A STUDY OF SURFACE WASH AND RUNOFF AT TEKALA FOREST RESERVE MALAYSIA
(Kajian Hakisan dan Aliran Permukaan di Hutan Simpan Tekala, Malaysia)

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ABSTRACT

The surface wash and runoff study was carried out using closed erosion plots in Tekala Forest Reserve in Hulu Langat, Selangor. Variation on the rate of surface wash and runoff were analysed for different slope gradient and at varying physical and chemical soil characteristic. It was found that silt and fine sand were subjected to higher erosion rate compared to clay and course sand. Content of fine sand and silt in eroded materials increased in the range of 4.8 to 7.0 % and 11.8 to 22.5% respectively. The average reduction of course sand and clay were 8.6% and 16.0% respectively. The average rate of surface wash at study site were 85.0 g m^{-2} yr^{-1} . This was relatively higher compared to soil loss in Sarawak of 35.5 g m^{-2} yr^{-1} . There was a significant and positive correlation between rates of surface wash and surface runoff with average product moment correlation, r of 0.75. During the study period, seven extreme events with rainfall greater than 50 mm in single storm were recorded. These storms account for 25% of the total rainfall and 29% of the surface wash during the one year study period between 7th August 1994 to 17th August 1995. There were also positive and significant correlation between slope angle and surface wash (0.92) and the surface runoff (0.77).

Keywords: surface wash, surface runoff, Tekala River Forest Reserve.

ABSTRAK

Satu kajian aliran dan hakisan permukaan menggunakan plot ujian tertutup telah dijalankan di Hutan Simpan Sungai Tekala, Daerah Hulu Langat, Selangor. Perubahan kadar bahan landa dan aliran permukaan bagi sudut kecerunan yang berbeza serta pelbagai ciri fizikal dan kimia tanih telah dianalisa. Didapati bahawa tanah kelodak dan pasir halus telah mengalami kadar hakisan yang lebih tinggi berbanding tanah lumpur dan pasir kasar. Kandungan pasir halus dan tanah kelodak dalam tanih terhakis meningkat sebanyak maing-masing, 4.8 hingga 7.0 % dan 11.8 hingga 22.5%. Manakala pengurangan purata kandungan pasir kasar dan tanah lmpung pula adalah masing-masing sebanyak 8.6% dan 16.0%. Kadar purata bahan landa permukaan di tapak kajian ialah 85.0 g m^{-2} tahun^{-1}. Kadar ini didapati tinggi secara relatif berbanding kepada kehilangan tanih dalam satu kajian serupa di Sarawak sebanyak 35.5 g m^{-2} tahun^{-1}. Terdapat satu korelasi positif dan signifikan antara kadar bahan landa dan aliran permukaan dengan purata korelasi produk momen, r sebanyak 0.75. Dalam tempoh kajian ini antara 7 Ogos 1994 dan 17 Ogos 1995, tujuh peristiwa lampau dengan jumlah hujan melebihi 50 mm telah direkodkan. Peristiwa ribut tersebut menyumbang masing-masing, 25% jumlah hujan dan 29% bahan landa permukaan dalam tempoh kira-kira satu tahun kajian

tersebut. Juga terdapat korelasi positif dan signifikan antara sudut cerun dan bahan landa permukaan (0.92) dan aliran permukaan (0.77).

INTRODUCTION

The study of soil loss from surface wash is very important in determining erosion prone areas which are very widespread in humid tropical regions such as Malaysia. Soil loss studies provide necessary data for the implementation of an effective and suitable erosion control measures. Erosion control minimises non point source pollution which is currently the major cause of pollution of Langat River. Tekala River is one of the upper tributary of Langat River, which in 1998 has been classified as a slightly polluted. In Malaysia, the content of suspended sediment from surface wash process entering into the river system rose drastically by 34% (DOE 1998). This resulted in the low water quality and high sediment yield output of most rivers in the country. This article aims to study relationship between slope gradient on runoff and surface wash of various physical, chemical and erosivity charecteristics of soil.

MATERIALS AND METHOD

a. Study Area

The study area is in the Tekala river catchment located in the Hulu Langat district, Selangor. Its latitudes are 3^0 3' 12" and 3^0 5' 34" N and longitudes 101^0 50' 18" and 101^0 52' 32" E. It is situated about 40 km east of Kuala Lumpur. The Tekala River is a tributary of Semenyih River, which is also a tributary of Langat River. Langat River system flows in the southwest direction into the Straits of Melaka. Langat River headwaters drain the western flank of the Main Range. The Tekala River falls into the dipterocarp forest reserve and covers an area of 10.27 km^2. Figure 1 shows the location of study area.

b. Wash Trap Design Location and Procedures

The design used in this research was a modification of the design used by Gerlach (1967). The traps were made from sheets of zinc tin and they consisted of four parts. The size of the collection tank was 100cm by 40 cm by 50 cm, the trap lip was 100cm by 25 cm and the cover was 100 cm by 60 cm. The purpose of the cover was to prevent direct rainfall and subsequently the evaporation of collected water. A divisor was fixed at the back of the highest position so as to channel the overflow discharge to another lower collection bin. The wash trap used in the study is shown in Figure 2. Altogether 12 wash traps were installed on three slope profiles of A, B, and C respectively. Four wash traps were located on each profile. Along slope profile A the wash trap were labeled as A1, A2, A3 and A4 and were installed on four slope segments of 8^0, 14.4^0, 23.4^0 and 40.9^0 respectively.
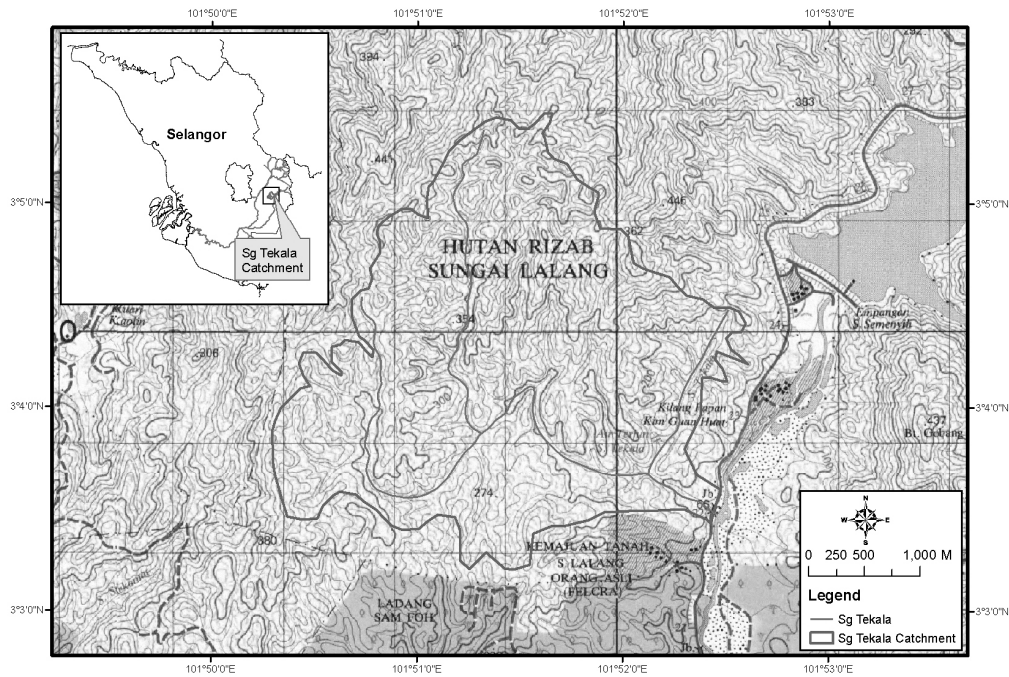
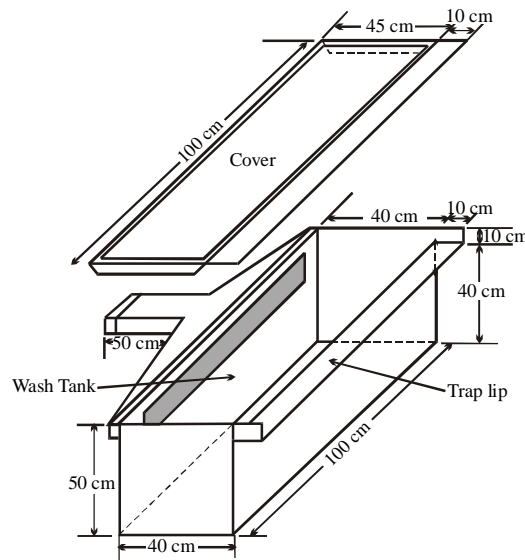Figure 1 : Catchment of Tekala River within Sg. Lalang Forest Reserve

Figure 2 : Wash Trap with Cover

Along slope profile B, four wash traps namely B1, B2, B3 and B4 were also installed on slope segments of 7^0, 16^0, 24^0 and 39.7^0 respectively. Slope profile C had four wash traps namely C1, C2, C3 and C4, located at 6.5^0, 17.4^0, 20^0 and 37.2^0 respectively. These wash traps were arranged from upslope to downslope direction as shown in Figure 3. The wash traps were located at convex points of the slope except for

wash trap C3, which was located at concave points, while two other plots (A1 and A3), were located on an exposed ground area without any vegetative cover except for the leaves litter.
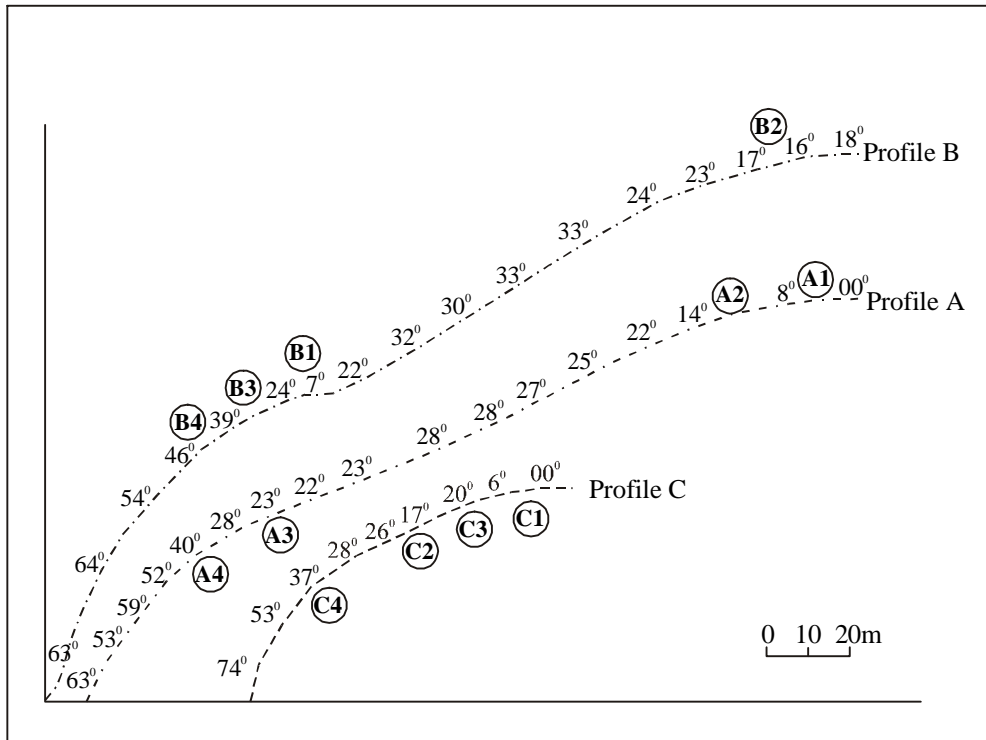

Figure 3: Location of the Open System Plots at Tekala Catchment
(Source: Fieldwork 1994-1995)

Samples were collected from the wash traps after each rainfall event for one year beginning from 7th August 1994 to 17th August 1995. Altogether 99 samples were collected during the study period. Before collecting the samples, the water and sediment were mixed with plastic scoop to ensure that all the water and the sediment were completely mixed. The samples were then collected using a one-litre polyethylene bottle. This sample represented all the suspension in the tank. The samples were then taken to the laboratory for analysis of soil loss in a form of suspended sediment.

Two rainfall stations were established at the Tekala river catchment. The first station was placed in the middle of profile A with a good exposure using an automatic rain gauge recorder. The second station sited in the Forest Department at Tekala catchment area used only one automatic rain gauge recorder. This station was inspected weekly and the time, day and date of visits were noted down. The charts were changed every four weeks over one year beginning from August 1994 to September 1995.

RESULTS AND DISCUSSION

a. Texture Analysis of Soil before and after erosion

The size distribution of soil in the study area before erosion was bimodal with coarse sand and clay being the two predominant textural classes. This could be due to the

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removal of fine fractions (silt and fine sand) by surface wash. Two textural classes were identified. They are sandy clay texture found at profile A and B and the second class was the sandy clay loam found at profile C.

Statistical analysis on soil texture showed that clay and silt fractions did not have significant correlation with both the rate of surface wash and the amount of surface runoff as shown in Table 1. This has been reported by many researchers such as Bryan (1974) and Mutter and Burnham (1990). In contrast, Epstein and Grant (1967) found that the rate of soil loss increased with increase in clay content. But in another study, it has been found that soil loss increased with an increased in the clay fraction up to its maximum of 19%. A further increase in the clay content resulted in a decrease in soil loss (Levy, *et al* 1994). Insignificant and negative correlations are found between coarse sand fraction with both the rate of surface wash and the rate of surface runoff (Table 1). In Africa, it was reported that there was a negative correlation between sandy soil and surface runoff and soil loss (Obi, *et al* 89).

Table 1: The Correlation Coefficient Between Soil Texture and Slope Gradient with Surface Wash and Runoff

Textural Classes	Rate of Surface Wash	Rate of Surface Runoff
Clay	0.37	0.10
Silt	0.14	0.27
Coarse Sand	-0.36	-0.17
Fine Sand	-0.36	0.10
Slope (degree)	**0.92	**0.77

** Significant at 0.001 level

The texture of the eroded soil contained a higher proportion of silt and fine sand than the source soil as shown in Table 2. This means that the fine fraction (fine sand and silt) was more susceptible to erosion and transportation by surface wash than coarse sand or clay. Overall, the result showed that the average reduction of clay and coarse sand content in the eroded sediment are 16% and 8.6% respectively. The range varies from 4.8 - 7% for silt and 11.8 - 22.5% for fine sand. Fine sand therefore are most vulnerable to erosion in the study area as compared with other textural classes.

b. The Rate of Surface Wash and Surface Runoff

Table 3 showed the rate of surface wash and surface runoff at all the study sites. The results ranged from 49.5 g m^{-2} yr^{-1} to 137.7 g m^{-2} yr^{-1} for surface wash and 80.17 L m^{-2}yr^{-1} to 189.4 L m^{-2} yr^{-1} for surface runoff. The average rate of surface wash and runoff were 85 g m^{-2} yr^{-1} and 133 L m^{-2} yr^{-1} respectively. There are considerable variations for both data, which was caused by the differences in the slope gradient and soil characteristics.

The trend in the rates of surface wash increased directly with slope angles. The steeper the slope angles the higher were the rates recorded for surface wash. However two stations namely C2 and C3 are the exceptions. This is probably due to the slope curvature, vegetation cover as well the characteristic of soil. Plots A4, B4 and C4 with slope ranges of 37^0 - 40^0 showed surface wash of 130 - 137 g m^{-2} yr^{-1}. The lowest rate of soil loss was associated with low gradient at A1, B1 and C1.

Table 2: Textural Analysis of the Eroded Material at the study plots in Tekala River

Plot site	Textural Classes							
	Clay		Silt		Fine Sand		Coarse Sand	
	a	b	a	b	a	b	a	b
A1	30.2	22	4.4	11	11.2	23	54.2	44
A2	46	36	5.0	11	10	27	39.0	33
A3	43	37	6.0	13	9.0	23	42.0	35
A4	44.9	38.3	3.3	9	8.8	30	43.5	36
B1	33.6	27.5	4.4	11	11	30	51.0	42
B2	31.5	27.1	4.1	11	12.2	29	52.1	43
B3	36.7	29.4	5.6	12	11.5	34	46.2	38
B4	42.2	35.0	6.4	12	10.9	33	41.5	34
C1	37.5	30.4	5.3	12	10.7	32	46.5	39
C2	27.7	21.6	5.2	12	13.6	27	53.2	44
C3	30.5	24.4	4.2	9	13.5	33	51.8	40
C4	31.4	26.4	4.5	10	11.5	30	52.6	42

a   Source soil before erosion
b   Suspended Sediment after erosion

The highest rate of surface wash was registered in March 1995 and the second in October 1994. The lowest rate occurred in February and July 1995. Generally high and low runoff in the study sites were also associated with steep and gentle gradient sites A1, B1, C1 recorded surface runoff from 69 - 85 L m^{-2} yr^{-1} while steep slope at B4 and C4 recorded high runoff of 187 – 189 L m^{-2} yr^{-1}, However, site at A4 is the exception because it recorded much less surface runoff at 137 L m^{-2} yr^{-1}.

Overall the study area has low surface runoff. This is probably due to the presence of vegetative cover that intercepts a certain amount of total rainfall, which subsequently evaporates to the atmosphere. It was found that in forest area of Peninsula Malaysia the ratio of surface runoff (Q) to precipitation rainfall (P), or Q/P between 0.20 and 0.25 (F Folliott, 1990). Nik Mohamad, *et al* (1979) reported Q/P value of 0.27. The average ratio of Q/P for all plots at Tekala river site was 0.20 with a range of 0.13 to 0.34 as shown in Table 3.

Results from other studies conducted in forest areas gives lower rate of surface wash. George (1987) found that average soil loss was 0.408 t ha^{-1} yr^{-1} (40.8 g m^{-2} yr^{-1}). Malmer (1996) reported the rate of surface loss was 38 kg ha^{-1} yr^{-1} (3.8 g m^{-2} yr^{-1}). Hatch (1978) reported that the rate of soil loss in Sarawak was 0.3553 t ha^{-1} yr^{-1} (35.5 g m^{-2} yr^{-1})

Table 4 and Figure 4, show the rate of monthly surface wash for the 12 study sites at Tekala River. The highest surface wash was registered in March 1995 and followed by October 1994. The lowest rate occurred in February and July 1995 respectively. Generally the monthly surface wash at the study area are bimodal with maximal occurring in March and October and two minima occurring in February and July. This is similar to the pattern of the monthly rainfall distribution at the study area.

Table 3: Rate of Surface Wash, Surface Runoff and Rainfall - Runoff Coefficient at Plot Sites

Plot Site/Slope Angle		Rate of Surface wash (g m^{-2} yr^{-1})	Rate of Surface Runoff (L m^{-2} yr^{-1})	Rate of Runoff/Rainfall (Q/P)
A1	8^0	60.98	80.17	0.30
A2	14.4^0	71.31	143.97	0.17
A3	23.4^0	96.03	123.7	0.19
A4	40.9^0	137.74	137.5	0.17
B1	7^0	56.46	85.5	0.27
B2	16^0	77.66	160.4	0.15
B3	24^0	113.31	145.45	0.16
B4	39.7^0	135.67	189.43	0.13
C1	6.5^0	20.32	69.6	0.34
C2	17.4^0	49.54	130.88	0.18
C3	20^0	70.96	145.6	0.16
C4	37.2^0	130.51	187.71	0.13

Table 4: Annual Variation of Monthly Surface Wash (g m^{-2}) at Tekala River

| Plot Site	Aug-94	Sep	Oct	Nov	Dec	Jan-95	Feb	Mar	Apr	May	June	July	Aug
A1	0.85	5.11	8.09	4.315	8.21	2.587	0.204	15.286	8.757	4.004	2.106	0.492	0.975
A2	0.62	5.78	7.51	2.415	6.512	4.364	0.172	16.382	9.760	6.410	5.190	2.661	3.533
A3	0.72	11.15	10.63	4.498	3.167	2.674	0.207	*	25.856	7.771	6.475	2.692	4.567
A4	*	8.39	14.10	5.694	8.071	5.893	0.181	37.777	23.820	5.337	4.677	3.839	4.998
B1	0.54	3.43	6.48	7.555	8.518	4.905	0.113	9.29	8.180	4.579	1.545	0.707	0.600
B2	0.85	5.89	6.18	5.566	5.28	8.232	0.221	15.989	11.892	7.217	6.148	1.405	2.840
B3	0.74	10.48	19.05	15.933	13.703	4.521	0.194	21.728	14.919	4.218	2.953	2.858	2.208
B4	*	11.97	18.59	20.621	17.978	6.150	0.323	23.576	18.071	6.715	6.170	3.199	2.297
C1	0.46	3.10	2.69	1.471	2.071	1.37	0.123	3.141	2.181	1.564	0.999	0.401	0.743
C2	0.72	4.62	6.12	3.273	3.022	2.370	0.164	8.876	7.9396	5.614	3.972	1.440	1.416
C3	0.92	7.42	8.74	5.975	4.827	3.6281	0.221	11.756	15.231	3.814	4.237	1.852	2.339
C4	1.42	11.81	23.89	19.545	12.338	9.078	0.218	17.325	16.382	9.489	5.864	1.438	1.775

*Data incomplete
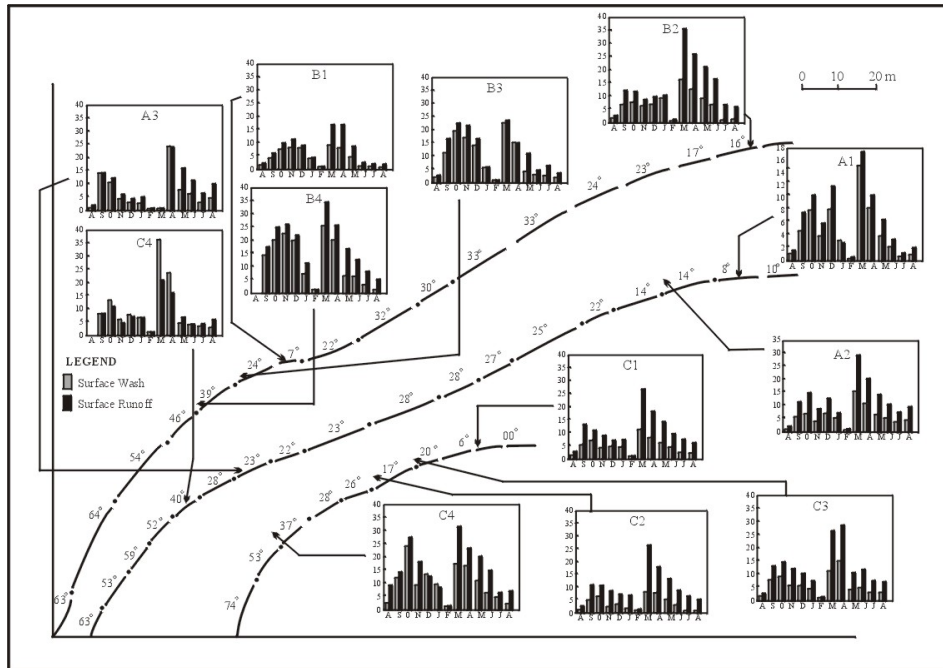
Figure 4: Annual Variation of Monthly Surface Wash and Surface Runoff at Sg.Tekala (Open System Plot)

c. The Relationship between Surface Runoff and The Rate of Surface Wash

A high significant and positive correlation is found between the rates of surface wash (SW) and (SR) at the twelve study sites as shown in Figure 5. The strongest correlation (0.96) was found at site C3 while the lowest but significant coefficient was found in site A3. Correlations of all plots are also significant at 0.75. The result from simple linear regression analysis between both SW and SR indicated that the rate of surface wash could be estimated from the runoff data as given in Table 5. Such relationship had been confirmed by many other studies (Huang 1995, Mutter and Burnham 1980).
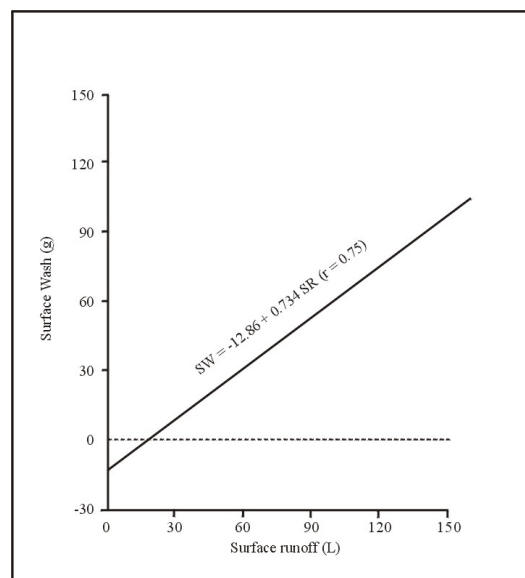

Figure 5 : Regression Line between surface runoff and Surface Wash at Sg.Tekala

Table 5: The Regression Relationships between Runoff and Surface Wash at Tekala River

Erosion Plot	Statistic Parameter				
	a	b	Product-moment correlation (r)	Coefficient of determination (r^2)	No. of obs.
A1	4.58	1.067	**0.92	0.81	79
A2	-2.89	0.673	0.93	0.84	79
A3	-8.98	1.33	0.63	0.39	79
A4	-11.22	1.71	0.79	0.61	76
B1	-6.11	1.02	0.89	0.72	77
B2	-1.69	0.63	0.83	0.62	77
B3	-8.98	1.16	0.76	0.38	80
B4	-11.21	1.32	0.81	0.56	77
C1	0.15	0.26	0.95	0.85	64
C2	-1.16	0.44	0.92	0.80	77
C3	-0.10	0.50	0.96	0.88	77
C4	-3.75	0.82	0.78	0.45	46
ALL	-12.86	0.73	0.75	0.57	12

d. The Surface Wash, Runoff and Extreme Event

The total amount of rainfall during the whole year of the study period was 2389.3 mm. This is considered as dry year as the annual range recorded for this study area was from 2794 to 3556 mm (Dale 1959).

The monthly rainfall is not evenly distributed throughout the year. The highest rainfall was registered in March 1995 (420 mm). The lowest rainfall (36.4mm) occurred in February 1995. In this study a single storm that exceeded 50 mm in the amount of rainfall is considered as an extreme event. Altogether seven extreme rainfall events are registered and analysed. The amount of rainfall that fell during these seven storms events was 595mm and that constitutes approximately 25% of the total rainfall during the study period. The amount of soil loss through the process of surface wash as a result of these events constitute an average of 29% with the range of 24% at plot C3 to 41% at plot A4. Less proportion was however found for surface runoff. The average runoff is 21% with the range between 15 to 27%.

e. The Interrelationship Between Surface Wash and Surface Runoff With Slope Angle

The study sites are located at three profiles that are close to each other. Hence, the rainfall is considered to be uniform. The differences in the rate of surface wash and the amount of surface runoff at all the trap sites should be related to site characteristics. Significant and positive correlations are found between slope angle and both the rate of surface wash (0.92) and the amount of surface runoff (0.77). Furthermore wide variations in the rate of surface wash could be noted between erosion plots that are located at the same slope angle at Profile A and B as compared to profile C. For example the rate of

surface wash at plots A1 and B1 are 60.98 and 56.46 g m^{-2} yr^{-1} but in plot C1 the rate decreases to 20.32 g m^{-2} yr^{-1} . At C2 with slope angle of 17.4^{o} the rate of surface wash was 49g m^{-2} yr$^{-1.}$ But gentler slope (16^{0}) at B2 registered higher rate of surface wash, that is, 77.66 g m^{-2} yr^{-1} . This can be explained by the physical and chemical properties of soil and slope curvature, which exerts an influence far, exceeds the influence of the slope angle. The same result can be noted with the amount of surface runoff at the Tekala catchment.

Literature is ambiguous about the effects of slope angle on both the rate of sediment transport and surface runoff. Many investigators have reported that the rate of sediment transport increases with slope angle (Hudson 1971, Lal 1984, Agassi *et. el* 1990 Huang 1995). There are also other researchers, which had not found any significant correlation between slope angle and the rate of surface wash (Baharuddin 1995). Wischmeier (1966), Agassi *et al* (1990) reported significant and positive correlations between slope angle and the volume of surface runoff. Jeje (1987) meanwhile reported that the relationship between slope angle and the volume of surface runoff was insignificant.

Conclusion

The result of this study showed that the rate of surface wash and surface runoff at various slope gradients and soil types varied in Tekala forest reserve. It also explains the importance of soil texture in the process of surface erosion. Fine sand and silt are most vulnerable therefore would indicate high erodibility of that soil. The significant relationship between surface wash and runoff are also analyzed in detail. The importance of extreme rainfall events in generating serious soil erosion has also been established. Positive significant, relationship were found between surface wash, surface runoff and slope in this study through other factors also contributed to the relationship, such as, slope curvature, chemical and physical characteristic of the soil.

Overall, the study would contribute significantly in the understanding of the rates of soil erosion that occurred in the forest area. Even though the rates of erosion is not critical, nevertheless it could be used in the design of a suitable soil management and conservation strategy which is necessary in order to ensure the sustainability of the Tekala forest reserve.

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