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SUSPENDED SEDIMENT CONCENTRATION AND SEDIMENT LOADING OF BERNAM RIVER (PERAK, MALAYSIA)

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ABSTRACT

This paper presents some of our preliminary results on the sediment discharge and load based on weekly sampling starting from Oct 2017 to January 2018. Results show that sediment rating curve of Bernam River was R^2 = 0.86 high flow and R^2 = 0.5 low flow. Average sediment loading throughout this sampling period is 1,144 t. Land use activity is expected to be the main contribution for the highest sediment concentration during rain events. The amount of annual sediment yield was estimated at 23 t/km^2/year and is comparable to other studies having similar land uses in the catchment area.

RÉSUMÉ: Concentration des sédiments en suspension et charge sédimentaire de la rivière Bernam (Perak, Malaisie).

Cet article présente certains de nos résultats préliminaires sur le déchargement et la charge de sédiments, basés sur un échantillonnage hebdomadaire commencé entre octobre 2017 et janvier 2018. Les résultats montrent que la courbe de cotation des sédiments de la rivière Bernam était R^2 = 0,86 en débit élevé et R^2 = 0,5 en débit faible. La moyenne de la charge sédimentaire tout au long de cette période d'échantillonnage est de 1.144 t. On s'attendait à ce que l'activité d'utilisation des terres soit la principale contribution à la plus forte concentration de sédiments pendant les épisodes de pluie. La quantité de sédiments produits annuellement a été estimée à 23 t/ km^2/an et est comparable à d'autres études portant sur des utilisations similaires des terres dans le bassin versant.

REZUMAT: Concentraţia sedimentului suspendat şi încărcătura în sediment a râului Bernam (Perak, Malaezia).

Această lucrare prezintă câteva dintre rezultatele noastre preliminare privind evacuarea şi încărcarea de sedimente bazate pe prelevări săptămânale începute în octombrie 2017 până în ianuarie 2018. Rezultatele arată faptul că, curba de evaluare a sedimentelor râului Bernam a fos R^2 = 0.86 la debite ridicate şi R^2 = 0.5 la debite scăzute. Media încărcării cu sediment pe parcursul acestei perioade de prelevare este de 1.144 t. Activităţile de utilizare a terenurilor a fost de aşteptat să fie cauza principală pentru cea mai mare concentraţie de sediment din timpul ploilor. Cantitatea anuală de sediment a fost estimată la 23 t/km^2/an şi este comparabilă cu cea a altor studii cu tipuri similare de utilizări de terenuri în bazinul de captare.

INTRODUCTION

Soil erosion is a world-wide phenomenon caused by natural agents. It is accelerated due to human activities and induced by socioeconomic development over years (Poons, 2008; Isaka and Ashraf, 2017). Soil erosion is a process of moving soil by water or wind and this is a natural process that has occurred for eons of time.

Erosion consists of three processes: detachment (from the ground), transportation (water or wind), and deposition. The deposition occurs often in places we don't want the soil such as streams, lakes, reservoirs, or deltas (Liu, 2016). A major concern with deposition is that the topsoil, which is often the most fertile for agricultural use, erodes away and exposes the subsoil, which is less productive. This process may pose a threat to sustained agricultural production (Li and Wei, 2011).

The eroded material from soil erosion may cause both on-site and off-site effects which are detrimental to ecosystem and environment as well (Parsons and Cooper, 2015). Massive soil erosion hinders the growth of plants, agricultural yields, water quality, catchment health, and recreation (Pimentel and Burgess, 2013). It can cause of degradation of soils as it occurs naturally on all lands (Ding et al., 2015; Posthumus et al., 2015).

The causes of soil erosion are basically water and wind, with each of these contributing to a significant level of annual soil loss (Ding et al., 2015). Soil erosion is a problem in areas with expanding population, agricultural production, construction, and urbanization as well as human activities. (Ding et al., 2015) Among the factors that cause soil erosion is poor land management which causes damages to the soil and results in water runoff across landscapes instead of adequate infiltration (Liu, 2016; Niu et al., 2015).

Water quality issues have brought a daunting task for water environment management; the spatial temporal differences of water quality could provide dynamic information for the decision-maker of water environment (Al-Wadaey and Ziadat, 2014).

Suspended load and suspended sediment are very similar but are not the same. Fine sediment can be found in nearly any body of water, carried along by the water flow. When the sediment is floating within the water column it is considered suspended. Suspended sediment contains sediment that is uplifted into flowing water. The sediment is kept suspended as long as there are flow velocities that transport the sediment above the bed. With low velocity the sediment will be deposited. Excessive transport or sediments such as silt, sand and gravel in rivers can cause problems for flood control, soil conservation, irrigation, aquatic health, etc. Erosion from land surface, bank erosion, and channel bed load contribute to the amount of sediment entering to the stream. Suspended sediment comes from turbulent currents and movement of coarser particles along the streambed. (Parsons and Cooper, 2015)

The aim of this study was to investigate the variation of suspended sediment concentration and suspended sediment loading, and estimate annual sediment load and yields of Bernam River.

The results of this research can support the building of an integrated conservation management system plan for the Bernam River watershed, such that the sediments effects on the aquatic habitats can be treated as a core issue, in the circumstances in which erosion and sedimentation do not negatively effect this lotic system natural resources and can offer optimum natural services.

The optimum reduction of sediment negative effects on the researched aquatic habitats will appear only if the conservation management system will be approached and planed finally for the whole Bernam Basin.

MATERIAL AND METHODS

Study area. Bernam River located in the south part of Perak and northeast Selangor, Malaysia located between N 03° 40’ 45’’ to E 101° 31’ 20’’ (Figs. 1-4). The catchment in the study area was 186 km^2 and the elevation above mean sea level is 41 m. The maximum length and breadth of the catchment area are 21 km and 14 km, respectively. (DID, 1986)

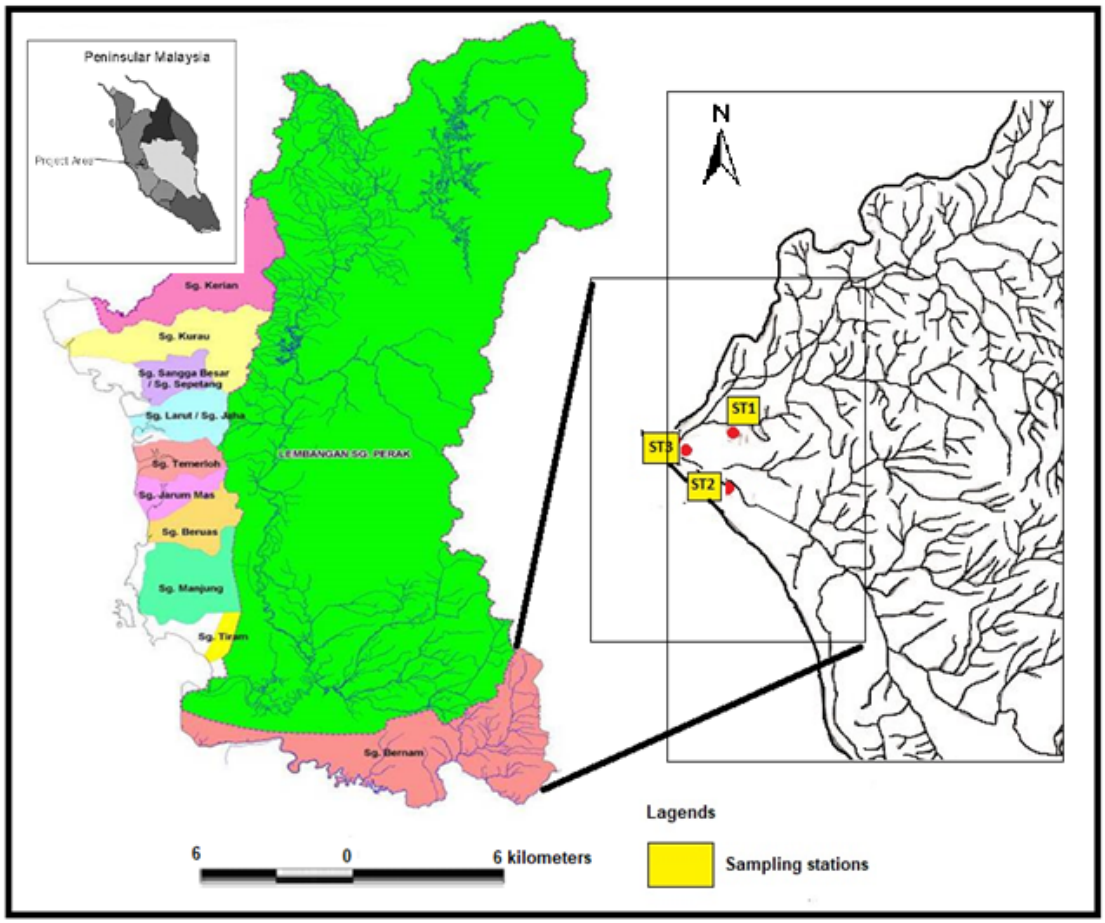


Figure 1: Bernam River Catchment Area location map.

About 78% of this catchment consists of steep mountainous country rising to heights of 1,830 m while the remainder is hilly country. The mountainous areas are under jungle, while the hilly undulating areas are mainly under mixed forest and rubber plantation. The majority of the catchment has a granitic soil cover consisting of fine to coarse sand and clay. The depth of the cover is generally only a few metres, but greater depths may be encountered in areas of intense weathering. A small portion in the south has a variable soil cover consisting of sandy loam grading to clay loam. The depth of alluvium in the valleys is between 8 to 15 m. Strike of sediments is approximately northwest to southeast with dip, varying between 45° to 65°, towards northeast and southwest. It is also a source of irrigation and water supply for 20,000 ha rice granary and eco-tourism activities for local people. (DID, 1986)



Figure 2a: Low flow of Bernam River at station 1.



Figure 2b: High flow of Bernam River at station 1.

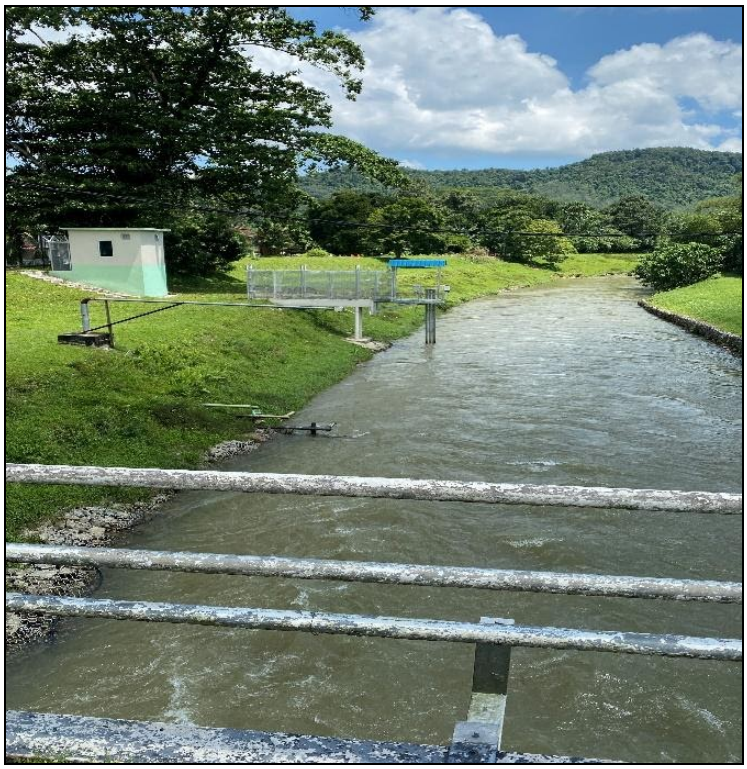


Figure 3a: Low flow of Bernam River at station 2.



Figure 3b: High flow of Bernam River at station 2.



Figure 4a: Low flow of Bernam River at station 3.



Figure 4b: High flow of Bernam River at station 3.

Tanjung Malim Perak area near at Titiwangsa Range received high amount of rainfall. Annual rainfall in the study area was 2,600 mm in 2017. Land-use in Bernam catchment in 2004 is mainly forest (47.7 %), rubber (14.8%), oil palm (25.9%), shrub (7%), built up area (3%) and 1.5% water body (Che Ngah et al., 2014).

Table 1 describes the location of the three sampling stations. These stations were chosen due to their accessible monitoring during the storm events.

Table 1. Sampling station in the downstream areas.

Station	River	Latitude	Longitude
1	Bernam River	3º68'14.5"N	101º53'04.9"E
2	Inki River	3º57'42.4"N	101º52'85.7"E
3	Bernam River	3º67'81.9"N	101º52'08.4"E

Discharge. River flow was measured using propeller current meter and discharge was calculated using a velocity-area method (Grdon, 1992). Discharge in the main inlets and the outlets was measured and the water level were recorded continuously. The cross-sectional view of each station was plotted on graph paper using the width and depth measurements obtained in the field to obtain cross-sectional area of flow. All statistical and data analysis were conducted in Microsoft Excel and SPSS. The discharge at each station was then estimated by the velocity area method using the relation:

Q = AV where: *Q* = discharge (m^3·s-1) *V* = mean velocity (m·s-1) *A* = area of cross-section (m^2) (Schumm, 1977; Ismail and Najib, 2011).

Calculation of sediment loading. The suspended sediments concentrations were then used to estimate the sediment load in the water at a given time at each station since the suspended load is the product of concentration and discharge, as follows:

Qs = QC where: *Qs* = Suspended load ($g \cdot s^{-1}$) *Q* = discharge ($m^3 \cdot s^{-1}$) *C* = concentration ($g \cdot m^{-3}$) (Bourne and Jones, 2002).

RESULTS AND DISCUSSION

Rainfall.

Tropical climate of Malaysia received high amounts of rainfall with an average 2,000-3,000 millimetres per year. The rain is also caused by monsoon regime, and there are two types of monsoons; Southwest Monsoons (May-September) and Northeast Monsoons (November-March) (Wilson, 1990). Monsoons make precipitation more abundant and frequent in some area. For example, when East coast monsoon occur, the eastern part of Peninsular Malaysia is affected by the rainy season in November and December and can exceed 500 mm per month. December is the rainiest month for the east coast area. During the El Nino event, Malaysia also experienced a substantial decrease in rainfall (Kamil and Omar, 2017). Based on data from Drainage and Irrigation Department Malaysia (Fig. 5), an average of 17 years of rainfall station at Bernam River at Tanjung Malim Perak from 2000 to 2017. Based on the annual rainfall data, the highest rainfall was recorded in 2006 (3,516 mm/year) while the lowest rainfall data was recorded in 2006 (1,535 mm/year). The highest average rainfall for 17 years was in November and April due to the monsoon regime. Soil erosion usually occurs in places that are susceptible, where the topography is sloped and when long duration rainfall coincides with inadequate vegetative cover (Thomas, 1985; Isaka and Ashraf, 2017).

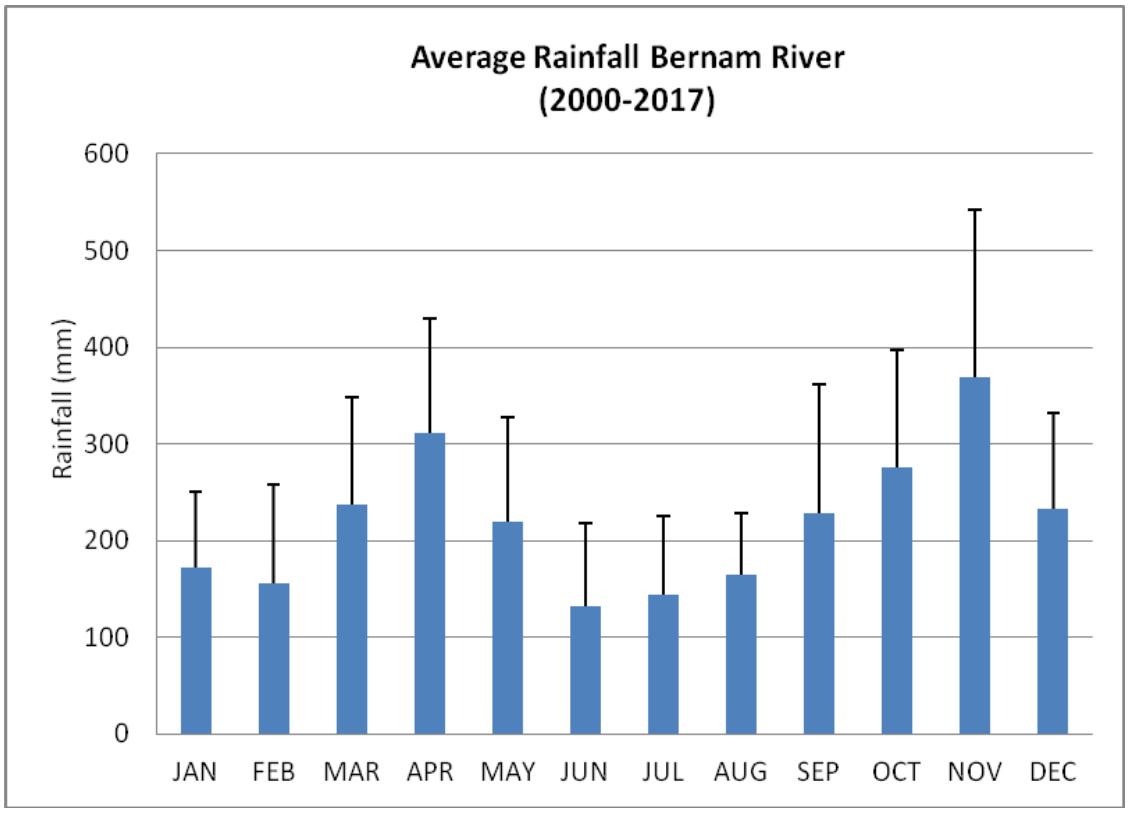


Figure 5: Average monthly rainfall of Bernam River at Tanjung Malim from 2000-2017.

Suspended sediment concentrations. Suspended sediment is defined as material that is kept in suspension by the upward components of turbulent currents or it may exist in suspension as a colloid. The SSC is the velocity weighted concentration of suspended sediment in the sampled zone, expressed as milligrams of dry sediment per litre of water-sediment mixture. Suspended sediment concentration has been used as a measure of fluvial sediment (Parsons and Cooper, 2015). The high amount of suspended sediment indicates that the soil erosion is serious in the watersheds (Thomas, 1985; White, 2005). Figure 6 showed weekly data from October 2017 until January 2018. The highest concentration is 128 mg/L in 11 December 2017 and the lowest concentration is on 19 November 2017 with only 8 mg/L concentration. Based on land-use of Bernam catchment, sediment contribution is come from agricultural and human activities in the catchment area. Sediment rating curve is a relationship between sediment concentration and discharge. Rating curves are used to calculate or predict a variable that is difficult to measure continuously (Willis, 2011). Discharge measurement must be made for at least three different water surface elevations such as low flow, median flow and high flow (James and James, 2017). For this study area, the regression of discharge and SSC is R^2=0.86 high flow sampling while for low flow sampling the regression is R^2=0.5. Best-fit regression lines represent the relation between SSC and discharge and can be used to evaluate how SSC responds to changes in discharge. The gradient of the lines provides an indication of how quickly SSC changes with changes in discharge. Lines with steep positive gradients from left to right indicate SSC increases quickly as discharge increases. Figure 6 shows the low flow and high flow and contribute to the high concentration of suspended sediment and turbidity.

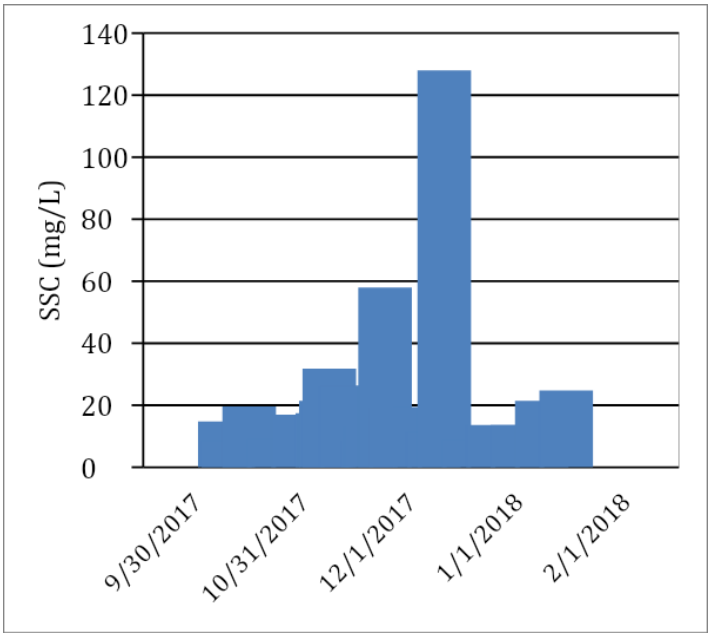


Figure 6a: Temporal variation of rainfall and suspended sediment concentration (SSC), and the relationship between SSC versus Discharge during low flow and high flow condition.

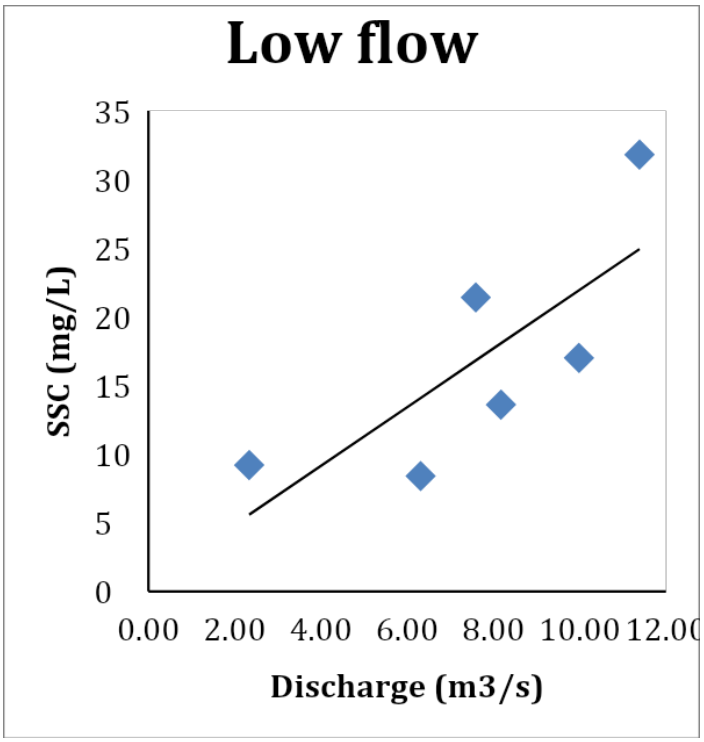


Figure 6b: Temporal variation of rainfall and suspended sediment concentration (SSC), and the relationship between SSC versus Discharge during low flow and high flow condition.

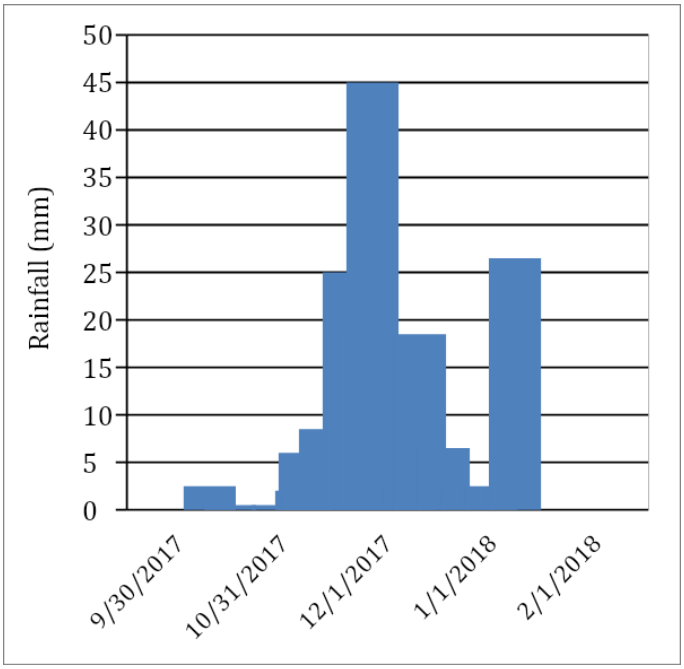


Figure 6c: Temporal variation of rainfall and suspended sediment concentration (SSC), and the relationship between SSC versus discharge during low flow and high flow condition.

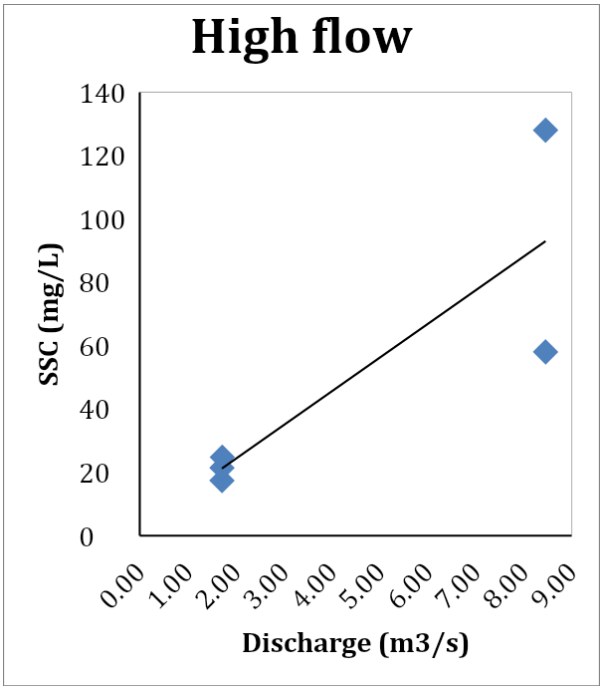


Figure 6d: Temporal variation of rainfall and suspended sediment concentration (SSC) during study period, and the relationship between SSC versus Discharge during low flow and high flow condition.

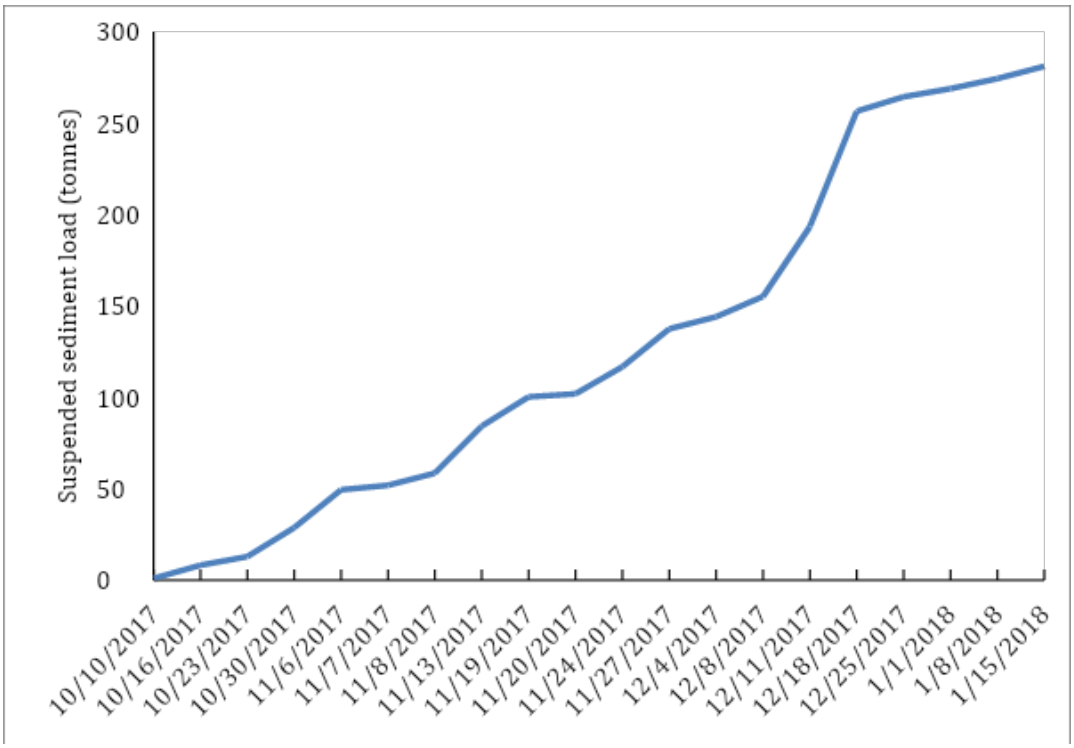


Figure 7: Cummulative of Sediment loading in Bernam River.

Suspended sediment loading and yields. The nature of water is never totally clear, especially in surface waters, such as rivers and lakes. Water has colour and some extent of dissolved and suspended material, usually dirt particles (suspended sediment). Suspended sediment is an important factor in determining the quality of water. In fact, so much sediment is carried during storms that over one-half of all the sediment moved during a year might be transported during a single storm period. Suspended sediment is defined as material that is kept in suspension by the upward components of turbulent currents or that exists in suspension as a colloid. The SSC is the velocity weighted concentration of suspended sediment in the sampled zone, expressed as milligrams of dry sediment per litre of water-sediment mixture.

Suspended sediment concentrations have been used as a measure of fluvial sediment. The high amount of suspended sediment indicates that the soil erosion is serious in the watersheds (White, 2005). Sediment loading is one of the parameters that show the high concentration of sediment in the catchment area. Loadings of suspended sediment between time intervals were calculated by multiplying the discharge Q (m^3 s^{-1}) by concentration S (mg L^{-1}) over the time interval K (s) between samples, based on the average sample load approach (Littlewood, 1992). All statistical and data analysis were conducted in Microsoft Excel. In order to get annual data, estimations can be made from 98 days sampling from this study. Based on this study, sediment load for Bernam River is 1,144 t and estimated sediment load per year is 4,264 t. Cumulative sediment loading is shown in Figure 5. Sediment yield (given as t per year) can be defined as the amount of sediment reaching in the catchment (White, 2005). The importance of study sediment yields is to understand and be aware of how much sediment is deposited in the catchment (Najib et al., 2017). Based on this study, estimation of sediment yields is 22.9 t/km^2/year. Land-use type of Bernam, with the mountainous area under

jungle, may contribute to low amount of sediment yield in comparison to other studies in forested catchments, such as Kalangan River, where the sediment yields was 15.5 t/km^2/year (Sinun et al., 1992), Tekam River yielded 29 t/km^2/year (DID, 1986), Bukit Berembun yielded 20 t/km^2/year (Baharuddin, 1988). From 1984 to 2020, land-use pattern in the Bernam area had undergone obvious transformations (Alasi et al., 2009; Che Ngah et al., 2014). The proportion of area under urban and oil palm increased, and the proportion of rubber and forest reduced. The change of land-use pattern has altered the runoff amount in the area. In the year 2020, predicted runoff has been increased in the rainy season due to large increase of land use changes especially in urban and forest areas, which then accelerate runoff and decrease base flow due to an increase in the impervious area.

CONCLUSIONS

In accordance to sediment study in Bernam catchment area, we suspect that main contributor came from the land-use activities in the catchment. Rainfall event is the driver of the erosion process causing the contribution of the amount of sediment discharged out of the basin. During the course of this three month study, we found that sediment loading for Bernam River amounted to 1,144 t, and this is equivalent to an annual loading of 4,264 t/year. The amount of annual sediment yield was estimated at 23 t/km^2/year and is comparable to other studies in the region that consist of more forested area in the catchment.

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