Sediment Load Distribution Analysis of Langat River Basin, Selangor

Mohd Fozi Ali, Siti Maisarah Ahmad, Khairi Khalid and Nor Faiza Abd Rahman

Abstract Rapid development in urban areas and uncontrolled deforestation are among the factors that contribute to the pollution of rivers through the process of erosion and sedimentation resulting from such activities. Stormwater runoff will flash out all the eroded soil and sediments to the downstream area, and sedimentation will occur in rivers and lead to other environmental problem. This research aims to evaluate the formation of suspended sediment and bedload sediment at the upper part of Langat River Basin, one of the most important river water catchments in Peninsular Malaysia. Sediment samples were collected using sediment grabber and analyzed in the laboratory. Three parameters were quantified throughout this study, namely concentration of suspended sediment (mg/L), river discharge values (m^3/s), and grain size distribution (g). The result showed that the estimated mean sediment load flow into Langat River is 5267.73 ton/km^2/year. Distributions of sediment grain size in upstream of Langat River consist of very rough sediment grains, showing a possibility of logging and deforestation activities within the catchment area. Hence, a long-term preventive measure such as environmental policies regulating land use development and management practices should be formulated and implemented to fix the sedimentation problems in Langat River Basin.

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1 Introduction

Sediments are defined as the materials deposited at the bottom of water bodies [1]. It is in solid fragments of organic or inorganic material form produced from the weathering processes of rocks and minerals, aided by the natural occurring agents such as the wind, water, ice, or others. Deposited material has varies shape and size. In other words, the size of sediment can be small such as silt, medium such as sand, or large such as boulders. Mostly, an estuary found to have fine-grained, such as sand and silt, sediments. The quantity of sediment to be carried away depends on the speed of water flows in a stream. The slower moving flows will have a lower rate sediment movement and adversely for faster moving flows [2].

River discharge from different rainfall distributions is being the important part in determining the sediment loads. In particular, the higher discharge value would increase the water velocity, thus will result in higher sediment load. Furthermore, time is also a vital factor where the higher amount of sediment relies on the longer duration of sediment process. The river is being the one of the essential sources of water for living thing beside lakes, sea, underground water, and other water catchment. However, some processes reduce the river water quality concerning the sedimentary product. These involve erosion, mobility, and deposition. This situation is closely related to a unidirectional flow, where the river will experience water level fluctuations, rates of flow, and rates of erosion during monsoons and droughts. Human activities are the major issue in clearing the natural resources. Urbanization is increasing the impermeable surface that potentially blocks the water penetrates through. It even increases the scale of surface runoff. Furthermore, agricultural practices such as mulching and contour terrace reduce erosion even so decrease the runoff [3]. Nevertheless, the higher the velocity and volume of surface runoff, the higher rate of erosion will increase the amount of soil will be carried away down the slopes. As a result, suspended sediment content will increase as well as the water turbidity of the stream channel, thus lowering the water quality status [4].

Langat River Basin, a tropical river watershed in Malaysia, is chosen for the study in accessing the sediment load distribution analysis. Several studies have been conducted on the basin related to water resources and hydrological behavior of the basin. The basin became a first watershed in the country is initiated toward implementing of Integrated River Basin Management (IRBM) [5]. Many researchers were studied on the hydrological processes of the basin. It includes a historical water discharge study [6] and the impact of land used change on discharge and direct runoff [7, 8, 9]. This study was carried out to determine the suspended sediment yields, the factors that are affecting sediment transport, and finally to assess the particle size range of bedload sediment in Langat River Basin.

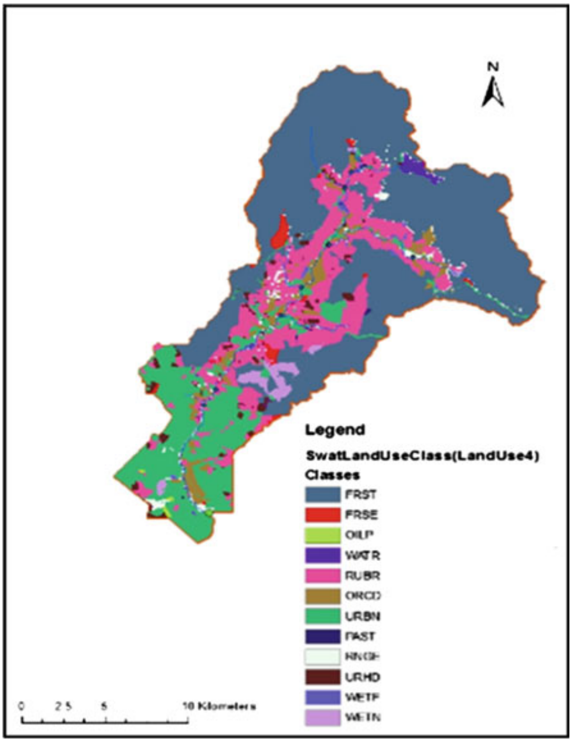

Fig. 1 Land used map of the study area

2 Study Area

The Langat River Basin is one of the most important river water catchments in Malaysia. Situated in Selangor state, the catchment is drained by three main tributaries: Langat River, Semenyih River, and Labu River [10]. The mainstream of the Langat River, which stretches for 141 km, has a total catchment area of 2271 km^2 and lies within latitudes of 2° 40′ 152″N–3°16′ 15″N and longitudes of 101° 19′ 20″E–102°1′10″E. Langat catchment presently consists of two reservoirs, the Langat Reservoir and the Semenyih Reservoir, respectively, and eight water treatment plants [11]. The upper part of Langat River as in Fig. 1 has a total catchment area approximately 331.9 km^2 [12]. The catchment area was found to have 12 broad classes of land cover [13] as shown in Fig. 1. The hilly part locates the study area was covered by steep land.

3 Methodology

A four sampling stations representing the length of the Langat River were selected: Station 1 (S1) at upstream Pangsun, Station 2 (S2) at Sg. Lui, Station 3 (S3) at mid-stream of Dusun Tua, and Station 4 (S4) at downstream Kajang as shown in

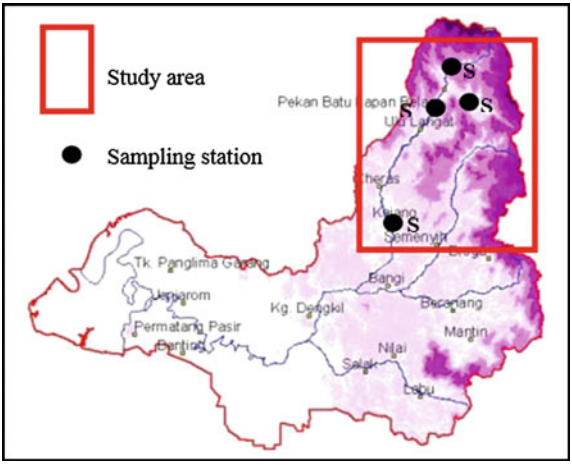

Fig. 2 Graphical location and sampling point of study

Fig. 2. Water samples were taken from each station and kept in polyethylene bottles for analysis to find the total suspended sediments (TSS) in the upper part of Langat River. Sediment samples were also collected using sediment grabber. The samples taken were analyzed in the laboratory. The cross-sectional length and water velocity were also measured at each station using several types of apparatus such as the measuring tape, poles, and stopwatch.

For the stream flow measurement, floating object (orange) was applied in this study to obtain the stream discharge value. Parameters, such as the flow velocity, width, and depth of the river, were determined in situ and used for purposes of measuring specific discharge values. Discharge value (Q) was calculated using several variables including stream cross-sectional area, stream length, and water velocity. Discharge was measured by solving the following equation:

$$Q = ALC/T \tag{1}$$

where

- A Average cross-sectional area of the stream (stream width multiplied by average water depth)
- L Length of the stream reach measured (usually 20 ft.)
- C A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams)
- T Time, in seconds, for the float to travel the length of L
- Q Discharge value (m^3/s)

The photometric method applied by spectrophotometer was used to determine the TSS value directly. This study required a 10 ml water sample for each study area plot. The measurement of suspended solids needs a blank sample of 10 ml of deionized water as an indicator. After both samples were completely prepared, the machine is ready to be set up for the testing. The blank sample should be assigned to zero by means of 0 mg/L. The real sample is then inserted, after the blank sample is removed. The TSS value is shown in the screen directly in mg/L.

The calculation of suspended sediment load value (SL) is based on the discharge value, TSS value, and area of sampling catchment. The data to be analyzed would be used to detect changes in the concentration of suspended matter and its relationship to hydrological parameters and other variables.

$$\begin{aligned} \mathrm{SL} &= (Q \times \mathrm{TSS})/\text{area of sampling point} \\ &= (\mathrm{L/day} \times \mathrm{kg/L})/\mathrm{km}^2 \\ &= \mathrm{kg/km^2/day} \times 365\ \text{days} \\ &= \mathrm{kg/km^2/year} \end{aligned}$$

The sieving method was done by spreading the sediments into the aluminum trays and marked them with each station representative. Grain samples then were put into an oven and leaving them to dry at 105 °C for 24 h. The grain samples collected from all stations mostly showed the coarser grain; that is, the greatest particle size is 4.75 mm. Therefore, for easy handling, the soil sample was approximately weighed into 500-g samples using an electronic weighing machine and sieved 15 min with a mechanical shaker. The sizes of sieve tray utilized in this study were 4.75, 3.35, 2, 1.18, 0.6, 0.425, 0.212, 0.15, 0.063 mm. Once all grain samples had been separated according to size, they were weighed on an electronic weighing balance to the nearest two-point decimal. The weight of each sample size represented a percentage size of the soil.

The Udden-Wentworth scale as rewritten in Table 1 and sorting classification in Table 2 are referred in this study. The graphical representations do simplify the analysis made. The *x*-axis scale is the phi value while the *y*-axis is the cumulative percentage scale value (0–100 %) using a linear scale is shown in Fig. 3. The cumulative curve was used to determine the phi size of each phi value (phi at 5 %, phi at 16 %, and so on, where % refers to cumulative percentage) is recorded in Table 3. The various statistical values above are used to calculate the following equations of statistical parameters:

Table 1 Distribution size of mean value

Distribution size of mean value	
Phi value (ϕ)	Udden-Wentworth size class
−2 to −1	Gravel
−1 to 0.0	Very coarse sand
0.0 to 1	Coarse sand
1 to 2	Medium sand
2 to 3	Fine sand
3 to 4	Very fine sand

Table 2 Sediment sorting range

Sediment sorting range	
Sorting range (ϕ)	Description of sorting
<0.35	Very well sorted
0.35–0.50	Well sorted
0.50–0.71	Moderately well sorted
0.71–1.00	Moderately sorted
1.00–2.00	Poorly sorted
2.00–4.00	Very poorly sorted
>4.00	Extremely poorly sorted

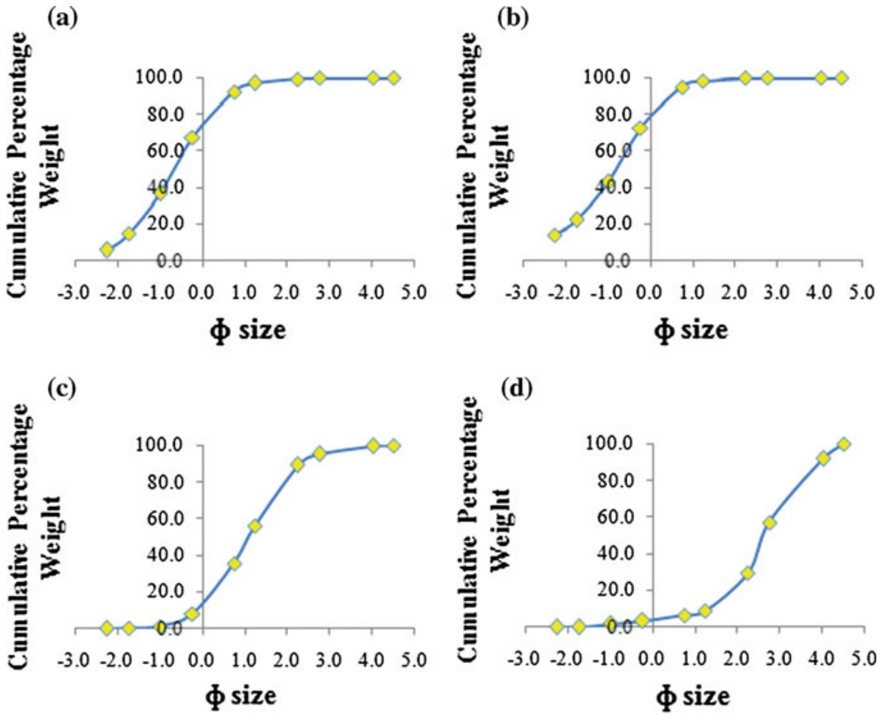

Fig. 3 Soil grain size graph obtained through the calculations in sieving analysis. **a** Station 1. **b** Station 2. **c** Station 3. **d** Station 4

$$\text{Median} = \phi\,50 \tag{2}$$

$$\text{Mean (M)} = (\phi\,16 + \phi\,50 + \phi\,84)/3 \tag{3}$$

$$\text{Standard deviation } (\sigma) = [(\phi\,84 - \phi\,16)/4] + [(\phi\,95 - \phi\,5)/6.6] \tag{4}$$

Table 3 Phi value derived from sieving analysis

Phi value derived from calculations in sieving analysis							
Station 1		Station 2		Station 3		Station 4	
Perc. (%)	Phi	Perc. (%)	Phi	Perc. (%)	Phi	Perc. (%)	Phi
5	−2.3	5	−3	5	−0.4	5	0.4
16	−1.7	16	−2.1	16	0.1	16	1.7
50	−0.7	50	−0.8	50	1.1	50	2.6
84	0.4	84	0.2	84	2.1	84	3.7
95	0.9	95	0.8	95	2.8	95	4.2

4 Results and Discussion

The observed discharge value was measured to be higher at the Kajang station compared to the other three stations on the upper of the watershed. The station is the largest area of sampling point where the difference in depth and width of the river significantly influences the flow value of the river. The average value of discharge was measured to be at 15.4, 6.8, 2.78, and 2.65 m^3/s for a Kajang station, Dusun Tua, Sg. Lui, and Pangsun station, respectively.

The results of TSS are shown in Table 4. Station 4 was found to have the highest average of TSS value at 326.91 mg/L. In contrast, the lowest value was recorded at the Station 2 with the mean TSS value of 9.53 mg/L. This sampling station was identified as the station located at the lower part of the area of the study placed within the greatest catchment area. The finding views a maximum amount of 780.33 mg/L suspended sediment on November 5, 2014, compared to September 9, 2014 (192.87 mg/L) at Station 4. This could have been due to the consequence of stream flow that was suddenly increased on November 5, 2014. Sedimentation is a complex problem in humid tropical areas such as Malaysia as the soil erosion often occurs when the presence of very high precipitation will increase a river discharge straight away deteriorating the river water quality.

The correlation between streamflow and suspended sediment values in Langat River has been analyzed in order to determine their relationship. A significant association of $R^2 = 0.998$ between observed discharge values and TSS values was

Table 4 Total suspended sediment (TSS) at Langat River Basin

Sta.	TSS (mg/L)						
	24/9	30/9	15/10	29/10	5/11	12/11	Mean
S1	8.96	10.27	10.97	12.67	12.91	13.33	11.5
S2	6.00	8.73	9.00	10.33	10.85	12.25	9.5
S3	104.33	117.3	122.20	156.04	168.3	172.40	140.1
S4	192.87	214.6	404.00	177.33	780.3	192.35	326.9
Total	312.16	350.8	546.17	356.37	972.3	510.33	–
Max.	192.87	214.6	404.00	177.33	780.3	192.35	326.9

gained for the Langat River. Linear graph exhibits that an increase in stream flow value would cause an increase in TSS value, leading to a higher value of water turbidity. Therefore, flow capacity value is the factor that could affect the mobility or TSS values. As a result, the higher velocity of water induced by river discharge will increase the rate of soil detachment and produce more suspended sediment yield in a river.

Sediment load is defined as the total mobility of sediment scoured onto the riverbed. The annual increase in suspended sediment load would leave a significant impact on the drainage system. Alluvial deposition, if not persistently controlled, will be an increasingly serious problem from now on. Consequently, a water quality of a river will decrease. Furthermore, a reduction of river's depth will lead to surface overflow or flooding within the surrounding area. Hence, it will adversely impact all living things, including demolishing the local inhabitants. Throughout this study, daily and yearly sediment yields were calculated at certain sampling stations due to the limitation of data as shown in Table 5. The catchment area of stations 2 and 4 has been identified as their watershed area of 68.1 and 331.9 km^2, respectively. The highest sediment load (9,322,032.31 kg/km^2/year) was observed at Kajang mainstream and the lowest (235,569.91 kg/km^2/year) at Lui River. High sediment load at Kajang stream was due to higher precipitation and probably related to the higher flow and concentration of sediment. The increase in water level during the monsoon season is owing to the softening of soil slopes, aided by the nearest human activities, causing them to be eroded easily, thus decreasing the depth of a river [2]. Therefore, it is reasonable that Station 4 shows the highest suspended sediment load values (owing to the higher TSS value at 326.91 mg/L). Other factors including the dumping of garbage and other domestic activities by residents also contribute to the increase of the sediment deposition in the catchment area.

The analysis of sediment grain size in this study is shown in Table 6. The measurement of phi (ϕ) introduced by Wentworth was used in the study. The median value is the mid-value in a set of data arranged in ascending order.

Table 5 Suspended sediment load

Sampling station	TSS (mg/L)	TSS (kg/L)	Total sediment per day (kg/km^2/day)	Total sediment per year (ton/km^2/year)
Station 2	9.53	0.00000953	654.36	259.67
Station 4	326.91	0.00032691	25,894.53	10,275.78

Table 6 Sediment grain size distribution

Station	Median	Mean	Standard deviation
S1	−0.7	−0.667 (very coarse sand)	1.010 (poorly sorted)
S2	−0.8	−0.900 (very coarse sand)	1.151 (poorly sorted)
S3	1.1	1.100 (medium sand)	0.985 (moderately sorted)
S4	2.6	2.667 (fine sand)	1.076 (poorly sorted)

The mean size of an individual grain size is the baseline for comparing the weight force and flow force needed before water movement would occur. Typically, rough grains demonstrate a strong energy flow, whereas fine grains demonstrate weak energy flow. As specified in Table 6, the median value of Station 4 situated at Langat downstream is the highest of the four stations at phi 2.6. The mean size analysis at the upstream mainly exhibited very coarse sand sizes between phi −1.00 and phi 0.00. The average values of the downstream and midstream stations of Langat River show fine sand at phi 2.667 and medium sand at phi 1.100. The values, therefore, indicated that energy flow at the two upstream stations was high. Otherwise, the downstream station experiences low energy flow. Thus, the overall energy flow of the Langat River at the time of the study (29/10/14) was varied depends on the elevation of the stations.

The standard deviation indicates the sorting classification of the grain size distribution. For instance, high amount of rough grain size would be having a huge value of standard deviation represents as poorly sorted. As exhibited in Table 6, it is discovered that three stations which are stations 1, 2, and 4 were having poorly sorted of sediment. Only the middle sampling station has moderately sorted. In short, this kind of condition justifies that the Langat River has poorly sorted of sediment that is possible from the influence of the surrounding activities. In brief, the study shows the sediment grain size in the Langat River is varied from very coarse-to-fine sand and having poor levels of uniformity.

5 Conclusion

The study shows that the suspended sediment concentrations of the four stations along Langat River are increasing to the downstream. According to the data tabulation, the average value of TSS obtained in the upper part of Langat River is relatively moderate (122.01 mg/L) compared to the other water column in Malaysia. Langat River also demonstrates that one of the stations exhibits the highest sediment production that is 10,275.78 ton per year within 331.9 km^2 of the area. Therefore, necessary steps toward its rehabilitation and prevention must be initiated and implemented immediately as suspended sediment load would affect water quality and aquatic life. The factor of sediment mobility at the Langat River was controlling with the observed streamflow value. Significantly, the increased rate of stream flow could influence the production of suspended sediment. Nevertheless, the reason for sedimentation increase through the Langat River was not due to flow alone. The adjacent activities such as urban development, agriculture, and logging do contribute to the increasing level of riverbed sediments. Based on the observations during the sampling days, Langat River experienced recurrent flooding and overflows from the Station 4 during the monsoon period.

A study on the distribution of sediment grain size was found that the upstream of Langat River consists of very rough sediment grains, showing a possibility of logging and deforestation activities within the catchment. The fine grains found an increase in the downstream locations demonstrate the presence of urban development including construction projects which owing to the major problem of flash flood occurrence. Therefore, a long-term preventive measure such as environmental policies regulating land use development and management practices should be formulated and implemented immediately to fix the sedimentation problems in Langat River.

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