Measuring Observed Sediment Yield from Three Sub-catchments of UKM Catchment, Peninsular Malaysia

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***Abstract*: A study was conducted to measure the observed sediment yield from small catchments. The discharge and water sampling for TSS analysis from the tributaries of Puri Pujangga (PP), Alur Ilmu (AI) and Tasik Kejuruteraan (TK) sub-catchments of UKM catchment were conducted on randomly selected dates. The area, elevation range, slope %, catchment length, mid width of the tributary, mid depth and velocity of the tributary of each sub-catchment was determined by watershed delineation procedure in ArcGIS 10.2 and rainfall was measured using the digitized HBO data logger. Discharge was calculated as the product of velocity and cross sectional area of the flow path at the base of the slope. The results show that with the daily discharge rate, the average Total Suspended Sediment (TSS) concentration recorded for each station were 567.33 mg/L 1053.33 mg/L and 1051.33 mg/L, and the average value of sediment yield for all stations calculated based on the formation of suspended sediment load per day falls as 15.50 tons/km^2/hr, 65.89 tons/km^2/hr and 36.95 tons/km^2/hr respectively. The study reveals that less surface erosion occurs under vegetation cover. Runoff from barren land discharges more sediment. At the same time, sediment concentration is closely related to rainfall events which increase river regimes especially in terms of river discharge. The study suggests the rapid controlling measures for soil erosion of such area.**

***Keywords*: Suspended Sediment Concentration, Sediment Yield, Alur Ilmu Sub-catchement, Puri Pujangga Sub-catchment, Tasik Kejuruteraan**

Introduction

Sediments figure extensively in the ecosystem assessment. Land and water use can profoundly affect soil and sediment by both quality and quantity. Habitat loss or change, eutrophication, reduction of nutrients and infilling of wetland have effect on biodiversity due to changes in sediment inputs (Apitz 2012). Sediment transports a many nutrients and contaminants (Bruijnzeel & Proctor 1995; Gasim et al. 2006). They also mediate their uptake, storage, release and transfer between environmental compartments (Toriman 2008). Most sediment in surface water originates from catchment surface. Erosion arising from bedrock comprises of organic component. Many of the studies emphasize on the impacts of land reclamation due to sediment concentration at downstream rivers (Lane 2004). Agricultural practice increase sediment load in plain land (Subramanian 1993) and logging activity in hill forest (Kasran 1988; Chu et al. 2009). Scientists agree that sediment flux may result changing the water quality and flow regimes (Whitehead et al. 2009). Factors such as channel slope, relief, basin size and seasonality of rains play a very important role in determining the amount of sediment yield from a catchment system particularly in the tropics (Syvitski et al. 2000). Holland (1981) estimated the average budget sediment flux from rivers to oceans of about 18,592.8 billion kg per year (Walling 1999). Land devoid of vegetative cover will generate high runoff and yield much more sediment from erosion than a covered area. Vegetation is the most effective control for erosion, although there can be slight variances due to differences in infiltration rates and intensity of runoff (Greene et al. 1994). The research revealed that erosion rate in undisturbed forest ranges from only 0.0004 to 0.05 tons/ha/year (Pimentel et al. 1995). Malaysia is progressing with huge anthropogenic development at the cost of losing vegetation cover (Biswajeet et al. 2011) though plantation cover is more than 20% of the land area in Peninsular Malaysia (Wicke et al. 2011).

Materials and Methods

1. Study Area

Site selection: To measure the observed sediment yield from small catchments, the study areas was selected as Puri Pujangga (PP), Alur Ilmu (AI) and Tasik Kejuruteraan (TK) sub-catchments in the UKM catchment and were determined by watershed delineation procedure in ArcGIS 9.3. Each of the sub-catchments is described below:

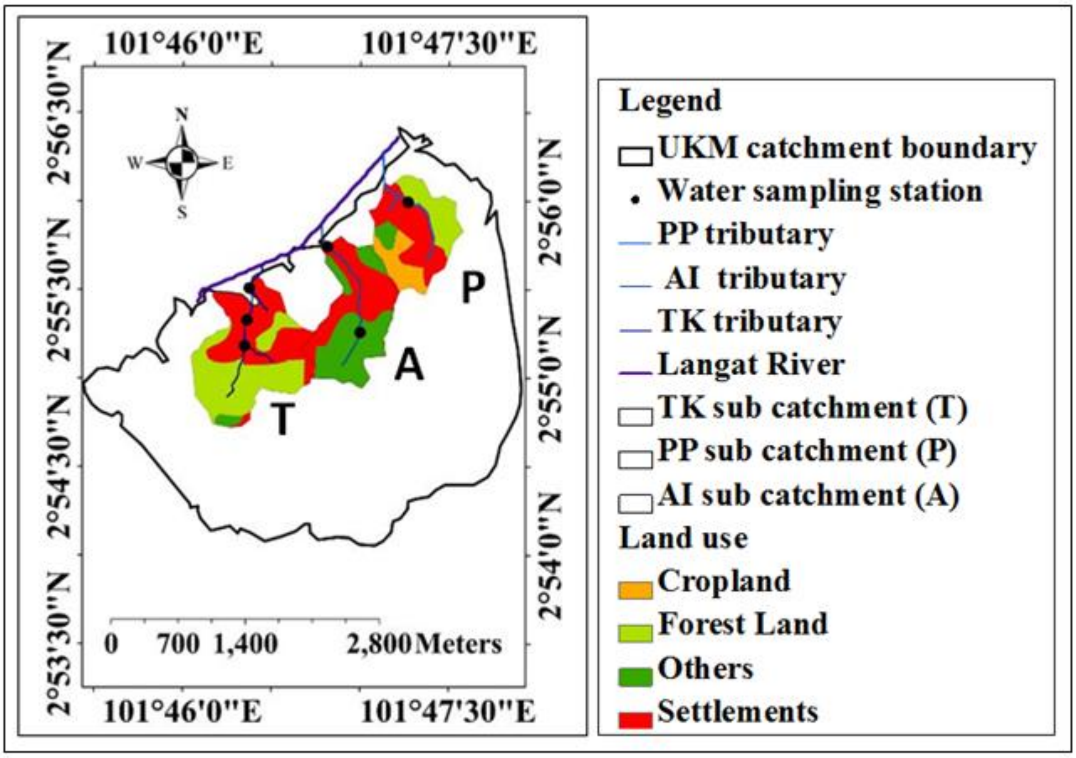

Figure 1: Location Maps of Puri Pujangga, Alur Ilmu and Tasik Kejuruteraan Sub-catchments

a. Puri Pujangga Sub-catchment

The area of Puri Pujangga sub-catchment is 0.75 km^2. The geological aspect of the area is weathered sedimentary rock. The soil texture ranges from coarse to fine sandy clay, falling into the Muchong-Seremban and Telemong-Akob-Local Alluvium major soil series. Sediment sampling station was fixed at the outlet of Puri Pujangga tributary. The coordinates of the station are 2° 56' 5.817" N and 101° 47' 6.927" E (Figure 1). The elevation range, slope %, catchment length, mid width of the tributary, mid depth of the tributary and the velocity are 19.50 m – 103.85 m, 0.3% – 57.03% 1246.0 m, 3.0 m, 0.42 m and 4.5 m/s respectively. The length of the tributary is 1440.0 m. (Table 1). Rainfall is 2880 mm for the year 2015 and the total amount of runoff is 1479 mm (Table 2)

b. Alur Ilmu Sub-catchment

The area of Alur Ilmu is 0.92 km^2. The geological aspect of the area is weathered sedimentary rock. The soil texture ranges from coarse to fine sandy clay with Muchong-Seremban and Telemong-Akob-Local Alluvium being the major soil series. Two sediment sampling stations were selected for this sub basin due to the presence of a permanent sediment trap at the center of the tributary length. Sampling Station 1 is at the upper side of the sediment trap (101° 46' 58.775" E, 2° 55' 30.082" N) and Sampling Station 2 is located at the outlet of the tributary (101° 46' 47.198" E, 2° 55' 46.525" N). These were fixed to obtain the average data of the samples and other parameters (Figure 1). The elevation range, slope %, catchment length, mid width and mid depth of the tributary and velocity during water sampling time are stated in Table 1. Rainfall is 2880 mm for the year 2015 and amount of runoff is 1479 mm (Table 2).

c. Tasik Kejuruteraan Sub-catchment

The area of of Tasik Kejuruteraan sub-catchment is 1.18 km^2. The geology of the area is weathered sedimentary rock. The soil texture ranges from coarse to fine sandy clay with Muchong-Seremban and Telemong-Akob- Local Alluvium being the major soil series. Sediment sampling for collecting sediments and measuring flow rate were fixed at the outlet of Tasik Kejuruteraan tributary. The coordinates of this point are 2° 55' 25.015" N and 101° 46' 23.18" E (Figure 1). The physical features of Tasik Kejuruteraan sub-catchment are stated in Table 1. Rainfall is 2880 mm for the year 2015 and total runoff is 1479 mm (Table 2).

Table 1: Physical Feature of Three Sub-catchments

Catchment Parameters	**Value**		
	PP	**AI**	**TK**
Area (km^2)	0.75	0.92	1.18
Soil Type	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
Elevation Range (m)	19.50 – 103.85	18.71 – 103.85	18.85 – 100.69
Mean Elevation (m)	48.00 ± 17.01	51.80 ± 17.49	50.96 ± 18.25
Slope % (Range)	0.3 – 57.03	0.52 – 61.93	0.55 – 48.55

Mean Slope	17.26 ± 9.5	20.35 ± 10.49	20.52 ± 9.13
Catchment Length (m)	1246.0	1702.0	1590.0
Tributary Mean Width (m)	3.0	4.1	2.97
Tributary Mean Depth (m)	0.42	0.64	0.70
Tributary Length (m)	1440.0	1753.0	2186.0
Mean Celocity (ms^{-1})	4.5	5.06	5.51

2. Methods

Rainfall was measured using the digitized HBO data logger located at the Faculty of Engineering (FKAB) new building UKM (02° 55' 21.48" N latitude and 101° 46' 15.48" E longitude). This rain gauge station was installed to record rainfall data on UKM catchment and was controlled by EOC, UKM. Runoff was calculated using the curve number (CN) method.

During the rainfall event, water samples for TSS concentration were collected and the discharge rate was measured at sampling stations fixed for each sub-catchment. All the measurements were repeated three times for three separate rainfall events. A GPS was used to record the coordinates of the sampling points. Each sub-catchment was digitized and area, slope and elevation measurement were generated using ArcGIS 9.3 software. Discharge was calculated as the product of velocity and cross sectional area of the flow path at the base of the hill slope. Five measurements were made to accurately characterize the velocity of the water moving downward the stream.

Table 2: Climatic Features of Three Sub-catchment

Climatic Feature	Value for Sub-catchment		
	PP	AI	TK
Total Rainfall (mm) in 2015	2880	2880	2880
No. of Rainy-days in 2015	183	183	183
Runoff Under Vegetation (mm)	145	145	145
Runoff from Grass Land (mm)	585	585	585
Runoff from Barren Land (mm)	1479	1479	1479
No. of Runoff under Vegetation	38	38	38
No. of Runoff from Grass Land	58	58	58
No. of Runoff from Barren Land	87	87	87

Observed discharge was measured manually using velocity-area method (Buchanan et al. 1969; Bedient & Huber 1988) at four water sampling points of each sub-catchments. Discharge was estimated using the equation below

$$Q = \sum Q_n$$
$$= W_1D_1V_1 + W_2D_2V_2 + W_nD_nV_n$$

Where,

W_n = The width at section n
D_n = The depth of the section at the midpoint (m)
V_n = The velocity of the section at the midpoint (m/sec)

All surface water samples were collected at a 0.3 m depth using a 1 Liter pre-cleaned polyethylene or glass bottle during storm events at all the points. Samples were then placed in ice filled cool box prior to transfer to ALIR, the UKM laboratory. The samples were analyzed in the laboratory. Suspended sediment concentration was measured using the gravimetric method. This procedure was outlined by (Morgan 1988; Rainwater & Thatcher 1960) The residue remaining on the filter paper was oven dried at 105° C for 24 hours, cooled, desiccated and weighed. The total amount of suspended sediment yield in tons/year was calculated by multiplying the weighted suspended sediment with the stream discharge (m^3/sec) during samplings (Toriman et al. 2009) and (Bartram & Ballance 1996).

Results and Discussion

The discharge and water sampling for TSS analysis from the tributaries of Puri Pujangga, Alur Ilmu and Tasik Kejuruteraan sub-catchments were conducted on randomly selected dates 23 April 2015, 03 May 2015 and 27 May of 2015 (Table 3). The amount of rainfall and runoff volume during sampling period are stated in Table 3 and the observed discharge rate and total suspended solids per liter (TSS/ L) from the same sub-catchments stated in Table 4.

Sediment yield was calculated from total runoff volume which is also total discharge for the respective rainfall event. The runoff volume was converted into liter and obtained the sediment yield. The sediment yield (SY) in rainfall event was calculated as in Puri Pujangga sub basin on 23/4/2015 15.13 tons in 76 mm of rainfall; on 3/5/2015 5.48 tons in 43 mm of rainfall and on 27/5/2015 6.33 tons in 45 mm of rainfall. Likewise in Alur Ilmu and Tasik Kejuruteraan sub basins on the same dates with same rainfall the amount of sediment yields were 30.97 tons, 11.18 tons and 9.95 tons; and 37.94 tons, 13.89 tons and 14.50 tons respectively (Table 4). And also the sediment yield/km^2/hr from these three sub-catchments in same chronological rainfall events was calculated 17.48 tons, 13.60 tons, 15.44 tons, 75.56 tons, 60.87 tons, 34.25 tons, 42.97 tons, 36.77 tons, and 31.10 tons respectively.

Table 3: Runoff Volume in 3 Sub-catchment in UKM Catchment

Date	Sub-basin	Total Area (km^2)	RF (mm)	Runoff (mm)			Sub-catchment Area (km^2)			Runoff Vol. (m^3)			Total Runoff Vol. (m^3)
				Veg	Gr.	Bar.	Veg.	Gr.	Bar	Veg.	Grass	Barren	
23-4-15	PP	0.75	76	8	27	52	0.17	0.22	0.36	1424.60	5922.40	18835.20	26182.20
3-5-15			43	1	8	23	0.17	0.22	0.36	85.00	1676.40	8319.60	10081.00
27-5-15			45	1	8	25	0.17	0.22	0.36	129.20	1832.60	8960.40	10922.20
23-4-15	AI	0.92	76	8	0	52	0.49	0.00	0.43	4106.20	0.00	22497.60	26603.80
3-5-15			43	1	0	23	0.49	0.00	0.43	245.00	0.00	9937.30	10182.30
27-5-15			45	1	0	25	0.49	0.00	0.43	372.40	0.00	10702.70	11075.10
23-4-15	TK	1.18	76	8	27	52	0.62	0.00	0.56	5195.60	0.27	29299.20	34495.07
3-5-15			43	1	8	23	0.62	0.00	0.56	310.00	0.08	12941.60	13251.68
27-5-15			45	1	8	25	0.62	0.00	0.56	471.20	0.08	13938.40	14409.68

(Area under vegetation, grassland and barren land is obtained from Land use map, 2011 of UKM catchment.)

Table 4: Calculation of Sediment Yield in Three Sub-catchments, Puri Pujangga (PP), Alur Ilmu (AI) and Tasik Kejuruteraan (TK)

Date	Sub-basin	Area (km^2)	Rainfall (mm)	Observed Discharge Rate (m^3/sec)	Observed TSS (mg/L)	Total Sediment Yield (Tons/Rainfall Event)	Total Discharge Time (hr)	Sub-catchment Sediment Yield (tons/hr)	SY tons/km^2/hr
23-4-15	PP	0.75	76	6.30	578	15.13	1.15	13.11	17.48
3-5-15			43	5.21	544	5.48	0.54	10.20	13.60
27-5-15			45	5.55	580	6.33	0.55	11.58	15.44
23-4-15	AI	0.92	76	16.59	1164	30.97	0.45	69.52	75.56
3-5-15			43	14.17	1098	11.18	0.20	56.00	60.87
27-5-15			45	9.75	898	9.95	0.32	31.51	34.25
23-4-15	TK	1.18	76	12.80	1100	37.94	0.75	50.71	42.97
3-5-15			43	11.50	1048	13.89	0.32	43.39	36.77
27-5-15			45	10.13	1006	14.50	0.40	36.69	31.10

1. The Rainfall - Runoff Relation

The rainfall (for the year 2015) and calculated runoff (CN method) relation (Figure 2) shows that monthly rainfall in vegetation covered land is significantly and strongly correlated with runoff ($P < 0.05$ and value 0.023, $r = 0.78$). Rainfall contributes 78% for increasing of runoff which may indicate that some other factors affect increasing or decreasing runoff such as litter fall, soil texture, rainfall intensity and infiltration (Hartanto et al. 2003). However, monthly rainfall on grass land and barren land is highly strongly and significantly correlated with runoff ($P < 0.01$, $r = 0.90$ and 0.97) where rainfall contributes ≥ 90% for increasing runoff.

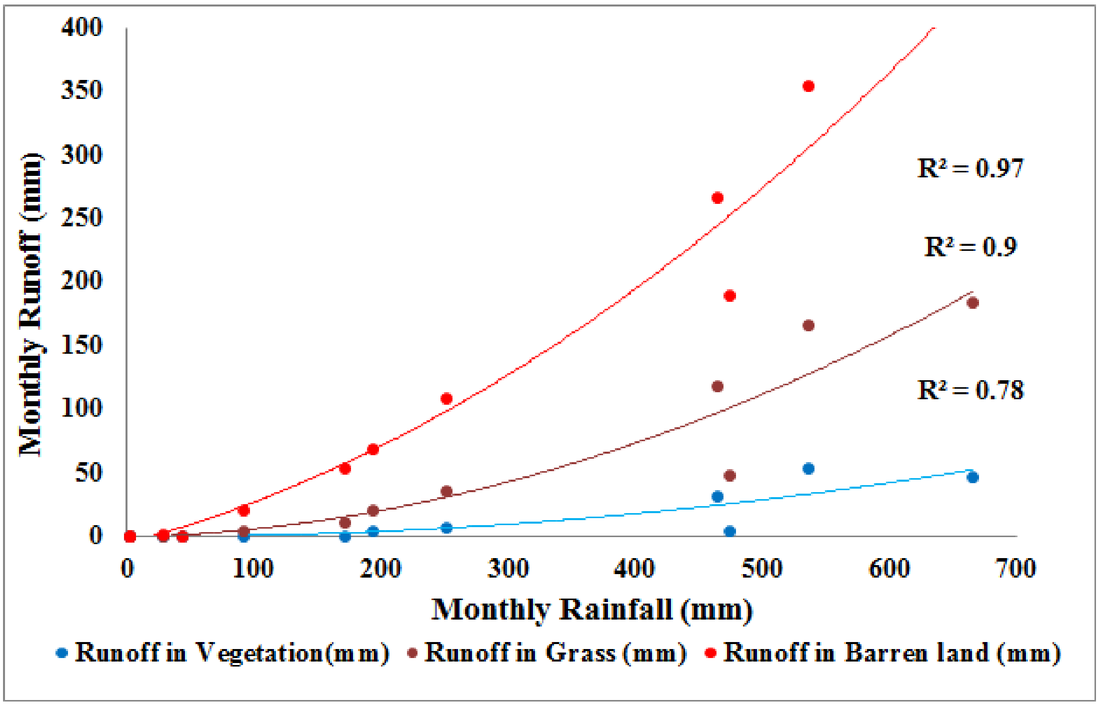

Figure 2: Runoff - Rainfall Relations

Trendline Equations

1. Runoff in Barren land (mm) = 0.0006 * $(\text{Rainfall})^2$ + 0.2659 * Rainfall – 5.8311
2. Runoff in Grass land (mm) = 0.0004 * $(\text{Rainfall})^2$ + 0.0272 * Rainfall – 1.249
3. Runoff in Vegetation (mm) = 0.0001 * $(\text{Rainfall})^2$ + 0.0065 * Rainfall – 0.317

2. Discharge Rate - Sediment Yield Relation

In this study discharge rate and sediment yield relation (Figure 3) showed that these are moderate strongly but not significantly correlated (r = 0.67, P > 0.05 and value 0.149). Trendline equations for these two parameter states that discharge rate contribute 55% (R^2 = 0.55) for changing in sediment amount. This reveals that there are other factors such as human interferences which include road and other concreted floor, sediment trap on the way of discharging water; land use pattern, rock type and structure, velocity of water due to channel roughness, precipitation intensity and runoff travel distance an and so on which affect sediment yield. Similar type of finding (Williams 1989) revealed that many factor affect sediment and discharge relations.Water related considerations include precipitation intensity and areal distributiion, runoff amount and travel rates and distances of flood water in the main channel. Sediment can also arrive by stream side land sliding, overland flow and the return of overbank flood waters to the channel. Anthropogenic activities like timber harvesting and agriculture provide sediment.

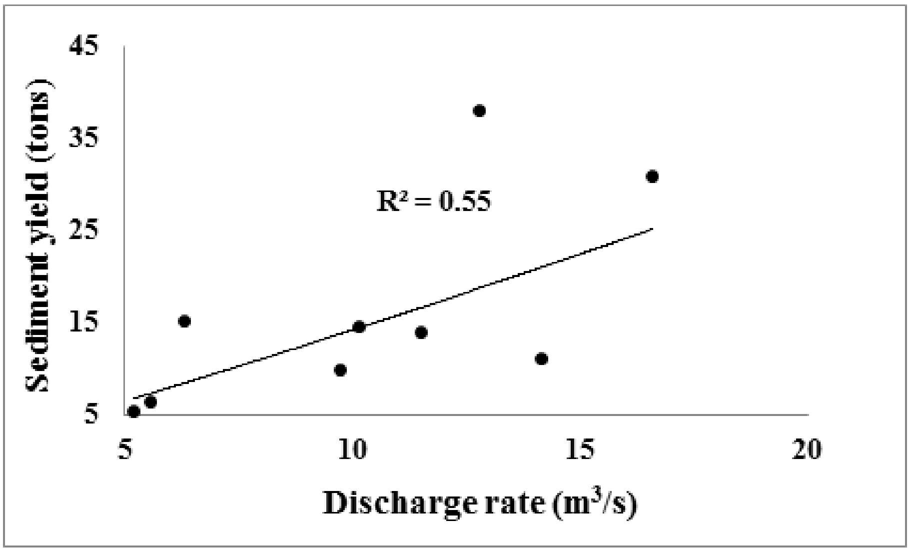

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Figure 3: Discharge Rate - Sediment Yield Relations

Trendline Equations: Sediment Yield (tons) = 1.0629 * $(\text{Discharge Rate } (m^3/s))^{1.1261}$

3. Sediment Yield - Runoff Volume Relation

The sediment yield and runoff volume (Figure 4) showed that these are highly strongly and significantly correlated (r = 0.9, P < 0.01 and value 0.00003). Trendline equations for these two parameter states that run off contribute 82% (R^2 = 0.82) for changing in sediment amount. This reveals that vegetation reduces sediment yield by reducing runoff volume and barren area contributes more runoff with suspended sediment. The similar type of works had been done by Mingguo et al. (2007). This implies that vegetation reduces sediment yield only by reducing runoff volume and the sediment-reduction rate approximates the runoff-reduction rate at the watershed scale.

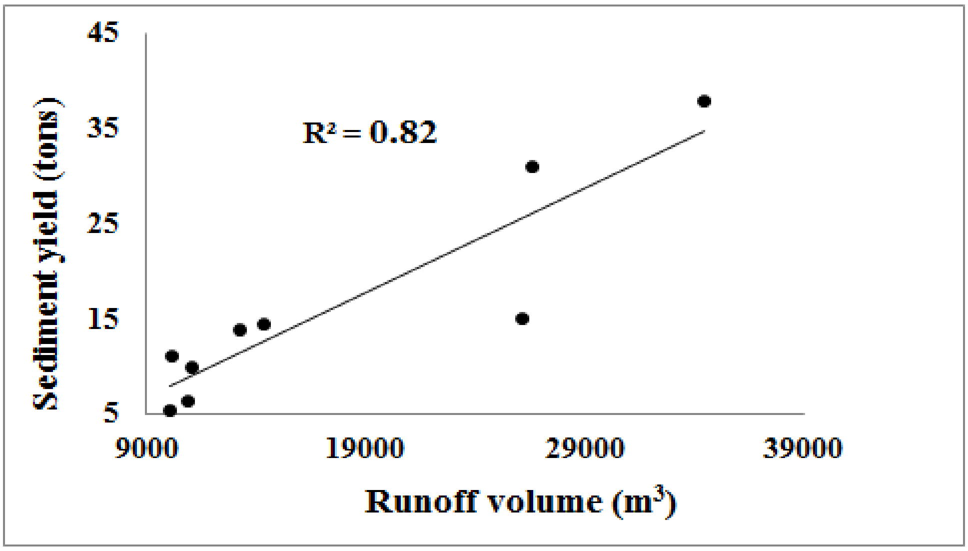

Figure 4: Runoff Volume - Sediment Yield Relations
Trendline Equation: Sediment Yield (tons) = 0.0011 * Runoff volume (m^3) – 2.9698

4. Prediction of Sediment Yield for UKM Catchment by Observed Sediment Yield

Figure 5 (a) shows that in rainfall event 76 mm, the area contributes 89% (R^2 = 0.89) for the observed sediment yield (r = 0.94; P < 0.05 and value 0.01). The trendline equation predicts the sediment yield (tons) = 50.865 * area – 20.308 which projects 655.18 tons of sediment yield for the UKM catchment in 76 mm of rainfall.

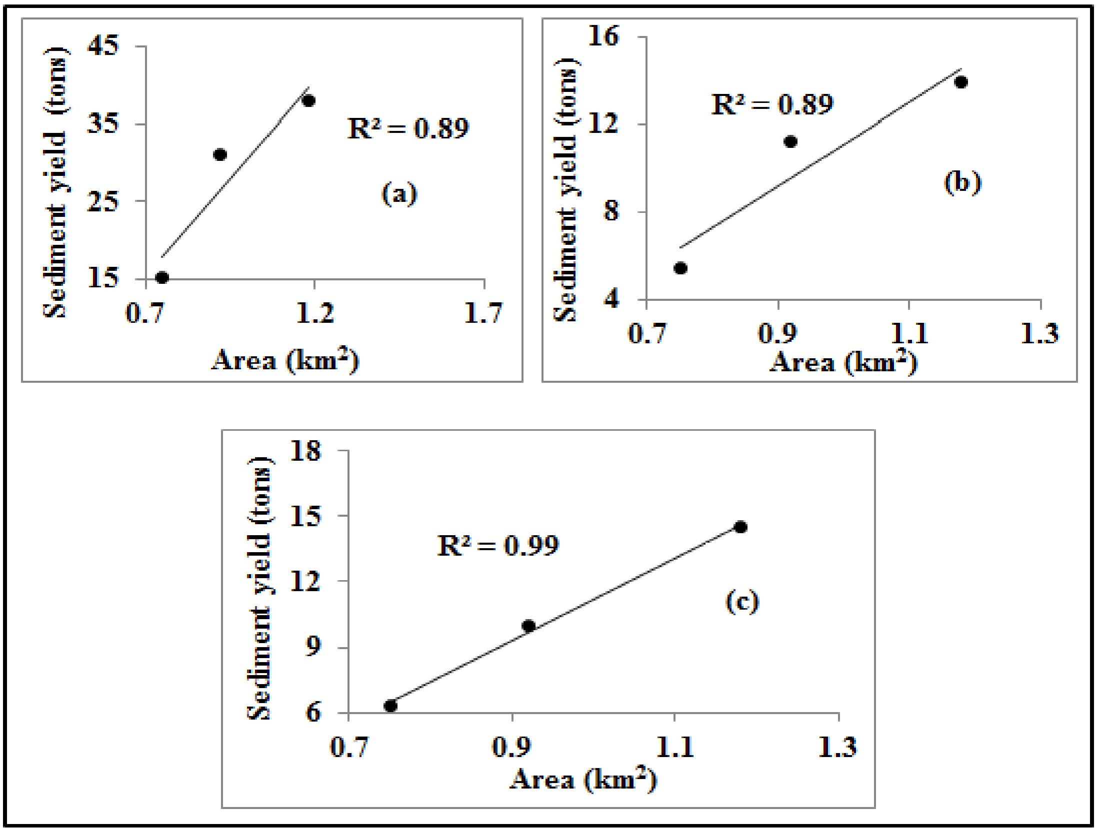

Figure 5: Area - Sediment Yield Relation in Rainfall Event (a) 76 mm, (b) 43 mm, and (c) 45 mm

Figure 5 (b) shows that in rainfall event 43 mm, the area contributes 89% ($R^2 = 0.89$) for the sediment yield ($r = 0.95$; $P < 0.05$ and value 0.02). The trendline equation predicts the sediment yield (tons) = 18.799 * area – 7.68 which projects 241.97 tons of sediment yield for the UKM catchment area in 43 mm of rainfall. Figure 5 (c) shows that in rainfall event 45 mm, the area contributes 99% ($R^2 = 0.99$) for the sediment yield ($r = 0.99$; $P < 0.05$ and value 0.017). The trendline equation predicts the sediment yield (tons) = 18.875 * area – 7.67 which projects to 242.99 tons of sediment yield for the UKM catchment in 45 mm of rainfall.

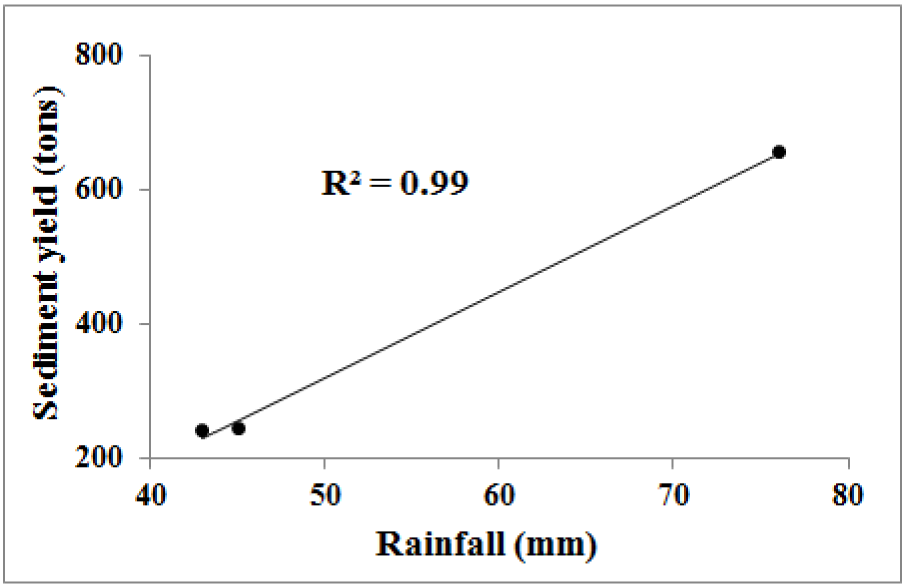

Figure 6: Rainfall and Observed Sediment Yield Ralation
Trendline Equation: Sediment Yield (tons) = 12.847 * Rainfall (mm) – 321.9

Rainfall and observed sediment yield relation (Figure 6) shows that rainfall contribute 99% ($R^2 = 0.99$) for sediment yield ($r = 0.99$; $P > 0.05$ and value 0.077). The trendline predicts 36677.5 tons of sediment for the whole year's (2015) rainfall which estimates 27.62 tons/ha/year of sediment yield from the UKM catchment.

Conclusion

The study shows the less surface erosion under vegetation cover. Runoff from barren land discharges more sediment. At the same time, sediment concentration is closely related to rainfall events which increase river regimes especially in terms of river discharge. The sub-catchments Puri Pujangga consists of 0.75 km^2 area which is fallen under 22.67% vegetation covered land, 29.33% grass land and 48.00% barren land, Alur Ilmu consists of 0.92 km^2 which fallen under 53.26% vegetation covered land and 46.74% of barren and Tasik Kejuruteraan consists of 1.18 km^2 area which fall under 52.54% vegetation covered land and 47.46% barren land. The TSS sample was collected at the outlet points of the tributaries which accumulated the sediment of vegetation area, grassland and barren lands of each sub-catchment. If the TSS concentration would be collected from barren land only then it is assumed that there would be more TSS per liter of water. The sediment yield from the vegetation area of Alur Ilmu and Tasik Kejuruteraan (53.26% and 52.54% of total area respectively) is only 15.43% and 15.06% of total sediment yield. On the other hand barren area of these sub basins is less than their vegetation area (46.74% and 47.46% of the total area) but sediment yield is 84.57% and 84.94% of total sediment respectively. Such huge amount of sediment would be transported to the Langat River and pollute the water quality and reduce the water holding capacity resulting flood in the lowland. These results prescribe the rapid controlling measures for soil erosion.

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