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The Relation of Neighbouring Land Use Type and Sedimentary Characteristics of Fluvial Sediments in Tropical Rivers

(Kaitan Penggunaan Jenis Tanah Jiran dan Pencirian Sedimen untuk Sedimen Fluvium di Sungai Tropika)

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ABSTRACT

This study investigates the relationship between land use types and sedimentary characteristics of fluvial bed at three rivers in Selangor, Malaysia; namely Sungai Tengi, Selangor and Langat. The diversity in population density and land development at the adjacent river banks gives associated dominant land use type as forest, agriculture and urban for Tengi, Selangor and Langat, respectively. Field sampling was conducted at consistent spatial locations for Tengi and Selangor, whereas for Langat, the bed sediment was taken at non-uniform spatial points due to limited access. Statistical analysis of the sediment bed mixture shows that forest dominated land gives finer bed sediment size at < 200 µm. Agriculture-type of land use increases the mean sediment size to medium sand, whereas bed material near to urbanized areas has coarser sediment size with > 650 µm. Correlation analysis proved that there is a relationship between types of land use with the mean sediment size. No distinctive correlation can be observed for sorting, skewness and kurtosis of the sediment with the types of land use.

Keywords: Correlation analysis; land use type; sedimentary characteristics; tropical rivers

ABSTRAK

Kajian ini melihat kepada hubungan antara guna tanah dan ciri sedimentari sedimen dasar sungai daripada tiga sungai di Selangor, Malaysia iaitu Sungai Tengi, Selangor dan Langat. Ketiga-tiga sungai ini mempunyai kepadatan penduduk dan jenis guna tanah yang berbeza dengan Tengi, Selangor dan Langat masing-masing didominasi oleh hutan, pertanian dan perbandaran. Pengumpulan sampel di tapak dilakukan pada lokasi jarak reruang yang tekal untuk Tengi dan Selangor manakala untuk Langat, sampel dasar diambil pada titik persampelan reruang yang tidak seragam disebabkan akses yang terhad. Analisis statistik bagi campuran sedimen menunjukkan kawasan didominasi guna tanah jenis hutan memberikan sedimen dasar bersaiz < 200 µm. Jenis guna tanah pertanian meningkatkan saiz purata sedimen kepada julat jenis pasir sederhana, manakala sedimen kasar dengan saiz > 650 µm dijumpai di dasar sungai dengan kawasan tebing adalah jenis perbandaran. Analisis korelasi membuktikan terdapat hubungan antara jenis guna tanah dan saiz purata sedimen. Tiada korelasi ketara dijumpai bagi pengisihan, kepencungan dan kurtosis bagi campuran sedimen diambil dengan jenis guna tanah.

Kata kunci: Analisis korelasi; ciri sedimen; jenis guna tanah; sungai tropika

INTRODUCTION

Grain size distribution is an essential fundamental physical aspect of soil and influences the soil properties including soil erosion, water movement and productivity (Dongwei et al. 2010). The value of mean sediment size, which is often used in engineering design is essential to be properly determined. Bed material size becomes the factor in regulating channel morphology and hydraulics, sediment transport and the downstream changes along the river (Reid et al. 1997). The underlying process of sediment structure and characteristics depend on the grain size distribution width, geographical setting and sediment mobility (Frings 2008). Physical characteristics of sediment give an indication of the historical transport behaviour and are useful in engineering design and modelling such as bridge construction, river rehabilitation work and self-cleansing velocity in pipes and urban drainage.

Spatial sediment characteristics from the upstream to downstream of a river experienced ‘downstream fining’ process, where the sediment mean size gets finer, particularly in a gravel riverbed (Gasparini 1999; Gomez 2001; Surian 2002). The abrasion process and the mobility of finer grain size (compared to coarse sediment) at the downstream course contribute to the concave profile of downstream fining process. However, downstream fining is not always the case and discontinuity of downstream pattern due to river tributaries, sediment addition-extraction and anthropogenic activities (Rice 1999; Frings 2008).

The bed material size is also one of the important parameters in sediment fingerprinting assess the sources of sediment within a watershed. It is commonly employed and used to identify the pollution behaviour and the potential source (Horowitz & Stephens 2008). Urban types of land use exert significant influence on the sediment-associated chemistry of the river bed, whereby the concentration of heavy metal constituents linearly correlates with the increasing population density (Horowitz & Stephens 2008). Sediment attribute such as particle size and its distribution strongly influenced the remobilisation of heavy-metal bound into the overlying water column (Simpson et al. 2012). Sediment fraction with size less than 63 µm is important for the adsorption and transport of metals due to its larger surface area and are more prone to be in suspension (Zhang et al. 2014).

In the same line, it is expected that type of land use plays important role in the physical sediment characteristics due to different runoff coefficient. Land use is one of the influential elements in global change due to human activities and its associated impacts on the natural ecosystem (Aguilar & Ward 2003; Lopez et al. 2001). High rainfall intensity and prolonged rainfall events (particularly at monsoon seasons) consequently give the big volume of surface runoff flowing into the river. High flow velocity increases the susceptibility of surficial erosion and resulted in excess sediment coming into a river.

The spatial information of land use or land cover mapping at the adjacent river banks using the Geographical Information System (GIS) provides accurate multispectral classification and is helpful particularly in areas with limited accessibility (Molenaar & Janssen 1992). The GIS-based mapping allows an integration with the latest localised land use type and the approach is more cost and time efficient compared to the field identification.

This study attempts to investigate sedimentary characteristics of three different categorical rivers and its associated effect of the neighbouring land use on the fluvial sediment characteristics. The sedimentary and textural characteristics are based on the statistical analysis including mean sediment size, sorting, skewness and kurtosis.

MATERIALS AND METHODS

STUDY AREA

Three main rivers in the state of Selangor, i.e Sungai (hereinafter Sungai is denoted as Sg.) Tengi, Langat and Selangor were chosen for this study. The location of the three rivers and their physical characteristics are described in Figure 1 and Table 1, respectively. These three rivers were considered based on its criteria population and development density with its respective catchment area.

SAMPLING METHODS

The collection of bed samples was conducted in February 2015, when the North East monsoon is reaching its end. A stainless steel grab sampler, with volume up to 1.5 L, was used to collect sediment in the active region and immediately sealed in an airtight container. The sampling procedure is ensured to be collected from the same location in the river and is continued until the volume of sample

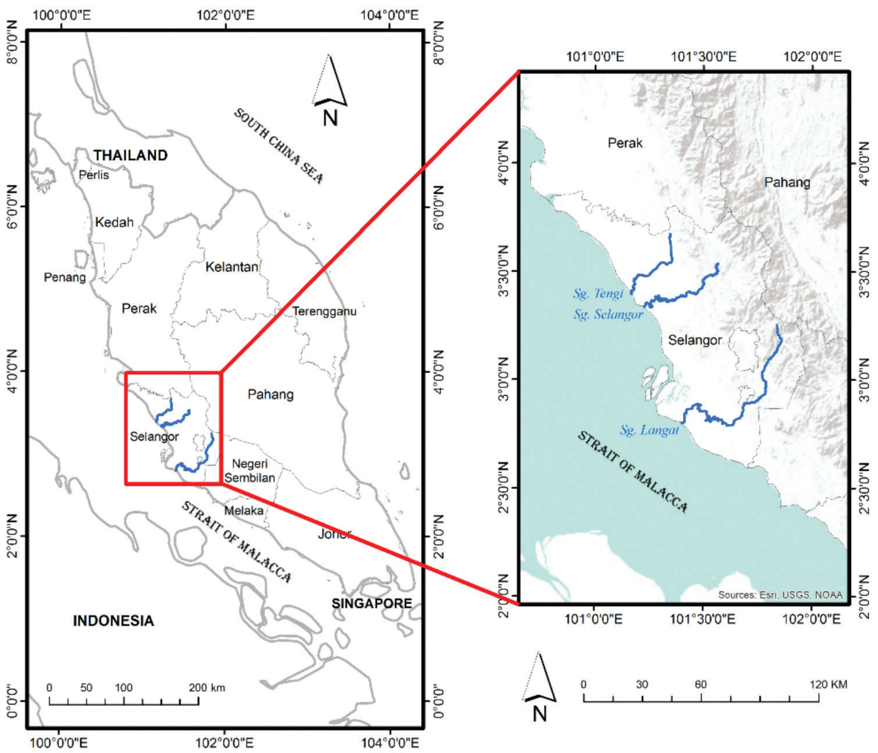


FIGURE 1. Location map of the studied rivers

TABLE 1. The characteristics of Sg Tengi, Sg. Langat and Sg. Selangor

River	Coordinates	Length (km)	Catchment area (km^2)	River pattern	Density population ('000)
Sg. Tengi	N 3° 32' 29.0034" E 101° 20' 38.328"	58	370	meandearing	138
Sg. Langat	N 2° 50' 53.6274" E 101° 25' 22.296"	180	2423	meandering	244
Sg. Selangor	N 3° 21' 43.92" E 101° 15' 35.532"	134	429	meandering	198

is more than 1 kg. Note that the active region is defined as the middle area of the river, where the flow velocity is at its highest. The active area was defined from the map prior sampling to ensure the samples were collected at the specified locations. A total of 27 samples were collected with nine, ten and eight samples from Sg. Tengi, Sg. Langat and Sg. Selangor, respectively. Both Sg. Tengi and Sg. Selangor was accessed by boat, whereas for Sg. Langat, as continuous water transportation (using boat) is not permissible, the bed samples were collected using a self-made vacuumed pipe. The PVC threaded pipes are individually 1.3 m long with an opening diameter of 3 in (80 mm). The screw-threaded ends at each pipe allowed for assembly and lengthen the tube up to 6 m long. The specific locations where samples were collected for Sg. Langat which can be easily accessed by car were identified using maps prior to collection. Note that although with limited access, attention was paid to where the samples were collected. We ensured that the sampling location is within the active area or as close as it can be. In this case, the active region is extended to areas 1/3 distance from the bank. At this point, the flow velocity is not significantly varied from the mean velocity and hence can still be deemed as the active region. Figure 2 shows the maps of sampling point from upstream to downstream for the three rivers discussed in this study.

All samples were brought back to the laboratory and dried in the oven at 105°C for 24 h prior to physical sieving. All samples were sieved using sieve series of sizes 4.75, 2.36, 1.18, 0.6, 0.3, 0.15, 0.075 mm and pan. The nest of sieves was put on the sieve shaker for about 20 min before the weight of retained sediment in each sieve was

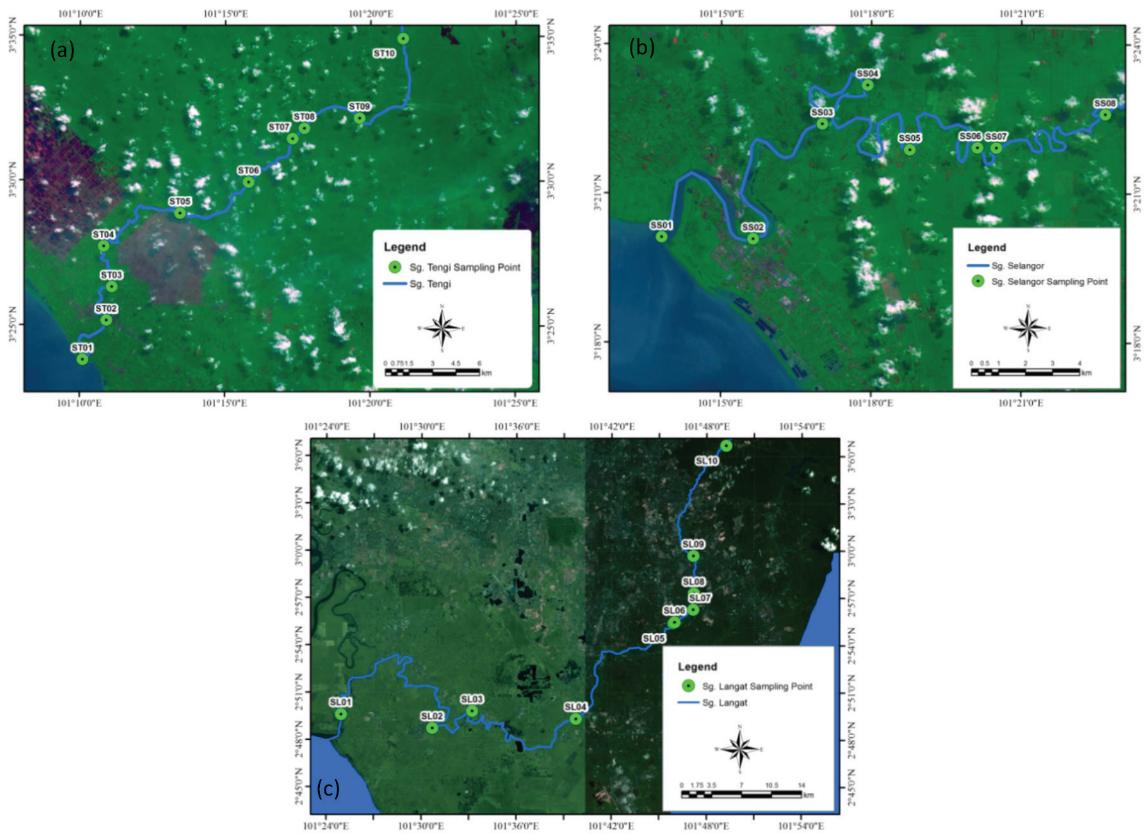


FIGURE 2. Map of sampling area (a) Sg. Tengi (b) Sg. Selangor (c) Sg. Langat

measured. For a full spectrum of grain size distribution particularly for smaller sediment size, retained sediment at the bottom pan was put into the Mastersizer 2000 (MU) to obtain its finer distribution. Analysis of sieving permits an assessment of the grain size distribution of the collected sediment mixture (Sonaye & Baxi 2012).

The retained sediment mass on each sieve size for all samples are recorded and tabulated. Based on the data, statistical analysis on the sediment distribution which includes the calculation of the mean (M_z), the degree of sorting (σ_I), skewness (Sk_I) and kurtosis (K_G) were performed using the established logarithmic original formula based on Folk and Ward (1957), presented here in Table 2. Following this, the sedimentary characteristics for each sampling points were obtained and analysed based on river distance and the associated land use types using the statistical approach.

DETERMINATION OF LAND USE

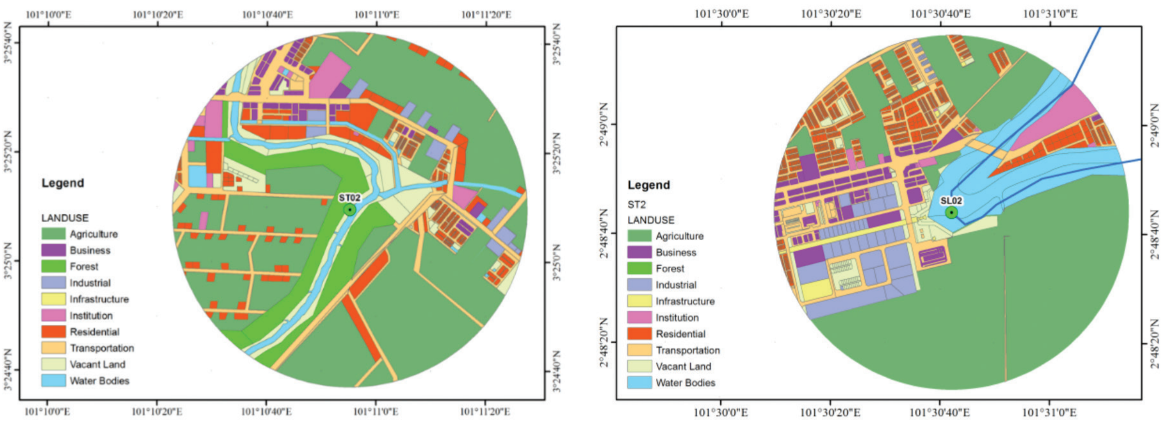
The type of land use at both river banks, which was determined based on 100 m^2 area from the location of sampling, was established using a set of GIS maps. To give a general idea of how the spatial features of land use identification conducted in this study, Figure 3 shows the representative maps of land use at selected locations.

Using the GIS map, the land use types were identified and colour coded. Initially, there were nine categories i.e. agriculture, business, forest, industrial, infrastructure, institution, residential, transportation and vacant land. Each category has its associated percentage of land use at each

TABLE 2. Statistical formulate used in the calculation of grain size parameters using the logarithmic Folk and Ward (1957) graphical measures

Mean	Standard deviation	Skewness	Kurtosis
$(M_z) = \frac{\varphi 16+\varphi 50+\varphi 84}{3}$	$(\sigma_I) = \frac{\varphi 84-\varphi 16}{4} + \frac{\varphi 95-\varphi 5}{6.6}$	$(Sk_I) = \frac{\varphi 16+\varphi 84-2\varphi 50}{2(\varphi 84-\varphi 16)} + \frac{\varphi 5+\varphi 95-2\varphi 50}{2(\varphi 95-\varphi 5)}$	$(K_G) = \frac{\varphi 95-\varphi 5}{2.44(\varphi 75-\varphi 25)}$

Sorting (σ_I)		Skewness (Sk_I)		Kurtosis (K_G)	
Very well sorted	<0.35	Very fine skewed	$^+0.3$ to $^+1.0$	Very platykurtic	<0.67
Well sorted	0.35-0.5	Fine skewed	$^+0.1$ to $^+0.3$	Platykurtic	0.67-0.9
Moderately well sorted	0.7-1.00	Symmetrical	$^+0.1$ to $^-0.1$	Mesokurtic	0.9-1.11
Poorly sorted	1.00-2.00	Coarse skewed	$^-0.1$ to $^-0.3$	Leptokurtic	1.11-1.5
Very poorly sorted	2.00-4.00	Very coarse skewed	$^-0.3$ to $^-1.0$	Very leptokurtuic	1.5-3.00
Extremely poorly sorted	>4.00			Extremely leptokurtic	>3.0



(a) (b)

FIGURE 3. Representative maps of land use at selected sampling points, covering an area of 100 m^2 size. The left and right figures represent points 2 of Sg. Tengi and Sg. Langat, respectively

sampling location. To have a better perspective in terms of land use contribution on the fluvial bed characteristics, these categories were reduced to three major classes, namely forest, agricultural (i.e. a combination of agriculture + vacant land) and urban (i.e. unification of business, industrial, infrastructure, institution, residential and transportation). The consolidation of categories (from nine to three) is permissible based on their similar runoff characteristics.

To provide an overview of the land use type for the three rivers (on the stretch of sampling points), Figure 4 shows the pie chart of the percentage of land use for each river. Forest dominates Sg. Tengi banks with 62%, whilst Sg. Selangor is more of an agricultural type of land use (with 48.9%) and the adjacent banks of Sg. Langat is 49% urbanised and developed areas. The runoff coefficient (*C*) obviously varied based on the land use types where *C* for urban, agricultural and forest is 0.8-0.9, 0.5-0.6 and 0.15, respectively. Sediment-laden flow is expected from urban areas due to the high coefficient runoff, whereas a low concentration of sediment is likely for the forest region. The available natural protection vegetation cover controls the susceptibility of surface sediment to be eroded by the surface runoff.

The type of land use (adjacent to each sampling point) is determined based on the majority percentage from the modified three major land use classification as discussed above. The determination of the type of land use is straightforward, that is, in the case of the percentage of the dominant class is more than 70%. However, where areas with the majority class are between 55 and 70%, direct labelling using the dominant category as the type of land use does not fully represent the runoff characteristics. As > 55% was considered as the value to be the majority land use for each sampling site, areas with quite a significant fraction of other land use type need to be incorporated. As such, six categories of land use are newly introduced to represent the type of land use more accurately. The type of land use includes both majority class (mandatory to be >55%) and sub-majority class (i.e. with the second highest percentage). This provides a holistic view of actual land use and avoids the dubious presentation of isolated land use.

The determination of land use type follows the following procedure:

For sampling point with the majority land use class is 70%, the name of land use follows the name of the dominant class; and for sampling point with the majority land use class has percentage < 70%, the name is a combination of the majority plus the second highest, whereby the name is referred to Table 3.

For example, if sampling site A is covered with 85% forest and agriculture is 15%, then the type of land use is denoted as forest (as the majority land use is > 70%). Whereas for sampling site B with land use percentages are of forest (60%), agriculture (30%) and urban (10%), the type of land use for site B will be known as AgriForest, following the description as given in Table 3.

RESULTS AND DISCUSSION

SEDIMENTARY AND TEXTURAL CHARACTERISTICS

This section is dedicated to discuss on the statistical characteristics of sediment distribution and associated type of land use at the sampling location. The analysis starts

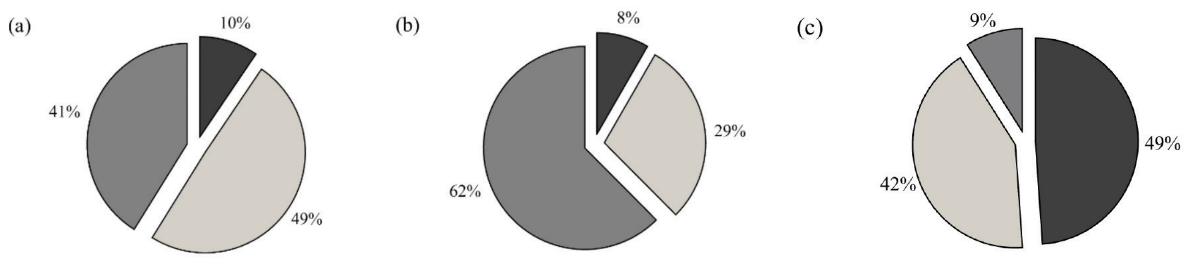


FIGURE 4. Percentage of the forest (medium grey), agriculture (light grey) and urban (dark grey) type of land use at (a) Sg. Tengi, (b) Sg. Selangor and (c) Sg. Langat

TABLE 3. The proposed name of land use type where the majority percentage is > 55% and < 70%

Majority class (55 < % < 70)	Sub majority class	Proposed new name
Agriculture	Forest	ForAgri
Forest	Agriculture	AgriForest
Agriculture	Urban	UrbanAgri
Urban	Agriculture	AgriUrban
Forest	Urban	UrbanForest
Urban	Forest	ForUrban

with Sg. Tengi, followed by Sg. Selangor and ends up with the most urbanized river reviewed here, i.e. Sg. Langat. The statistical sediment characterisation is described in both phi scale $\phi = \log_2 d$ and its corresponding mm scale, in particular where the mean sediment size is concerned.

SUNGAI TENGI

Table 4 and Figure 5 show the statistical characteristics of sediment distribution and sampling points at Sungai Tengi, respectively. The type of land use for points ST10 to ST6 is forest, followed by agriculture at downstream areas of ST6 (i.e. ST5 - ST3). There is a fraction of urban on the river bank at ST 2 before less urbanisation at the river mouth (i.e ST 1).

Mean sediment size of the upstream parts (i.e. ST 6- 10) shows a range of 2.6 to 3.36ϕ (0.1 to 0.17 mm), indicating the presence of fine size sediment. Downstream of the river have coarser sediment size ranging about the same size of 1.3 - 1.7ϕ (i.e. 0.3 to 0.4 mm) within the 20 km length.

Here, a distinguished pattern of mean size with the type of land use is rather evident. The land use type of forest has low runoff coefficient (C) value (about C=0.15) which resulted in low flow velocity. Coarse sediment tends to settle or deposited within the flow path prior to being discharged into the river. The demolition of trees for conversion to agriculture land obviously changed the runoff coefficient into much higher value (C=0.3-0.6), increasing the chances of coarse and fine sediment to be transported into the river. There was no obvious spatial trend of mean size in this river that is either downstream fining or coarsing. The relatively coarse sediment size (categorised as medium sand) was found even at the river mouth of Sg. Tengi (look at ST1).

In general, the sorting behaviour with regards to the sediment mixture is poorly sorted and is found to be independent of spatial and type of land use. However, it can be said to a certain extent that sediment distribution at the upstream part is better sorted since based on Table 2, the values lies at the lower value of the poorly sorted range (about 1.2ϕ) for ST7 and ST10. Low sorting values in sedimentary characteristics are usually found in the sediment mixture where the mean grain size lies within the range of fine sand (Griffiths 1967).

The sediment found at Sg. Tengi has the range of skewness from -0.089 to 0.466ϕ (1.064 to 0.724 mm). The range falls within very fine skewed to symmetrical. Overall analysis presented that 60% of the sediment is in the fine skewed classification and the other 20% fall under the very fine skewed and symmetrical groupings. The sediment distribution shows the spatially fluctuating behaviour of symmetrical to fine skewed and no pattern with regards to the type of land use was observed.

In general, the kurtosis profile for Sg. Tengi sediment is varied where 60% of the samples fall under mesokurtic and another 10% are categorised as platykurtic, extremely leptokurtic, very leptokurtic and leptokurtic. The values of kurtosis lie in the range from 0.849ϕ to 8.301ϕ (0.555 to 0.003 mm). There is no obvious relationship between the spatial characteristic of kurtosis with the type of land use. However, the bed sediment at the downstream of Sg. Tengi displays relatively similar values of kurtosis and falls under the category of mesokurtic. It is worth to highlight that for Sg Tengi, the highest value of kurtosis was found at sampling point (ST10) where forest is the type of land use.

SUNGAI SELANGOR

The map of areas at each sampling point at Sg. Selangor is shown in Figure 6 and the data shows that the dominant type of land use in this river is agriculture. Even so, the percentage of agriculture does not reach up to > 70%, where forest takes up the second highest land use category. As such, ForAgri type of land use dominates the landscape from SS 8 to SS 4. A dip percentage of agriculture at SS 3 changes the land use to AgriForest before quite a significant fraction of urban was found at ST 2. The most downstream part of Sg Selangor (i.e SS 1) is mostly forested land.

Data of statistical characterisation of sediment mixture collected for Sg. Selangor is shown in Table 5. Most of the sediment found in the river bed of Sg. Selangor is medium sand, where mean size ranging from 1.57 to 1.96ϕ (equivalent to 0.26 - 0.34 mm), except at SS 7 with higher mean size of 0.989ϕ (i.e. 0.5 mm). The point at the

TABLE 4. The statistical characteristics of bed sediment collected at Sg. Tengi

	Percentage (%)			in phi (ϕ)				
Sampling point	Forest	Agriculture	Urban	mean	sorting	skewness	kurtosis	Majority land use
ST1	68.19	21.14	10.67	1.684	2.018	0.209	0.933	AgriForest
ST2	11.84	56.70	31.46	1.606	1.905	0.199	1.177	UrbanAgri
ST3	26.62	59.86	13.51	1.313	2.154	0.466	1.089	ForAgri
ST4	3.01	89.52	7.47	1.607	2.050	0.247	0.972	Agriculture
ST5	51.97	35.53	12.5	1.716	1.906	0.149	0.849	AgriForest
ST6	100	0	0	3.356	1.780	0.005	2.166	Forest
ST7	100	0	0	2.564	1.253	0.140	1.000	Forest
ST9	100	0	0	3.302	2.088	0.451	0.942	Forest
ST10	100	0	0	2.569	1.263	-0.089	8.301	Forest

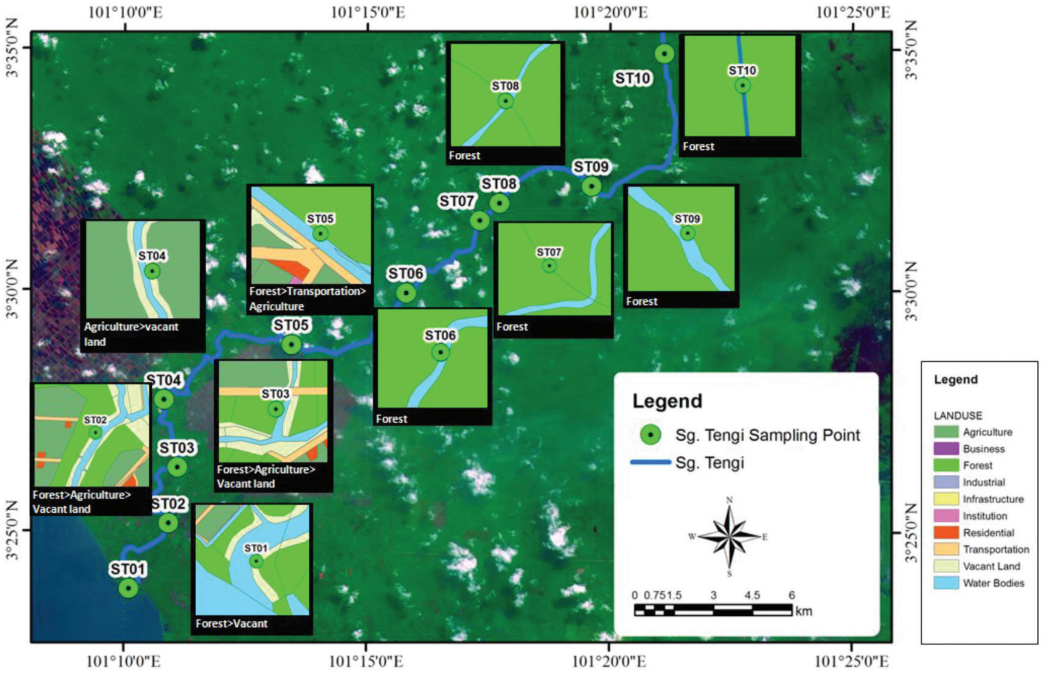


FIGURE 5. Map of sampling points collected at Sg. Tengi

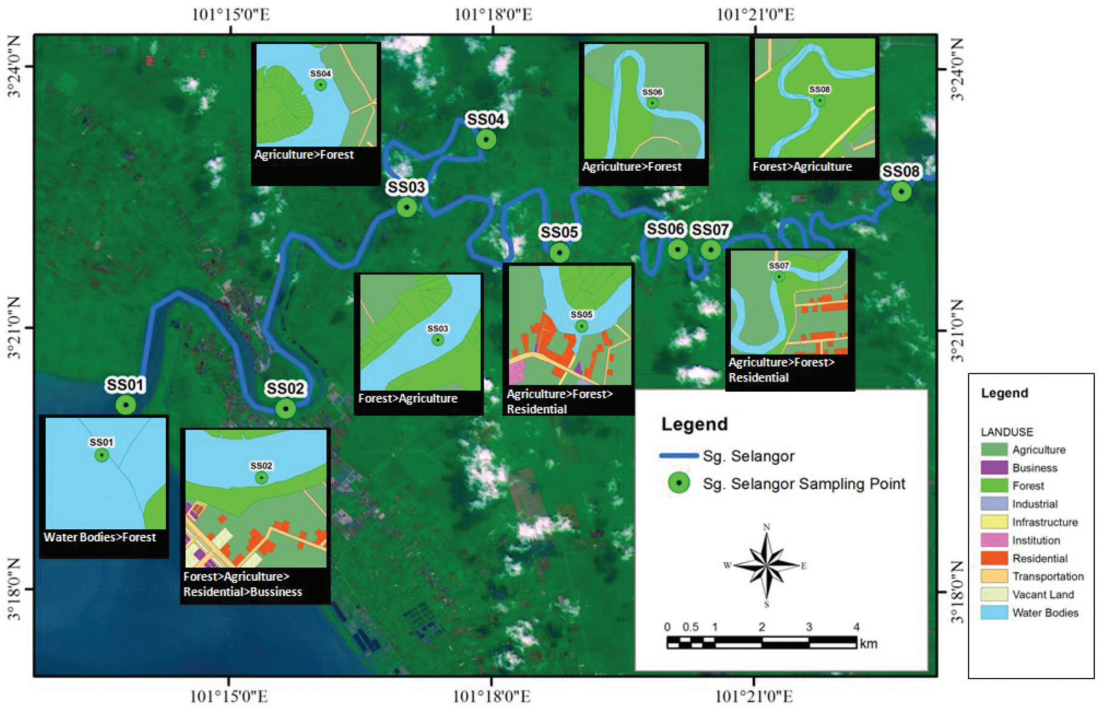


FIGURE 6. Map of sampling locations at Sg. Selangor

estuary has finer sediment size with 2.5ϕ (equivalent to 0.17 mm), much lower than the one obtained at Sg. Tengi (recall d = 0.31 mm). Most of the sediment exhibit sorting values within the range of 1 - 1.8ϕ, indicating poorly sorted (except at SS 7, where it was well sorted). It is noted that the range of sorting is below than the one obtained at Sg. Tengi which range is from 1.3 - 2.2ϕ.

The sediment distribution was found to be symmetrical and fine skewed (except for SS 7 where coarse skewed was observed). There was no relationship between the skewness values with the type of land use. We note that the highest kurtosis value is 10.75 ϕ, found at SS2 and is the highest kurtosis value obtained for all samples in this study. The sediment distribution covers most of the

TABLE 5. The statistical characteristics of bed sediment collected at Sg. Selangor

	Percentage (%)			in phi (φ)				
Sampling point	Forest	Agriculture	Urban	mean	sorting	skewness	kurtosis	Majority land use
SS1	98.15	1.85	0	2.549	1.091	-0.014	1.498	Forest
SS2	29.73	39.16	31.11	2.532	1.339	-0.083	10.750	UrbanAgri
SS3	56.51	41.43	2.06	1.966	1.752	0.265	0.872	AgriForest
SS4	32.1	63.68	4.22	1.627	1.861	0.164	1.108	ForAgri
SS5	25.02	62.47	12.51	1.613	1.605	0.027	0.804	ForAgri
SS6	30.53	62.62	6.85	1.565	0.961	-0.165	1.208	ForAgri
SS7	16.16	73.12	10.72	0.989	0.468	0.643	0.496	ForAgri
SS8	40.37	50.68	8.95	1.671	1.095	0.009	1.494	ForAgri

kurtosis spectrum including leptokurtic, platykurtic, very platykurtic, mesokurtic and extremely leptokurtic.

SUNGAI LANGAT

The sample collection points at Sg. Langat and its associated types of land use are shown in Figure 7. The most upstream sampling points taken were at SL10, which recorded almost 77% of the land is categorised as agriculture. Moving downstream from this point, urbanisation comes in with heavily populated areas (i.e. SL 5-9). The majority red and light purple colours in Figure 6 indicate the residential and institutional area, respectively. The less urban area was found at the downstream of point SL 5, where agriculture is more dominant, covering up to 83%.

Table 6 shows the mean bed sediment size of Sg. Langat varies from -1.035ϕ to 2.56ϕ (i.e. 2.049 to 0.17 mm) and data shows the upstream of the river (SL10 as shown in Table 3) has the highest value of mean which equivalent to -1.035ϕ (2.049 mm). Moving downstream to the next point of SL9, a decreasing trend in mean value was observed with a size of -0.009ϕ (≈1.006 mm). Interestingly, similar mean sediment size (which can be known as coarse sand) was found along the river stretch up to the point SL 6. At 20 km downstream from SL 6, the mean size is much smaller with 1.66ϕ (equivalent to 0.32 mm) and is categorised as medium sand. The type of land use here is dominated by agriculture. Although it is expected that SL 2 will have similar sediment characteristic as it has UrbanAgri as its land use, the reason behind of increasing mean sediment size for this area is unknown. What can be speculated is that SL 2 is situated at the river bend, where there is a possibility that the coarser size is due to uneven distribution of flow velocity across the channel. The most downstream point of Sg. Langat (i.e. SL 1) has neighbouring ForAgri areas. The increasing percentage of forest clearly reduced the sediment size to a much finer, with a mean value of 2.56ϕ (equivalent to 0.17 mm).

It is interesting to see that sorting values were well below 2ϕ for each sample studied obtained here. The range is found to vary between 0.74 and 1.9 ϕ, indicating that the sediment yield into the river is better sorted. Meanwhile,

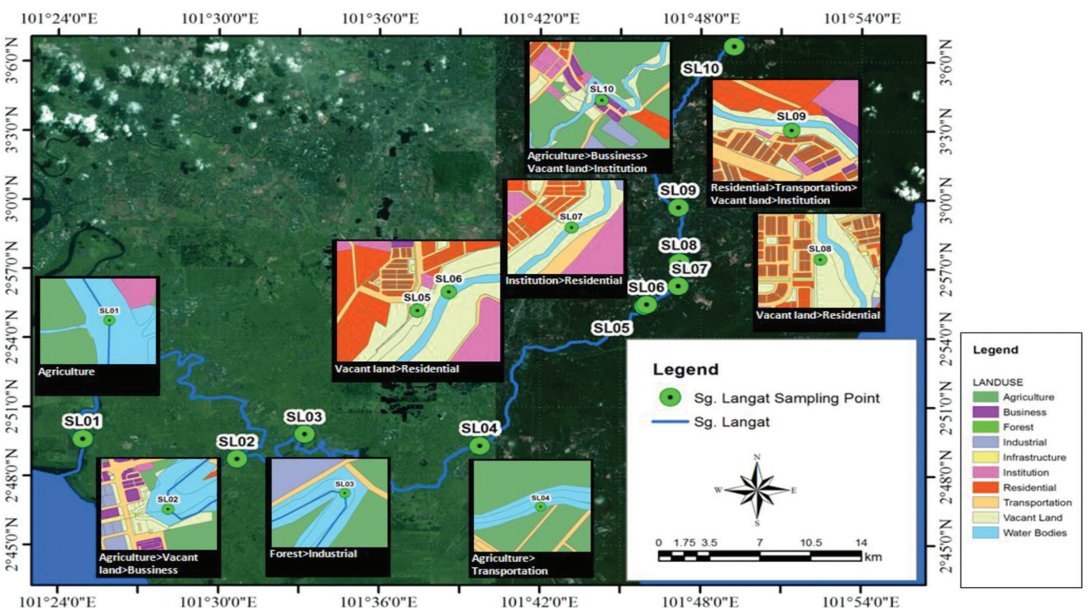


FIGURE 7. Map of sampling areas at Sg. Langat

TABLE 6. The statistical characteristics of bed sediment collected at Sg. Langat

	Percentage (%)			in phi (ϕ)				
Sampling point	Forest	Agriculture	Urban	Mean	Sorting	Skewness	Kurtosis	Majority land use
SL1	29.43	57.61	12.96	2.560	1.732	-0.571	0.839	ForAgri
SL2	10.8	52.76	36.44	0.685	1.914	-0.014	0.825	UrbanAgri
SL3	11.33	58.76	29.91	1.588	1.782	0.169	1.007	UrbanAgri
SL4	10.65	82.57	6.78	1.661	1.785	0.132	0.734	Agriculture
SL5	10.66	21.84	67.5	0.253	1.550	-0.186	0.720	Urban
SL6	8.7	20.62	70.68	0.253	1.335	-0.115	1.434	Urban
SL7	2.38	14.95	82.67	1.947	1.868	-0.220	0.783	Urban
SL8	2.48	20.64	76.88	0.034	1.382	0.359	0.863	Urban
SL9	1.75	11.88	86.37	-0.009	1.674	0.313	0.861	Urban
SL10	2.22	76.61	21.17	-1.035	0.735	0.483	1.166	Agriculture

skewness values in the sediment bed at Sg. Langat are between -0.571 and 0.483 ϕ. The urban areas are either fine or coarse skewed, where the agriculture dominated areas fluctuate between fine and coarse skewed. The highest value of skewness at either coarse or fine end tails was found at SL1 that is the most downstream point.

Most of the sediment samples are platykurtic with exceptions deficiently peaked (i.e. leptokutic) at SL 10, SL 8 (leptokurtic) and SL 3 (mesokurtic). Even so, statistical analysis showed no obvious relationship between kurtosis values and the type of land use.

CORRELATION ANALYSIS

Throughout Tables 4 to 6, it is rather evident that the type of land use neighbouring the river bank has an influence on the sediment characteristics particularly the mean sediment size. It can be seen that areas where forest is the dominant land use, the fluvial sediment is fine sediment with mean size < 200 μm. Changes in land use to agriculture increase the sediment size to the medium sand category with mean size ranging 200 μm < d < 650 μm. The urbanisation increases the fluvial bed sediment size to coarser sediment with d more than 650 μm. Sediment-laden flow is presumed due to low runoff coefficient (at the urban areas), which brings a higher possibility of coarser sediment to be available in the river bed.

Based on the preliminary hypothesis described, correlation analysis was conducted to investigate the relationship between land use and sedimentary characteristics. In this case, all 25 samples were considered regardless of which river the samples originated from. To get a visual representation of the relationship between mean sediment and land use type, a box plot was constructed and is as shown in Figure 8.

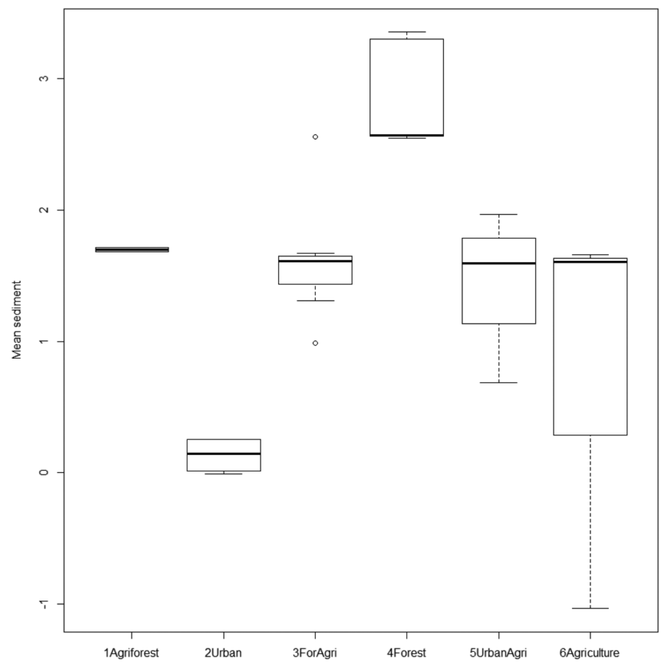


FIGURE 8. Boxplot of mean sediment versus modified land use types2

Data shows that the land type Forest has the highest mean sediment size ϕ distribution relative to all other land type usage, while Urban has the lowest mean size distribution. There are two apparent outliers for ForAgri type of land usage. Nevertheless, for mixed areas such as AgriForest, ForAgri and UrbanAgri, the mean sediment size distribution is within the similar range between 1.6-1.7ϕ. Sediment loss through sheet or rill erosion from agriculture land consists of both organic and mineral, transported into the river through runoff. Eroded sediment can be either from surface soil or subsurface soil, where the size of transported sediment can be varied according to the erosion agents. Changes in the composition of transported sediment are believed due to selective erosion process, which depends on the rainfall characteristics, runoff path and wind.

The variation of the distribution of mean sediment size is smallest for AgriForest area, followed by Urban while Agriculture type of land use has the highest variation. There are two potential outliers for ForAgri type with values were more than 3 times the inter-quartile range (IQR) above and below the third and first quartiles. The median value for Urban type indicates a rather symmetrical profile. The median values for ForAgri, UrbanAgri and Agriculture types are close to the upper quartile values, whereas Forest showed an adverse pattern that is much closer to the lower quartile value. To confirm the association between the mean sediment and land use type, a correlation study using regression analysis was applied. Taking AgriForest, which is the land type with the smallest variation as the reference level for land use, the following model presented in Table 7 was obtained.

The estimated intercept gives the value of the mean sediment of AgriForest as 1.7 and the estimated coefficients for the dummy variables implies that Urban was on average 1.567 shorter than AgriForest, while mean sediment size for Forest was 1.168 higher than AgriForest. The coefficient of determination is R^2=0.7061, meaning this model explains about 71% of the variance in mean sediment. The multiple correlation coefficients, R is 0.84, which is the correlation value between the *observed* mean sediment and the ones *predicted* (fitted) by the model

TABLE 7. Statistical analysis obtained through regression analysis

Coefficients	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	1.70010	0.45296	3.753	0.00135
Urban	-1.56730	0.55477	-2.825	0.01081
ForAgri	-0.08032	0.51361	-0.156	0.87738
Forest	1.16792	0.53595	2.179	0.04211
UrbanAgri	-0.23868	0.55477	-0.430	0.67186
Agriculture	-0.95560	0.58477	-1.634	0.11869

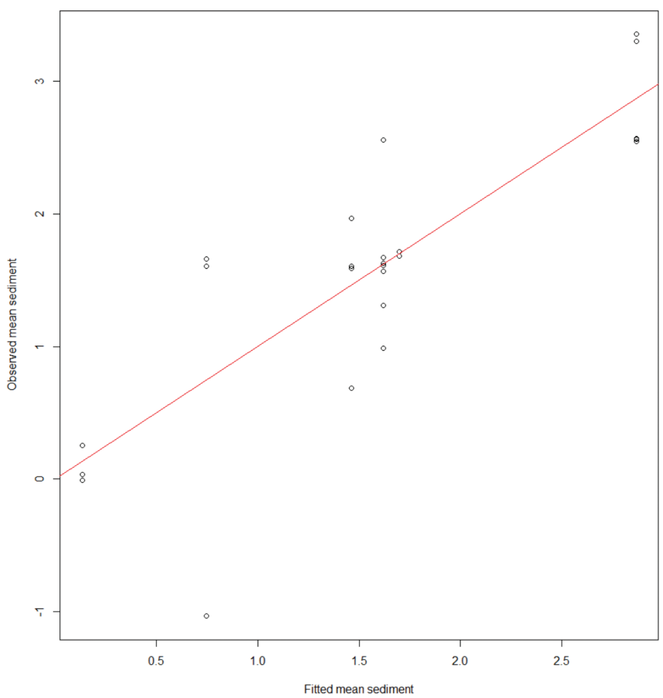


FIGURE 9. The performance of fitted mean sediment size through multiple regression analysis against observed mean sediment size

(Figure 9), implying that this model closely resembles the data, hence a good representation of the data. Hence, it can be concluded that correlation between the type of land use and mean sediment statistically exists as shown by the data obtained in this study.

Conclusion

This study discusses the spatial sedimentary characteristics of three tropical rivers, where two rivers were sampled from the mouth of estuary towards upstream. The analysis is extended to investigate the relationship between land use type and sedimentary characteristics. Sediment mean size are found to be correlated with the type of land use where the dominant type of forest, agriculture and urban have decreasing trend of mean size from approximately 2.5ϕ (fine sand), 1.8ϕ (medium sand) and 0.2ϕ (i.e. very coarse sand), respectively. The median of mean sediment size for the mixed type of land use lies about 1.8ϕ, indicating medium sand.

It is noted that majority of the sediment samples collected at these three rivers, the sediment distribution is poorly sorted with middle range values of sorting. The individual land use type does not ensure a better sorting value and well-distributed sediment, whereas the combination of land use categories too does not mean a bad sorting; in other words, there is no distinct relationship between the type of land use with sorting, skewness or kurtosis.

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