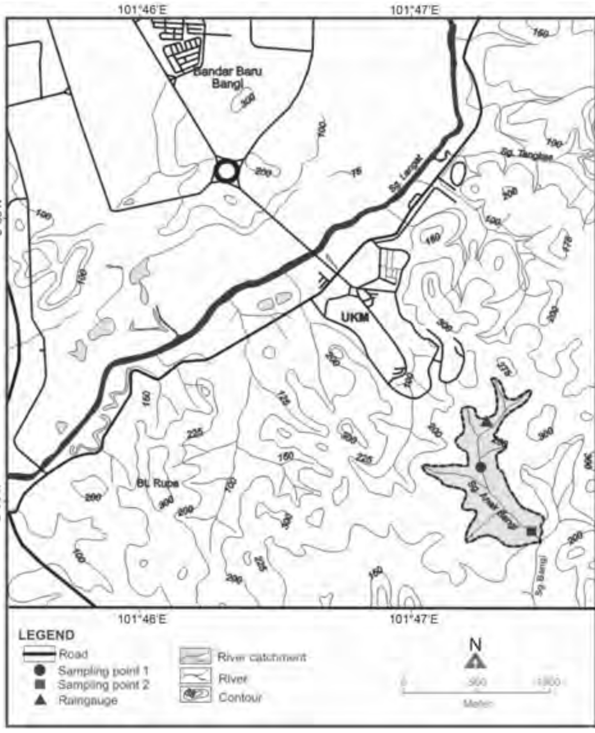

Figure 1: Topography and location of sampling points of Sg Anak Bangi.

Figure 2: Google Earth image showing the existing land use surrounding the study catchment.

Table 1: Physical and climatic features of Sg Anak Bangi.

River catchment detail	value
Physical fectures	
catchment size (km^2): Station 1	1.5
: Station 2	2.2
Elevation (m) : Max	200
: Min	100
Catchment length (km)	2.5
Σ stream length (km)	3.6
Stream order	3
Drainage density	1.29
Catchment width ratio	0.8
Climatic fectures	
Annual rainfall (mm)	2250.7
No of raindays	158
Relative humidity (%)	85
Temperature (^{o}C) : Max	33
: Min	24.6

STUDY AREA

The study was conducted at Sg Anak Bangi in Bangi Forest Reserve, Selangor (02° 55′ 44.0″ N latitude and 101° 47′ 12.6″E longitude, Figure 1). The total catchment area for Bangi Forest Reserve is 34 km^2, while for Sg Air Anak Bangi is 3.7 km^2. A description of the physical and climatic features of the catchments is given in Table 1.

The geology of the area is predominantly of granitic rocks. The soil texture ranges from coarse to fine sandy clay with Muchong-Seremban being the major soil series. The land cover of the study area is mostly hill dipterocarp forest. This forest has been logged in late 1960s and early 1970s. Towards downstream, the catchment has been transformed by oil palm plantations and development of Pekan Bangi Lama (Figure 2)

MATERIAL AND METHODS

Rainfall was measured using the manual tipping bucket raingauge located at the Hutan Pendidikan Alam, UKM (02° 55′ 123.0″ N latitude and 101° 47′ 65.2″E longitude). It consists of a large copper cylinder set into the ground with funnel at the top of the cylinder to collects and channels the precipitation. This raingauge was installed temporarily over two months of study period (September-November 2006).

Observed discharge was measured manually using mean-mid technique (Wan Ruslan 1994; Mohd Ekhwan & Haryati 2007; Philip *et al*., 2008) at two water sampling points, namely the Station 1 and Station 2. Station 1 located at the upper reach of Sg Anak Bangi while Station 2 is just before the river joint with Sg Bangi. In this study, discharge calculation was estimated using the equation below:

$$Q = \text{sum of } Q_n$$
$$= W_1D_1V_1 + W_2D_2V_2 + W_nD_nV_n \quad \ldots\ldots\ldots\ldots [1]$$

Where W_n is the width of the section (m); D_n the depth of the section at the midpoint (m); and V_n mean velocity of the section at the midpoint (m/s). Water samples were taken using the grab sampler method during rainy and storm events at both stations. Water samples were analysed in the School of Social, Development and Environmental Studies, FSSK UKM laboratory for suspended concentration following the procedure outlined by Rainwater & Thatcher (1995) and Morgan (2005). The residue remaining on the filter paper was oven dried at 105°C for 24 hours, cooled in a dessicator and weighed. The total amount of suspended sediment yield in kg/day then was calculated by multiplying the weighed suspended sediment with the stream discharge (m^3s^{-1}) during samplings (Bartham & Ballance, 1996).

Table 2: Rainfall duration, rainfall depth and suspended sediment concentration at Sg Anak Bangi.

Rainfall events	Rainfall duration (minute)	Rainfall depth (mm)	SSC (mg/l)	
			Stnt. 1	Stnt. 2
18.09.06	125	3.1	8.4	9.2
22.09.06	140	3.5	12.1	18.5
23.09.06	45	2.2	2.2	7.1
25.09.06	120	12.9	13.7	17.5
28.09.06	210	32.2	34.2	42.5
30.09.06	240	34.2	32.4	40.3
02.10.06	300	36.7	43.5	48.1
08.10.06	75	1.9	8.6	15.8
16.10.06	103	3.1	12.3	14.1
31.10.06	90	35.8	10.4	14.2
17.11.06	18	12.3	1.2	5.5
19.11.06	405	30.3	54.6	69.8
Σ	31 hrs	208.2	233.6	302.6
Average	155.92	17.35	19.47	25.23
Max	405	36.7	54.6	69.8
Min	18	1.9	1.2	5.5

Table 3: Hydrological data for Sg Anak Bangi.

Date	Observed Q (m^3/s)		Estimated daily Q (m^3/day)		Estimated daily Q (L/day)	
	Stnt. 1	Stnt. 2	Stnt. 1	Stnt. 2	Stnt. 1	Stnt. 2
18.09.06	0.012	0.013	1036.8	1123.2	1036, 800	1123, 200
22.09.06	0.013	0.013	1123.2	1123.2	1123, 200	1123, 200
23.09.06	0.004	0.005	345.6	432.0	345, 000	432, 000
25.09.06	0.013	0.015	1123.2	1296.0	1123, 200	1296, 000
28.09.06	0.035	0.052	3024.0	4492.8	3024, 000	4492, 800
30.09.06	0.042	0.043	3628.8	3715.2	3628, 800	3715, 200
02.10.06	0.051	0.052	4406.4	4492.8	4406, 400	4492, 800
08.10.06	0.005	0.010	432.0	864.0	432, 000	864, 000
16.10.06	0.032	0.036	2764.8	3110.4	2764, 800	3110, 400
31.10.06	0.004	0.010	345.6	864.0	345, 600	864, 000
17.11.06	0.002	0.005	172.8	432.0	172, 800	432, 000
19.11.06	0.072	0.091	6220.8	7862.4	6220, 800	7862, 400

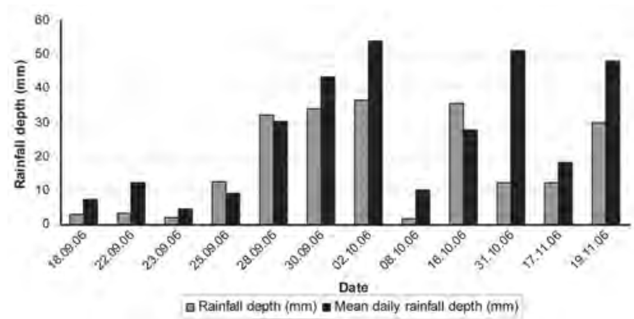

Figure 3: Daily rainfall depth recorded at study site and UKM rainfall station.

RESULTS AND DISCUSSION

The two sampling stations along Sg Anak Bangi were selected in order to gain some idea of sediment yield between upstream and downstream sites. Generally speaking, the sediment productions at Sg Anak Bangi are very much relied to rainfall events. During the study period, 12 rainfall events were recorded with highest rainfall of 36.7 mm was received on October 02 2006 while the lowest rainfall depth was recorded on October 08 2006 (1.9 mm). Most of the rainfall events occurred within the short and moderate durations (< 7 hours) from 75 to 405 minutes. The daily rainfall depth pattern during the study period exhibited fairy similar pattern compared with average 10 years mean daily rainfall depth recorded at Universiti Kebangsaan Malaysia Rainfall stations (240ºN 101º 44'E) (Figure 3). The relationships when expressed into statistical showing positive significant relationship with $R^2 = 0.56$ (Figure 4). Nevertheless, certain observed days recorded highest than the long term average namely day-4, day-5 and day-9, while others recorded less than the long term average rainfall. Detailed of rainfall depth and results of individual stations on suspended sediment production is tabulated in Table 2.

From the Table 2, weighted suspended sediment concentration (SSC) discharge from the two sampling stations varied from minimum 1.2 to maximum 54.6 mg/l (Station 1) and 5.5 to 69.8 mg/l (Station 2). Both maximum SSC were recorded during the prolonged rainy day on November 19 2006 while the minimum SSC for both stations were recorded on November 17 2006. The average values recorded for both stations were considered low compared with other study areas. For example, average SSC recorded for Sg Air Terjun (CA = 28 km^2) was 111.04 mg/l (Wan Ruslan, 1996), Bebar (CA = 36.2 km^2) was 104.2 mg/l (Mohd Ekhwan, 2005) while 12.27 mg/l was recorded at Chini River (CA = 4.36 km^2) (Mohd Barzani Gazim *et al.*, 2006).

The results show that the present of stable density forest canopy of the Bangi Forest Reserve plays an important role in minimising surface erosion which is expected as one of a major contributor on sediment yield in rivers. The successive layers of the canopy were act as a great filter through interception process (Mohd Ekhwan & Shukor, 2006) and reducing the impact from splash erosion by rain drops (Pinet & Souriau, 1988). Changed in land use from forested to other human activities may lead to higher sediment yield particularly during unstable condition. For example, Hamilton & King (1983) reported that the erosion rate on newly constructed was 154.8 t/ha/yr at logging areas while Douglas (1984) reveals that the transformation from forest to urban catchment will leave the soil surface more exposed to erosion.

In the context of catchment physical characteristics, the size of the catchment and topography of the land surface also have significant relation to sediment yield production. It is clear from field studies that the dominant response mechanisms behind the link, along with the sediment yield itself, was the process of sediment being transported from the source to the outlet. This includes the sediment transport modes (wash load, bed load or suspended load), sediment properties (size and shape of grain), bedforms (ripple, dunes and antidunes), bed roughness, *ks* and effective shear stress, τb. Combination of these factors with other physical

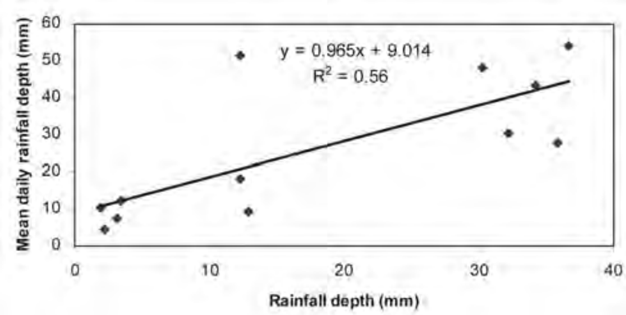

Figure 4: The relationships between observed rainfall depth and mean daily rainfall depth.

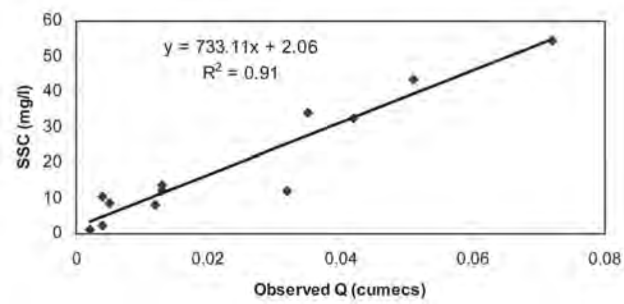

Figure 5: Relationship between observed Q and SSC at Stnt. 1.

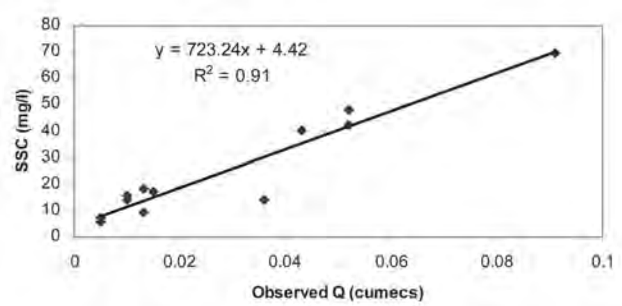

Figure 6: Relationship between observed Q and SSC at Stnt. 2.

aspects such as scale of basin area and hydro-meteorological conditions have been shown to influence the sediment yield of many catchment areas as studied by Bruijnzeel (1990), Wan Ruslan (1996), Mohd Ekhwan (1997, 2002) and Mohd Ekhwan & Noorazuan (2003).

The regime of the Sg Anak Bangi reflects the rainfall events associated with north-east monsoon occurred during the study period. Using equation [1], detailed observed discharge (Q) and estimated daily Q calculated for each sampling points during water collection were tabulated in Table 3. At Station 1, the daily Q sampled ranged from 172.8 m^3/day to 6220.8 m^3/day or 172,800 L/day to 6220,800 L/day. Meanwhile at Station 2, daily Q sample ranged from 432.0 m^3/day to 7862.4 m^3/day or 432,000 to 7862,400 L/day. All together, the mean observed Q and daily Q (m^3/day) for Station 1 and Station 2 are 0.024 m^3/s, 0.029 m^3/s, 2052 m^3/day and 2484 m^3/day, respectively.

There are also significant correlations between observed Q and the present suspended sediment concentration for both sampling stations (Figures 5 and 6). At Station 1, observed Q was correlated as positive slope with SSC (R^2= 0.91) showing that the highest Q will follow with an increase in suspended sediment concentration. Meanwhile at Station 2, the measurement of observed Q and SSC showed a statistically significant relationship between both variables (R^2 = 0.91).

To gain the suspended sediment yield in the river, the daily suspended sediment concentration was calculated. It is the gross amount of suspended sediments carried past the sampling stations over a 24 hour period. The information is important because of the fact that sediment yield from the catchments is that portion of the eroded soil which leaves the catchment. The result is presented in Table 4. Average suspended sediment yield estimated at Station 1 was 75.04 kg/day while at Station 2 was 103.26 kg/day. As the volume of sediments at Station 1 are flowing to Station 2, it can be estimated that gross amount of sediment yields produced at Station 2 (103.26 minus 75.04 = 28.22 kg/day) is much lesser than the amount of sediment yield calculated at Station1. At Station 1, suspended sediment yields were recorded between 0.76 kg/day to 339.66 kg/day while at Station 2, suspended sediment yields ranged from 2.38 kg/day to 548.79 kg/day, respectively. The large sediment yield on the latter occasion (November 19 2006) was partly derived from high discharge occurred on that day. Total catchment area for Sg Anak Bangi is 3.7 km^2. This is the estimated area of which sediment leaved the catchment. When converted into per square km, the gross value of suspended sediment yield leaved from Sg Anak Bangi is estimated about 27.91 kg/ km^2/day or 10, 186 kg/ km^2/yr.

CONCLUSION

The study shows the importance of forest covers in reducing the surface erosion. The present of Bangi Reserve Forest plays a vital role in controlling surface erosion and rainfall interception. At a same time, sediment concentration is closely related to rainfall events which increase river regimes especially in terms of river discharge. Suspended sediment yields carried out by the Sg Anak Bangi are much smaller than those reported for other rivers in Malaysia. This indicates that erosion although occurred in the study area but still within the acceptable value. It is extremely important to preserve the forest as well as Sg Anak Bangi as one of the best practices in controlling over sediment yield in the study area.

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Table 4: Suspended sediment yield per day in Sg Anak Bangi.

Date	Estimated daily Q (L/day)		SSC (mg/l)		SSC (kg/l)		SSC yield (kg/day)	
	Station 1	Station 2	Station1	Station 2	Station 1	Station2	Station 1	Station 2
18.09.06	1036, 800	1123, 200	8.4	9.2	0.0000084	0.0000092	8. 7091	10.3334
22.09.06	1123, 200	1123, 200	12.1	18.5	0.0000121	0.0000185	13.5907	20.7792
23.09.06	345, 000	432, 000	2.2	7.1	0.0000022	0.0000071	0.759	3.0672
25.09.06	1123, 200	1296, 000	13.7	17.5	0.0000137	0.0000175	15.3878	22.6800
28.09.06	3024, 000	4492, 800	34.2	42.5	0.0000342	0.0000435	103.4208	195.4368
30.09.06	3628, 800	3715, 200	32.4	40.3	0.0000324	0.0000403	117.5731	149.7226
02.10.06	4406, 400	4492, 800	43.5	48.1	0.0000435	0.0000481	191.6784	216.1037
08.10.06	432, 000	864, 000	8.6	15.8	0.0000086	0.0000158	3.7152	13.6512
16.10.06	2764, 800	3110, 400	12.3	14.1	0.0000123	0.0000141	34.0070	43.8566
31.10.06	345, 600	864, 000	10.4	14.2	0.0000104	0.0000142	3.5942	12.2688
17.11.06	172, 800	432, 000	1.2	5.5	0.0000012	0.0000055	2.074	2.3760
19.11.06	6220, 800	7862, 400	54.6	69.8	0.0000546	0.0000698	339.6557	548.7955
Average	258900	1929600	19.5	25.2	0.0000195	0.0000253	75.0415	103.2559

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