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Rainsplash erosion: A case study in Tekala River Catchment, East Selangor Malaysia

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Abstract

This paper discusses rainsplash erosion in forest reserves. The study was carried out at a dipterocarp forest reserve area in the Tekala river catchment, Hulu Langat Selangor. It shows that even under forest cover, soil erosion still occurs. Most of the eroded material from the study sites enters the Langat river system as suspended sediments. Specifically, the results showed that the largest mass of soil splashed upslope was 7.5 g. The highest mean quantity splashed upslope was 2.25 g and that downslope 2.74 g, while the lowest mean quantities of soil splashed upslope and downslope were 0.28 g at station D and 0.97 g at station C . Overall, the mass splashed upslope was highest at profiles A and B on the lower slope. The maximum heights splashed downslope were 98 cm, 95 cm, 93 cm and 92 cm while maximum heights splashed upslope were much less at 93 cm, 91 cm, 90 cm and 80 cm. The rainfall parameters most significantly correlated with the quantity of soil splashed upslope and downslope were the amount of rainfall, kinetic energy with a maximum of 60 minutes intensity, and daily erosivity. A simple linear regression analysis showed that both upslope and downslope splashed soil had a direct relationship with six rainfall indices while a stepwise regression showed that both were directly related to MI, EI60, I60, EVd and API indices. Thus, these indices could be used as the best linear estimator in explaining soil splash erosion.

Keywords: best linear estimator, dipterocarp forest, erosivity, rainsplash erosion, river catchment, suspended sediments

Introduction

Accelerated soil erosion is endemic throughout the humid tropics where less developed countries can ill afford to loose such valuable soil nutrient. Yet, relatively little is known of its dynamics and rates of occurrence under different land use and management conditions in Malaysia. However, authors such as Douglas (1964, 1967a, 1967b, 1968, 1969, 1990, 1992) are well known for their studies of sediment concentrations in Malaysian rivers, while Peh (1978) and Leigh (1982) work on erosion under undisturbed rain forest cover. Aiken *et. al*. (1982), Maene *et. al*. (1975), and Soong (1980) have worked on rates of erosion in agricultural areas, while Leigh (1982), Gupta (1985), and Mykura (1989) have studied soil loss in urban areas.

In Malaysia, accelerated soil erosion occurs when land clearing and earth moving activities expose the ground surface. The present study shows that even under forest cover, soil erosion still occurs. Most of the eroded material from the study sites enters the Langat river system as suspended sediments. In 1998, the Langat river was classified as slightly polluted. For the whole of Malaysia, the mean suspended sediment concentration in the rivers due to soil erosion rose by 34% in 1998 (DOE, 1998) causing a lowering of water quality while siltation of these suspended sediments in the river caused a transformation of channels from natural to urban conditions.

This paper discusses rainsplash erosion in forest reserves. Although a common process under the high intensity rains of the humid tropical environment, rainsplash erosion is not a well understood phenomenon. Here the quantities of material being splashed upslope and downslope and the height to which material is lifted were studied. Various slope gradient and rainfall parameters were used to explain the erosion process. Rainsplash erosion was measured using the splash board method.

Study area

The study area is a dipterocarp rain forest reserve area located in the Tekala river catchment on the western flank of the Main Range in the Hulu Langat district Selangor (Fig. 1). Its latitudes are 3º 3' 12" and 3º 5' 34" N and longitudes 101º 50' 18" and 101º 52' 32" W. It is situated about 40 km east of Kuala Lumpur. The Tekala river is a tributary of the Semenyih river which is also a tributary of the Langat river. The Langat river system flows in the southwesterly direction into the Straits of Melaka.

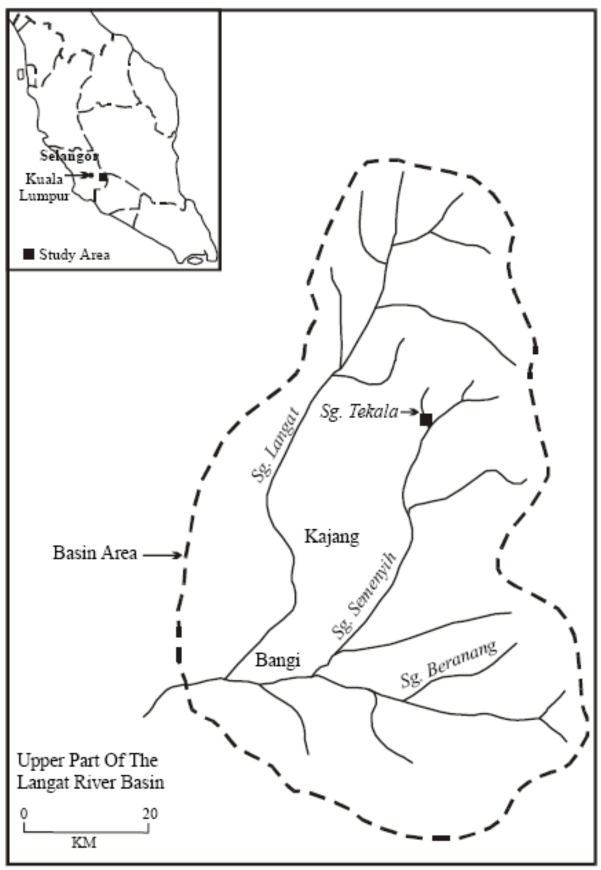
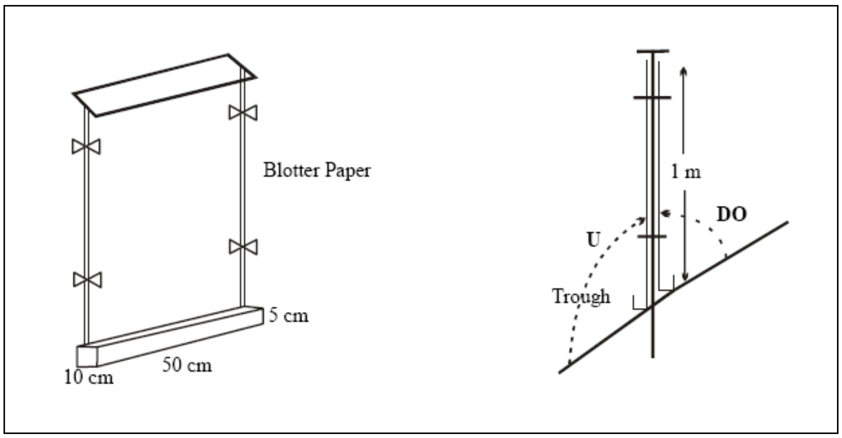


Figure 1. *Location of study area: Tekala River, Selangor*

Methodology

Rainsplash erosion was measured using a splash board designed to monitor the amount of soil splash upslope and downslope, as well as the height of the soil being splashed. The board was based on Sharifah Mastura's (1989) modification of Trudgill's (1983) design. The board was 1 m high, 0.5 m wide and made of stainless steel plate. It was mounted vertically emplacing the lower 20 cm of the board in the soil so as to achieve stability. At the base of the board was a trough to catch splashed material. After every rainfall event, when the splashed material had been collected, the board was rinsed. The trough had a small lid to minimise splash out from the trough. Large sheets of blotting paper fitted to both sides of the board to record the height reached by any splashed material were marked at every 10 cm wide for easy reading (Fig. 2). The blotting papers were changed at every rainfall event. Five individual boards were installed, one each on 0º, 2.5º, 7.5º, 14º and 20º slopes (Fig.3).

Two recording raingauges (Fig. 3) were installed at the study site to collect the data used to compute 14 rainfall and erosivity indices at 15 minute interval rainfalls (Sabry, 1997) (Table 1).



Source: Sharifah Mastura (1989)

Figure 2. *The Design of the Splash Board*

Table 1. Rainfall and erosivity indices

Symbol	Description
Rainfall Indices	
AM	The amount of rainfall for each event in mm.
MI	The mean intensity of each event. AM/duration (mm/h^{-1}).
AI_{15}	The kinetic energy (joules/m^{-2}/mm). Calculation on 15 min interval from KE = 29.8 - 127.5/I; I is rainfall intensity
TKE	The total kinetic energy for each storm which was used to determine rainfall erosivity for all events together (Jm-2).
I_{15}	Rainfall intensity index for 15 minutes.
I_{30}	Rainfall intensity index for 30 minutes.
I_{45}	Rainfall intensity index for 45 minutes.
I_{60}	Rainfall intensity index for 60 minutes.

Erosivity indices	
I_{15}	TKE the maximum sustained intensity for 15 minutes (Jeje & Agu 1990).
I_{30}	TKE the maximum sustained intensity for 30 minutes (Wischmeier & Smith 1958).
I_{45}	TKE the maximum sustained intensity for 45 minutes
I_{60}	TKE the maximum sustained intensity for 60 minutes
EVd	Daily erosivity = 16.64 Rd – 173.82 where Rd is the daily rainfall (Morgan 1974)
API	Antecedent precipitation index. API = pt. 1/t or pt.kt Where pt is precipitation for a given day; t is time (number of days-hours) since last rainfall; k is recession factor that is less than one but ranges from 0.85 to 0.98 (Gregory and Walling 1973)

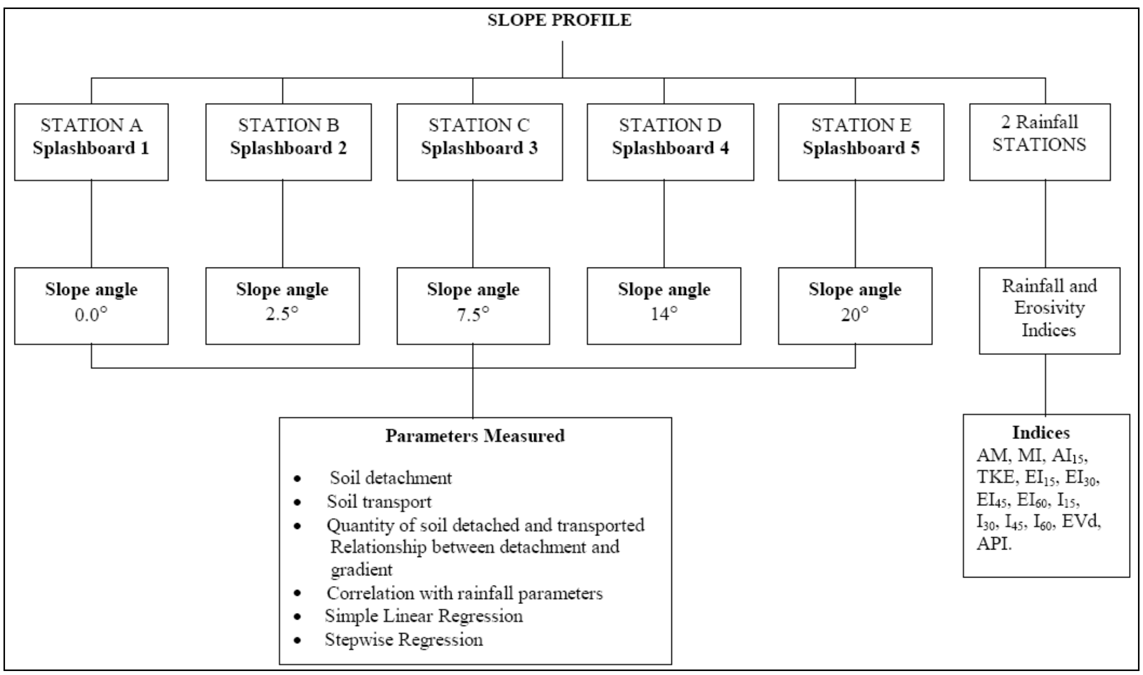


Figure 3. *Rainsplash erosion study design at the Tekala River Catchment*

Sampling procedures

Splash board measurements were taken after 49 individual rainfall events occurring between August 1994 to August 1995. The wet seasons (October, March and April) and dry seasons (August and February) were well represented in the study. The maximum heights of the soil splashed on the upside and downside of each board were measured and noted. Water and soil collected on the trough and the suspensions were poured carefully into a plastic bag. The bag was then tied carefully and the troughs cleaned to make them ready for the next event of rainfall. The blotting papers were duly changed and the troughs were returned to the same place for the following readings.

Results

Average Splash Height

The largest mass of soil splashed upslope was 7.5g on March 28, 1995, when the highest rainfall (75 mm) and intensity (I_{60} = 68.5mmh^{-1}) also occurred. Soil splash downslope varied from 7.41g on March 3, 1995 to the lowest at 0.0754g on February 22, 1995 (Table 2). Station B (2.5º slope) had the highest mean quantity splashed upslope (2.25 g) and downslope (2.74g). While the lowest mean quantities of soil splash upslope and downslope were 0.28g at Station D and 0.97g at Station C respectively. Thus, overall, the mass splashed upslope was higher at A and B on the lower slopes, but at D and E downslope the splash was similar to that from A and B. Figure 4 gives the total and average of soil splash upslope and downslope at Tekala river catchment.

Table 2. Total and average splash heights at the study area

Station	Slope angle (º)	Average soil splash upslope (g)	Average soil splash downslope (g)	Total soil splash upslope (g)	Total soil splash downslope (g)	Height of soil splash upslope (cm)	Height of soil splash downslope (cm)
Station A	00.0	2.1658	2.1332	93.13	93.8596	69.5	70.6
Station B	02.5	2.258	2.7435	103.87	126.205	71.9	73.0
Station C	07.5	0.4811	0.9771	22.13	45.82	63.9	67.0
Station D	14.0	0.2817	2.0265	13.2403	95.2441	58.4	70.3
Station E	20.0	0.6771	2.2209	30.47	99.94	62.3	79.2

Source: Fieldwork 1994-95

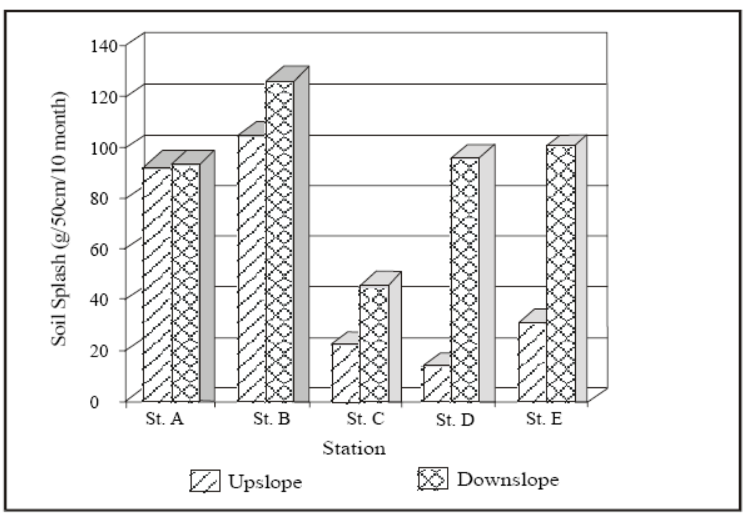


Figure 4. *Total and average soil splash upslope and downslope at the Tekala River Catchment*

Relationship between soil splash and rainfall parameter

The quantity of soil splashed upslope and downslope varied from storm to storm and with the total amount, energy, intensity and erosivity of rainfall. The rainfall parameters most significantly correlated with the quantity of soil splashed upslope and downslope were the amount of rainfall (AM), kinetic energy with a maximum of 60 and 30 minutes intensity (I_{60}, I_{30}), and daily erosivity (EVd) (Table 3). The strongest correlation coefficient recorded, and significant at 0.001 level, was related to EI_{60} index found at Stations B, C and D. Other indices that showed strong correlation and significant at 0.001 level were I_{45} (at station D) EVd and I_{60} at all stations except for the total downslope splash at station E.

Correlation coefficients significant at 0.05 level were mostly associated with I_{15}, EI_{15}, API and AI_{15}. The API index showed a significant positive relationship with soil splashed upslope and downslope. However, at Stations A and E, the total soil splashed downslope was not significantly correlated with the API index.

The Simple Linear Regression

To explore the relationship between rainfall parameters and either upslope or downslope splashed soil further simple linear regressions were calculated for soil splashed upslope and downslope against individual rainfall parameters (AM, MI, EI_{60}, I_{60}, EVd, API) (Fig.5 and 6). The regression equations varied according to the location of the stations. For instance, the regression equations for the relationship between soil splash downslope with EVd index for Station A to Station E are as follows:

$$D = 2.08 + 0.0026\ Evd \quad \text{.....Eq. 1}$$
$$D = 2.07 + 0.004\ Evd \quad \text{.....Eq. 2}$$
$$D = 0.51 + 0.002\ Evd \quad \text{.....Eq. 3}$$
$$D = 2.14 + 0.002\ Evd \quad \text{.....Eq. 4}$$
$$D = 2.4 + 0.001\ Evd \quad \text{.... Eq. 5}$$

where D = soil splash downslope in grams and EVd is the daily erosivity of rainfall.

Table 3. Correlation coefficient between total soil splash upslope and downslope and rainfall parameters

Rainfall parameter	Station									
	STATION A		STATION B		STATION C		STATION D		STATION E	
	upslope	downslope	upslope	downslope	upslope	downslope	upslope	downslope	upslope	downslope
AM	**0.66	**0.61	*0.76	**0.72	**0.68	**0.69	**0.89	**0.78	**0.72	**0.48
MI	0.16	0.17	*0.37	0.16	*0.32	*0.39	0.14	0.13	0.11	0.14
AI_{15}	**0.58	**0.54	*0.41	**0.50	*0.35	*0.34	**0.69	**0.46	**0.48	*0.33
TKE	**0.60	**0.57	**0.74	**0.68	**0.67	0.70	**0.87	**0.72	**0.73	**0.48
EI_{15}	**0.57	**0.52	*0.40	**0.47	*0.36	*0.34	**0.67	**0.43	**0.47	*0.31
EI_{30}	**0.56	**0.50	**0.52	**0.53	**0.49	**0.48	**0.72	**0.50	**0.52	0.35
EI_{45}	**0.59	**0.52	**0.61	**0.53	**0.61	**0.58	**0.78	**0.56	**0.56	**0.34
EI_{60}	**0.62	*0.51	**0.67	*0.48	**0.7	**0.66	**0.78	**0.55	*0.56	0.40
I_{15}	0.25	*0.32	*0.32	**0.47	**0.19	0.23	**0.55	*0.39	*0.44	*0.42
I_{30}	*0.36	**0.39	*0.46	**0.59	*0.35	*0.41	**0.61	**0.54	**0.52	*0.49
I_{45}	**0.51	**0.52	**0.61	**0.65	*0.55	**0.58	**0.77	**0.69	**0.62	*0.50
I_{60}	**0.57	**0.55	**0.71	**0.63	**0.68	**0.67	**0.82	**0.71	**0.62	*0.52
EVd	**0.58	**0.52	**0.70	**0.67	**0.64	**0.69	**0.85	**0.73	**0.67	0.26
API	**0.47	0.24	**0.55	*0.40	**0.49	*0.42	**0.42	**0.54	*0.43	0.26

** Significant at the 0.001 level

* Significant at the 0.05 level

Source: fieldwork 1994-95

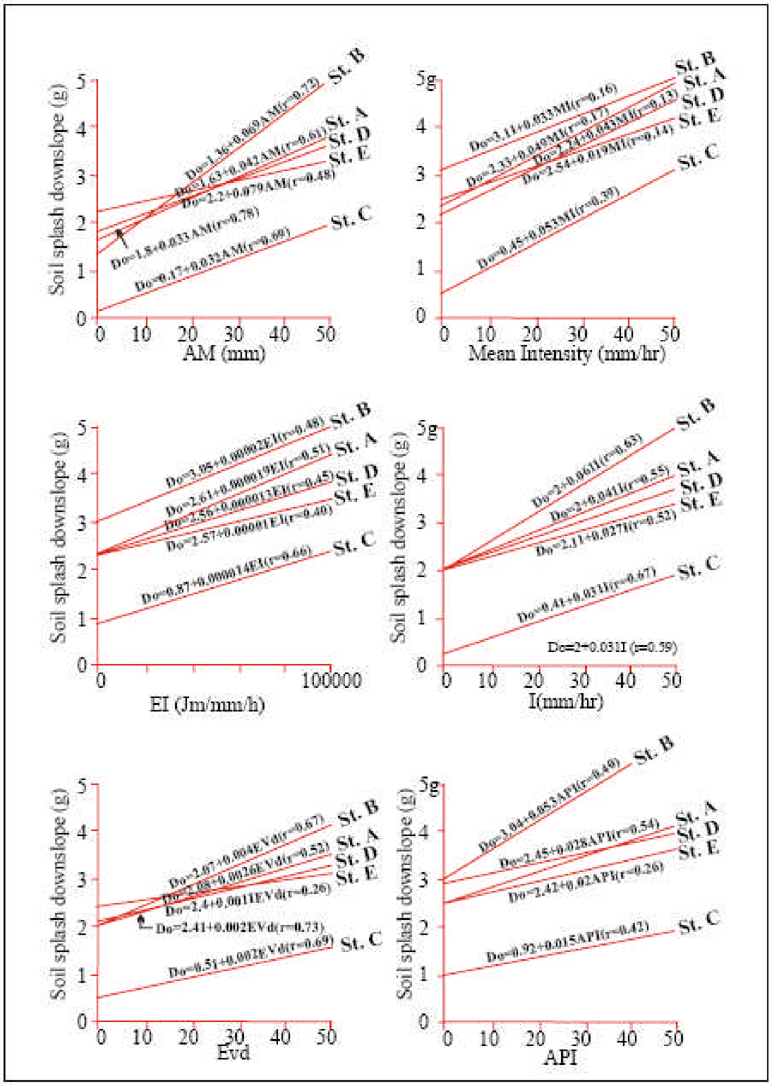


Figure 6. *Total average soil splash upslope and downslope at Tekala River Catchment*

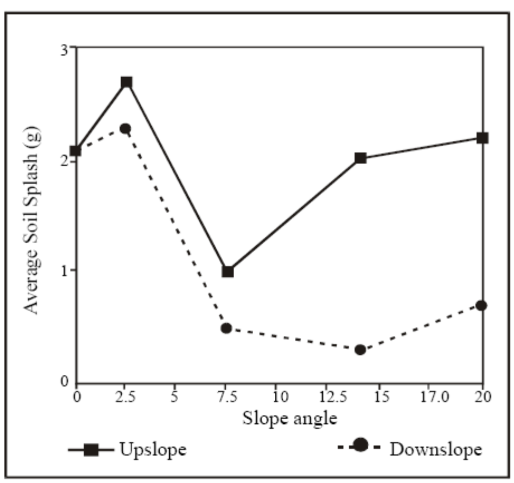


Figure 6. *Total average soil splash upslope and downslope at Tekala River Catchment*

Nevertheless, all the results showed that, either upslope or downslope, soil splash had a direct relationship with all the six indices.

Among previous studies of the relationship between rainfall parameters and the amount of soil splashed either upslope or downslope, Kinnell (1976) found a positive correlation and a linear relationship between the quantity of soil splash and total rainfall when rainfall intensity remained constant.

Ellison (1944) reported that the quantity of soil splash increased with drop size, drop velocity and rainfall intensity. Mazurak & Moshier (1968) found that the detachment of soil particles was linearly related to the rainfall intensity with uniform size and velocity of raindrops. There was a positive relationship between rainfall intensity and soil splash (Quansah, 1981).

EI_{30} has been widely used as the best rainfall parameter for expressing the relationship between soil splash and rainfall. Bollinne (1980) provided an empirical equation between EI_{30} and soil splash. In the case of EI_{30} for all rain > 1mm, the relation given was:

$$Y = 2.24 x \ 0.876, \quad \text{with } r = 0.86 \qquad ...\text{Eq.6}$$

where Y was soil splash in t/ha and x was EI_{30}

Many authors, for instance, Wischmeier & Smith (1958), Morgan (1978), Al-Durrah and Bradford (1982), and Morgan (1985) found that the kinetic energy (KE) of rainfall was the best variable to predict soil splash. Brandt (1988) reported that the basic relationship between the quantity of soil splash and kinetic energy (KE) according to a linear regression was:

$$Y = 16.3 + 2.83x, \quad \text{with } r = 0.81 \quad \ldots\text{Eq.7}$$

where Y was the soil splash and X was the kinetic energy

Stepwise Regression

Stepwise regression was used to study the relationship between the quantity of soil splashed and rainfall parameters. It was run for 10 times to assess rainfalls which were best related in predicting the quantity of soil splashed upslope and downslope (Table 4 and 5).

The key points to note from the results are:

i. The MI, EI60, EVd and API indices accounted for more of the variance in the amounts of soil being splashed upslope or downslope.
ii. At station A, the EI60, I15, API and I60 indices were the best rainfall parameters, explaining up to 81 per cent of storm-to-storm variance in the amount of soil splashed upslope. As expected, the rainfall erosivity index (EI60) was the best rainfall parameter explaining 31 per cent of variance in the quantity of soil splashed upslope. The second parameter I15, explained 29 per cent. API and I60 explained about 15 and 6 per cent respectively.
iii. At station B, the AM and I15 indices respectively accounted for 52 and 24 per cent of the variation in the amount of soil splashed upslope, while EVd, EI60 and I60 combined explained around 81 per cent of the variance in the amount of soil splashed downslope. EVd is considered the best parameter, explaining up to 46 per cent of the variance in the amount of soil splashed downslope at Station B.
iv. At station C, the MI index was the best parameter accounting for 46 and 54 per cent respectively of the variation in the amount of soil splashed upslope or downslope. In addition, API index was the second parameter, explaining 23 and 16 per cent of the variance of the soil splashed upslope and downslope respectively at Station C.
v. At station D, the TKE, I60, I30, EI30 and MI indices accounted for 96 per cent of the variation in the amount of soil splashed upslope. TKE explained up to 78 per cent of soil splashed upslope, while, EVd, I45, I15 and MI accounted for 63 per cent of the variation in the amount of soil splashed downslope at Station D.

vi. At Station E, EVd and EI15 explained 20 and 19 per cent of the variation in the soil splashed upslope or downslope respectively.

The above results showed that the same parameters accounted for the largest percentage of the variance at different stations. These parameters were EI60, I60, EVd, MI, I15 and API. However, TKE index explained up to 78 per cent of soil splashed upslope at station D. This index did not appear to be a significant index for other stations and was difficult to explain. As the indices of MI, EI60, I60, EVd and API were directly related to soil splashed upslope and downslope these indices could, therefore, be considered as a good erosion index to be used in an equatorial region as compared to EI30 index which was more suitable for application to other regions.

Lo *et al.* (1985) found that EI30 was the best linear estimator, explaining up to 98 per cent of variance in sand splash, and they recommended EI30 as suitable for quantifying the erosivity of Hawaiian rainstorms. However, they did not explain the justification for using EI30 as an erosion index. By comparison, the present study not only chose various rainfall parameters based on significant correlation results between soil splash and rainfall parameters but also did so according to the linear regression between soil splash erosion and rainfall parameters.

Figure 5 shows that all rainfall parameters produced a linear relationship with the quantity of soil splashed either upslope or downslope. But the best parameter can be determined by applying the stepwise regression analysis. In this study I60, EI60, EVd and API could be recommended as the best rainfall parameters as compared to the others which registered less significance.

Table 4. Coefficient of determination (r2) resulting from regression analysis (stepwise regression) between soil splash upslope and rainfall parameters

Rainfall Parameter	Station				
	A	B	C	D	E
AM		**0.52 a			0.06
MI			**0.46 a	0.01	
AI15			0.04		
TKE	0.01			**0.78 a	
EI15	0.01		0.01		
EI30	0.02		0.01	*0.05 c	
EI45			0.01	0.01	
EI60	*0.31 a		*0.09 c		
I15	*0.29 b	*0.24 b	0.02	0.02	
I30	0.10		0.02	*0.04 d	
I45			0.02		
I60	*0.06 d	0.03	0.01	*0.08 b	
EVd					*0.20 a
API	*0.15 c		**0.23b		0.11
Cumulative r2	0.81	0.76	0.78	0.95	0.20

** Significant at the 0.001 level
* Significant at the 0.05 level
a, b, c are the sequence of important variable
Source: fieldwork 1994-95

The Relationship between soil splashed upslope and downslope

The difference between the mean and total quantity of soil splashed both upslope and downslope increased positively with the slope gradient. The mean and total quantity of soil splashed downslope were equal to 1.2 times soil splashed upslope at station B, three times at station E and seven times at station D (Figure 6).

Table 5. Coefficient of determination (r2) resulting from regression analysis (stepwise regression) between soil splash downslope and rainfall parameters

Rainfall Parameter	Station				
	A	B	C	D	E
AM			0.02	0.04	
MI			**0.54 a	*0.08 c	
AI15			0.02	0.09	
TKE			0.01		
EI15			*0.10 c	0.07	*0.19 a
EI30			0.04		
EI45					
EI60		*0.24 b			
I15				*0.07 d	
I30			0.01	0.03	0.14
I45			0.01	*0.11 d	
I60		*0.11 c			
EVd		**0.46 a	0.01	**0.37 a	
API			**0.16 b	0.03	0.11
Cumulative r2		0.81	0.80	0.63	0.19

** Significant at the 0.001 level
*   Significant at the 0.05 level
a, b, c are the sequence of important variable
Source: fieldwork 1994-95

Table 6. Regression Equations and Correlation between the Amount of Soil Splash downslope and upslope

Station	Slope	Equation	Correlation coefficient	Calculated F-value
Station A	0.00°	Do = 0.79 +0.73U	0.83**	20.36
Station B	2.5°	Do = 1.65 +0.73U	0.68**	4.62
Station C	7.5°	Do = 0.087 +1.73U	0.88**	58.07
Station D	14°	Do = 2.26 +0.556U	0.69**	3.55
Station E	20°	Do = 1.53 +1.445U	0.55**	2.54

** Significant at the level 0.001 level
Where Do is the amount of soil splash downslope and U is the amount splashed upslope.
The F-value are all significant at the level.

A simple regression analysis was carried out to study the relationship between the amount of soil splashed upslope or downslope. Linear relationships were obtained between the amount of soil splash upslope and downslope for all the five stations (Table 6).

This is consistent with the findings of Mati (1991) as cited by Smith and Wischmeier (1962), namely, the amount of soil splashed downslope was seven times that splashed upslope on bare fallow land and six times under maize crop. The proportion was, however, lower (within 1-3 times) under beans and intercrops. Mati carried out his experiment under 25 per cent slope gradient.

Smith and Wischmeier (1962) explained that the different movement between upslope and downslope soil splash was caused by the rainsplash impact. The downslope movement went further downslope before re-contacting the soil surface and that the resulting angle of impact was greater in a downslope direction. Overall, the mean height of downslope soil splash was higher than that of the upslope. This is normal as soil splash is affected by gravity and slope direction.

The rainsplash height

The maximum heights splashed downslope on March 8, 1995 were 98, 95, 93 and 92cm for Stations E, A, D, B,and C respectively (Table 7a, b, c, d and e). None of these heights was associated with the highest of any one of the 14 rainfall parameters used in this study. The March 8, 1995 event was associated with the high energy and intensity of the 41.4 mm rainfall amount. Such an event could also wash the filter paper clean. As such, intensive monitoring over such events is often required.

Meanwhile, the maximum heights splashed upslope were 93, 91, 90, 90 and 80 cm high for Stations A, B, C, E and D respectively. These heights were much less than those of the downslope direction and did not coincide with the highest value of the rainfall amount. The soil splashed downslope were 70, 60, 50, 50, and 50 cm at Stations E, B, A, C and D respectively.

Sharifah Mastura (1989) reported that the highest soil splash in her study area was 90cm but the height was not associated with the highest rainfall amount and intensity. Mason and Andrew found that the maximum height of splash was 60 cm as cited by Smith and Wischmeier (1962).

Table 7a. Station A: minimum, maximum, mean and total amount splashed on the board

Soil Parameter	Min.	Max.	Mean	Std.Dev.	Total
Upslope-amount	0.33g	7.58	2.16	1.72	93.13
Height con.%75-Upslope	20cm	40	34.5	5.9	
Height-Upslope	50cm	93	69.5	10.8	
Downslope-amount	0.35g	7.41	2.13	1.49	93.85
Height con.%75-Downslope	20cm	50	37.1	6.4	
Height-Downslope	40cm	95	70.6	11.8	

Table 7b. Station B: minimum, maximum, mean and total amount splashed on the board

Soil Parameter	Min.	Max.	Mean	Std.Dev.	Total
Upslope-amount	0.43g	5.97	2.25	1.47	103.87
Height con.%75 –Upslope	20cm	50	36.4	6.0	
Height-Upslope	50cm	91	71.9	13.2	
Downslope-amount	0.18g	7.10	2.74	1.75	126.25
Height con.%75 -Downslope	20cm	60	37.3	6.7	
Height-Downslope	40cm	93	73.04	13.0	

Table 7c. Station C: Minimum, Maximum, Mean and Total Amount Splashed on the Board

Soil Parameter	Min.	Max.	Mean	Std.Dev.	Total
Upslope -amount	0.0007g	2.09	0.48	0.37	22.13
Height con.%75-Upslope	20cm	50	32.8	7.6	
Height-Upslope	40cm	90	63.9	12.7	
Downslope - amount	0.08g	3.77	0.97	0.70	45.92
Height con.%75-Downslope	20cm	50	34.2	7.07	
Height-Downslope	40cm	92	67	12.5	

Table 7d. Station D: minimum, maximum, mean and total amount splashed on the board

Soil Parameter	Min.	Max.	Mean	Std.Dev.	Total
Upslope - amount	0.08g	1.52	0.65	0.65	13.24
Height con.%75-Up	10cm	50	29.2	9.2	
Height-Upslope	20cm	80	58.4	15.7	
Downslope - amount	0.41g	4.48	1.96	1.10	92.54
Height con.%75-Downslope	20cm	50	35	7.1	
Height-Downslope	40cm	95	70.3	13.4	

Table 7e. Station E: minimum, maximum, mean and total amount splashed on the board

Soil Parameter	Min.	Max.	Mean	Std.Dev.	Total
Upslope - amount	0.13g	1.43	0.67	0.36	30.47
Height con.%75-Up	20cm	50	33.5	7.2	
Height-Upslope	30cm	90	62.3	13.9	
Downslope - amount	0.07g	6.06	2.22	1.38	99.94
Height con.%75-Downslope	20cm	70	40.42	9.7	
Height-Downslope	40cm	98	79.2	13.3	

Relationship between soil splash height and rainfall parameter

The product moment correlations between the heights of downslope and upslope splash erosion with all rainfall and erosivity indices (Table 8) show the following:

1. Two parameters (TKE, AM) were found to be significantly and positively correlated with soil splash height at all the five stations.
2. I45 index was correlated with soil splash erosion except for upslope splash at Station B.
3. I60 was strongly correlated with soil splash erosion at Stations A, B (downslope), C, D and E (downslope)
4. Indices that had the most value of significant correlation with rain splash erosion were EI45, AI15, MI, API and EI60.

This could be due to various causes. One was that heavy or long duration rainfall events tend to wash the blotting paper clean. Thus, recorded height was difficult to ascertain accurately while MI index appeared weak because it was an average intensity index. The disadvantage of this index was that it was affected by extreme values.

The difference between the height of downslope and upslope soil splash increased with the increase in slope gradient, being 1.1, 3.1, 11.9 and 16.9 cm for stations B, C, D and E respectively. This could be explained by the gravitational effects and the manner the 100 cm high splash board was mounted perpendicular to the ground surface. When the height of downslope and upslope soil splash was subjected to a regression analysis for each station, linear relations were obtained for all stations (Table 8).

Table 8. Regression equation between height of soil splash upslope and downslope, correlation coefficient (r) and calculated F values

Station	Slope Degrees	Equations	Correlation Coefficient	Calculated F - Value
Station A	0.00°	U = 20.8 + 0.7 Do	0.82∗∗	8.124
Station B	2.5°	U = 17.8 + 0.75 Do	0.82∗∗	21.83
Station C	7.5°	U = 11.07 + 0.77 Do	0.79∗∗	8.125
Station D	14°	U = -14 .19 + 1.04 Do	0.83∗∗	16.32
Station E	20°	U = 47.9 + 0.23 Do	0.52∗∗	0.669

∗∗ Significant at 0.001 level
Where U is the height of soil upslope and Do is the height of soil downslope .
The F-values are all significant at 0.001 level.

Conclusion

Both the quantity and the height of soil splashed upslope and downslope varied from storm to storm and according to rainfall amount, energy, intensity, and erosivity. This study showed that there were marked variations in the upslope and downslope splashing of soil. However, the relationship with gradient was not very clear and more intensive work therefore is needed. Overall results revealed that there was clear evidence of splash erosion process occurring under forest reserve land use in this study. The average amount of soil splashed indicated that splash erosion could increase manifolds in areas of disturbed ground.

Generally, the study also showed that most of the rainfall and erosivity indices used were suitable indicators for predicting erosion, although some indicators were much better than others in explaining the process. These were EI60, I60, EVd and API which could be considered as the best rainfall parameters to relate with both upslope and downslope soil splash erosion. The regression equations for soil splashed upslope and downslope for these indices given in this study may serve as a good predictor equation to be used in tropical rainforest areas. Overall, EI60 index is most significant and could be recommended for use in the study of rainsplash erosion.

The linear relations obtained between both the amount and height of soil splashed upslope and downslope revealed that rainsplash erosion was an important first step action in the soil erosion process. The quantity of soil provided by this initial process would determine the total amount of eroded material that could be carried out by the surface wash process. The latter process transported the splashed as well as the top soil downstream from the source area. The impact of soil removed in this manner could be further accelerated by human activities such as land clearing and earthwork often associated with economic development. Accelerated soil erosion could have serious impacts on the environment in the way that it affects soil fertility, reduces water quality and causes excessive siltation downstream. Such impacts should be mitigated by practising the soil conservation strategy so as to ensure long term sustainability of the soil.

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