AN EXPERIMENT ON ERODIBILITY ON TWO SLOPES

BY

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CHAPTER I

INTRODUCTION

A particle of sediment is a particle of rock fragment or a mineral and it is the by-product of erosion (Gottschalk, 1964, p.14) Its movement, particularly by water, is of great importance to Man. Not only does this movement lower the land surface by several metres per 1000 years (Judson, 1968, p.358) and modify the hill slopes (Gerlach, 1968, p.129) but it also affects the development and the progress of any nation new or old (FAO, 1965, p.3) In fact, its uncontrolled removal by water in nature is a scourge causing widespread damage to cultivated land in Africa and Madagascar (Charreau, 1968, p.241) and its deposition has already cost Americans millions of dollars annually (Gottschalk, 1964, p.3)

It is therefore not surprising to find that the study of this movement and the resulting sediment yield, "which implies a consideration of the hydrologic events which cause sediment movement, and thus involves the important notion of the magnitude and frequency of denudation processes" (Douglas, 1968, p.2), has attracted not only the geomorphologists but also the agriculturists, the economists, the hydrologists, the geologists, engineers and technologists. In the process several methods of sediment collection have been thought out and employed for the study. These methods can be broadly classified into those which depend on the sediment load of the stream or river water and those which study the sediment yield on the site itself.

SEDIMENT LOAD SAMPLING

Two examples of the methods which depend on the sediment load of the stream or river water are the measuring of the amount of sediment collected at a reservoir or at a lake after a known period of time (Judson, 1968, p.363) and the measuring of sediment suspension in the river water at different spots along the river (Douglas, 1968, p.1) These methods give the amount and the rate of erosion of the river basin upstream of the sampling station but neither of them will show the relative contributions of either bank nor the local effects of rain-water on different parts of a slope. They are not meant to.

COLLECTION FROM SITE

The method which depends on the sediment yield at the site itself usually employs a frame to mark off the area from which the sediment is to be collected. This method has been used quite frequently in the temperate regions. An example of its use is given in the study of a slope in Spitsbergen (Jahn, 1960, p.54)

While this method may have been satisfactorily used in the temperate countries where the intensity and the amount of rainfall are very much less than those within the Tropics, one wonders if in Malaysia this method may not result in having to collect too much run-off. Taking the area within a frame to be 1 square metre and a rainfall intensity of 5 cm in 15 minutes as may be expected in West Malaysia (Douglas, 1968, p.6) and assuming a coefficient of run-off[1] of 0.2 (Charlton, 1964, p.53) or 0.25 (Low, 1964, p.30) one would have approximately 10 or 12.5 litres of run-off respectively in a 15-minute

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[1] Coefficient of run-off = $\frac{\text{Rate of run-off}}{\text{Rate of rainfall}}$ (Ayres, 1936, p.86)

rain. One would need a fairly large container at the downslope[2] end of the frame to hold that amount of run-off and then would probably need only a small portion of that for analysis[3]. Further, while a 10-litres collection may not be too bulky if only one sample is required from a slope, it becomes quite inconvenient if a few samples are required simultaneously from different 'frames' within the area or stream basin.

Thus both methods have certain drawbacks and it is these that prompted this student to experiment with a very much modified form of the "frame" method.

AIM OF METHOD

The method used in this graduation exercise was to induce a run-off and a sediment yield at pre-determined spots on a slope, using a controlled input of a uniform quantity of distilled water in the form of a simulated rainfall. By this, it was hoped that the method would

(a) eliminate the variability of the amount of run-off caused by a variability of the amount of rain,

(b) eliminate the variability of the intensity of the rainfall,

(c) eliminate the variability of the acidity of the input rainwater,

(d) show the relative local erodibility at different parts of a slope, and

(e) show the relative effects of a difference in the main vegetation cover on the slope.

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[2]See Appendix I

[3]Kellman appears to have used the "frame method" in his Mindanao observations. He took 400 c.c. for analysis (Kellman, 1968, p.47)

AIM OF THE TESTS

The induced run-off and the sediment yield were collected and analysed for their volume, the amount of sediments that could be filtered with a filter paper, the pH values of the run-off and the amount of dissolved minerals. These variables were tested for correlations not only among themselves but also against the slope angle, the altitude above the stream channel and the distance from the middle of the stream in an attempt to compare the validity of the observations and hence the method, with the observations established by other methods.

No attempt, however, was made to estimate the probable natural sediment yields of the two areas studied, from the mean sediment yields of the observations. This was because the simulated rainfall was about 123 times the maximum probable intensity for West Malaysia. To estimate the probable natural sediment yield by proportional decrease will be to oversimplify the complex relationship between rainfall and sediment yield.

Further, the student does not claim that the eight variables used in the tests to be comprehensive nor the tests conducted to be exhaustive. The student nevertheless hopes that the results obtained from this experiment will serve as an introduction to others to conduct further and more exhaustive experiments with the method described.

CHAPTER II

THE EXPERIMENT

LOCATION

Two areas located approximately one mile (1.7 Km) north of the University of Malaya Meteorological Station were studied. These areas (Figure 1) are adjacent to a common open space below the power-lines and are part of the same hillslope face on the right bank of a stream. The common bedrock is the Kenny Hill Formation (Morgan, 1970, p.18) sedimentary rock with beds of shales alternating with sandstone. Outcrops of this bedrock were seen at a levelled building site (Plate I) a short distance downstream and also at the spur across the stream valley.

The soil of the two areas is a latosol soil but the land use and the vegetal cover for the two areas were different. These two areas were accordingly designated the "Rubber Estate Slope" and the "Lalang[1] Slope" to differentiate them and to indicate the main vegetation as well.

THE RUBBER ESTATE SLOPE

The Rubber Estate Slope was the earlier of the two areas studied. It measured 100 feet (30.480 m) upstream from the upstream edge of the open space below the power-lines and 120 feet (36.576 m) upslope[2]. At the foot of the slope is a floodplain of varying width (Plate II) and

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[1] Lalang is the local name for Imperata cylindrica

[2] For illustration of this term and other similar terms as used in the context of this graduation exercise, see Appendix I.

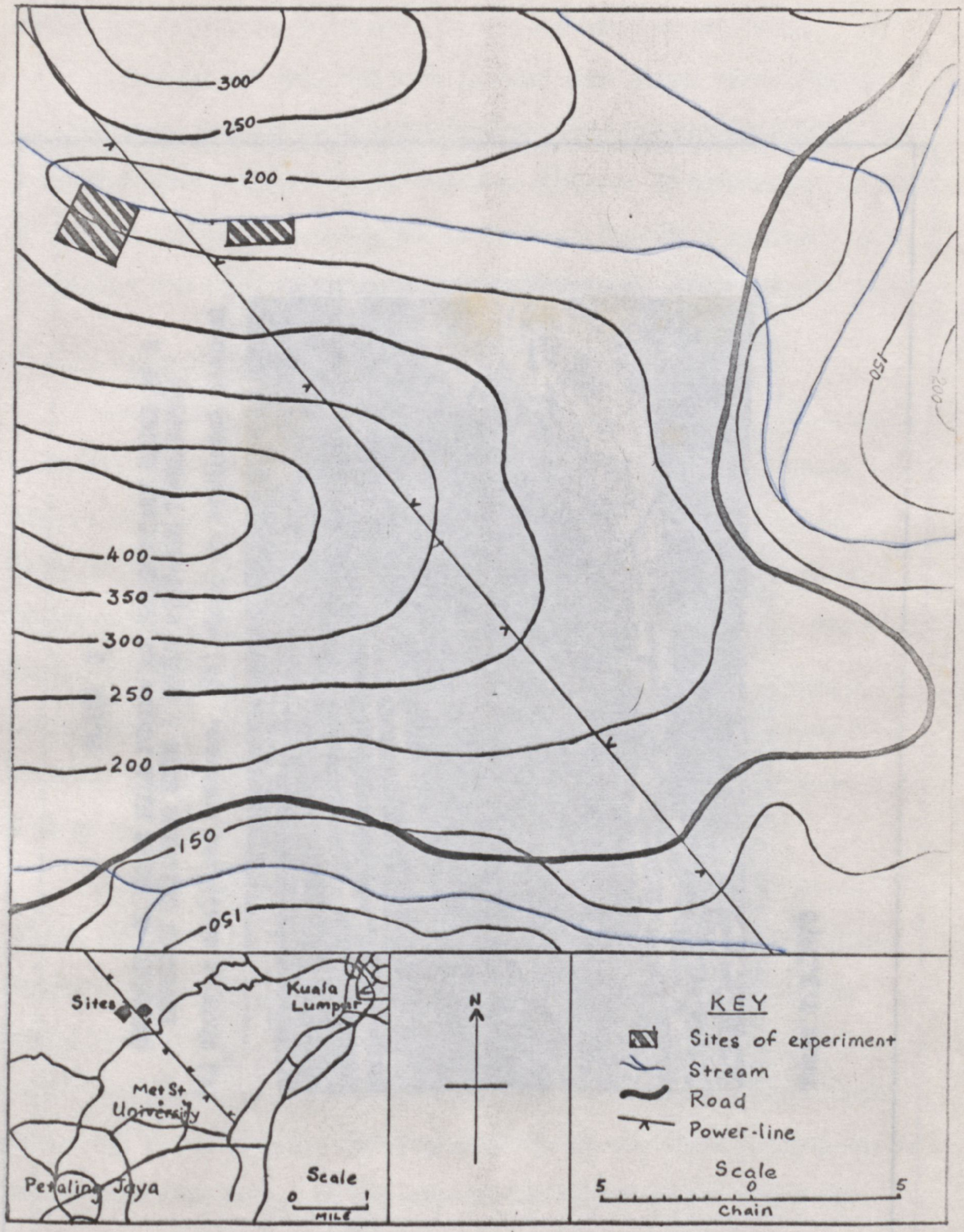

Figure 1 Location of Experiment

PLATE I

OUTCROPS OF KENNY HILL FORMATION SEDIMENTARY ROCKS AT A LEVELLED BUILDING SITE A SHORT DISTANCE DOWNSTREAM

(A) shows a shale bed outcrop. (B) shows an erosional channel

Taken 2.3.1970

PLATE II

FLOODPLAIN OF VARYING WIDTH AT RUBBER ESTATE SLOPE
(LOOKING DOWNSTREAM)

The sticks in the stream channel indicate the points from which transects upslope were made

Taken 2.3.1970

first, and second order stream channels cut through the area.

Although the area had been planted with rubber trees (Hevea brasiliensis) for over a decade the slope form had remained relatively unaltered (Plate III). There were some evidence of erosion in the form of gullies and natural subterranean drainage tunnels ("pipings") near the stream channels cutting the area. There was no sign of slumping.

THE LALANG SLOPE

The lalang slope area, on the downstream side of the open space below the power-line, measured 100 feet (30.48 m) from the downstream edge of the open space and only 45 feet (13.716 m) upslope because about 10 feet (3.048 m) further upslope, the slope had been cut and levelled off apparently to be used as future building sites. The slope itself was largely covered by lalang, other grasses (Scleria bancara and Paspalum), ferns like Lycopodium and Gleichenia linearis and some "Straits Rhododendron" (Melastroma malabathricum) shrubs. The slope form is shown in Plate IV.

A comparison of the frequency distributions of the slope angles of the sites of the experimental stations at the two areas understudy is shown in Figure 2. It can be seen that the modal class for the Rubber Estate Slope is at 20° to 24° while that for the Lalang Slope is at 30° to 34°. Each of the two slopes has 5 sites with a slope angle of the 25° to 29° class. Further, each of the two distributions has a second but lower peak. In the case of the Rubber Estate Slope this second peak is at the 35-39° class while at the Lalang Slope it is at the 10-14° class.

The Lalang Slope appeared to be influenced by human activity.

PLATE III

A SECOND-ORDER STREAM-CHANNEL AND THE SLOPE-FORM AT RUBBER ESTATE SLOPE

The slope form at the area is generally a gentle convex as seen at the right middle distance of the photograph

Taken 2.3.1970

PLATE IV

SLOPE-FORM AT LALANG SLOPE WITH RUBBER ESTATE AT THE BACKGROUND

(A) shows position of slumping. (B) shows approximate position of break of slope.

Taken 2.3.1970

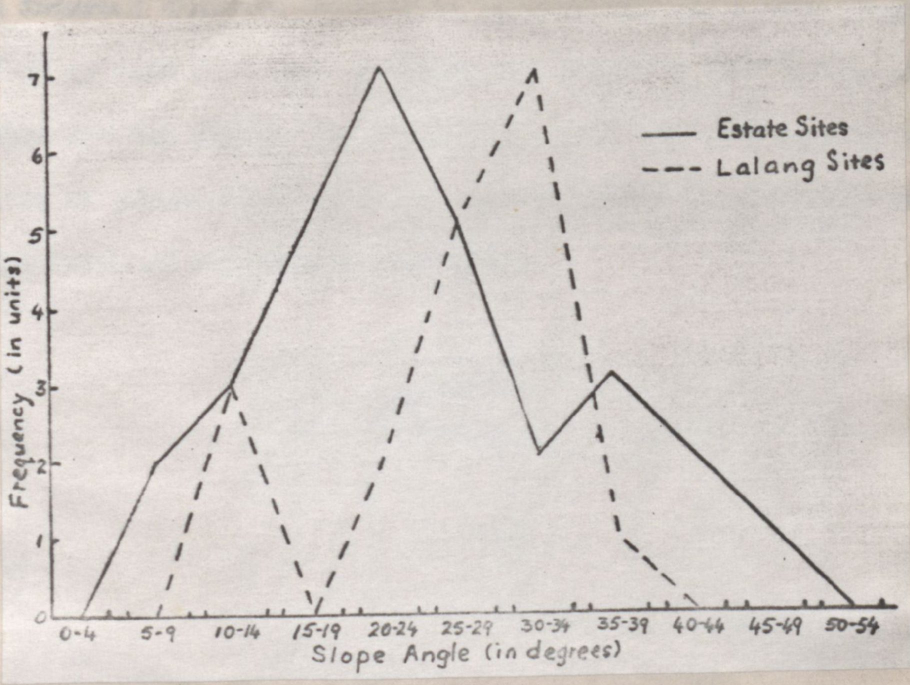

FIGURE 2. Frequencies of Slope Angles of the sites of the Experimental Stations at the two areas understudy.

For example, wooden pegs were used for impaling turfs of grass onto the slope to reduce if not to prevent erosion. In spite of this there was evidence of slumping. There were no stream channels dissecting the area and there was also no floodplain. There was however a clear break of slope[1] at most places along the footslope about 5 feet (1.524 m) from the middle of the stream channel.

EXPERIMENTAL STATIONS

The experimental stations were demarcated sites from where the

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[1] See Appendix I

observations were made. A sketch of a demarcation cylinder[1] is shown in Figure 3. It is made from a discarded condensed milk tin with a mean internal diameter of 8.17 cm (± 0.04 cm) and a mean height of 7.20 cm (± 0.05 cm). Each cylinder was placed normal to the slope surface and was gently tapped into the soil with a hammer knocking on a piece of plank placed over the top rim until the cylinder was buried to the level of the foot of the spout.

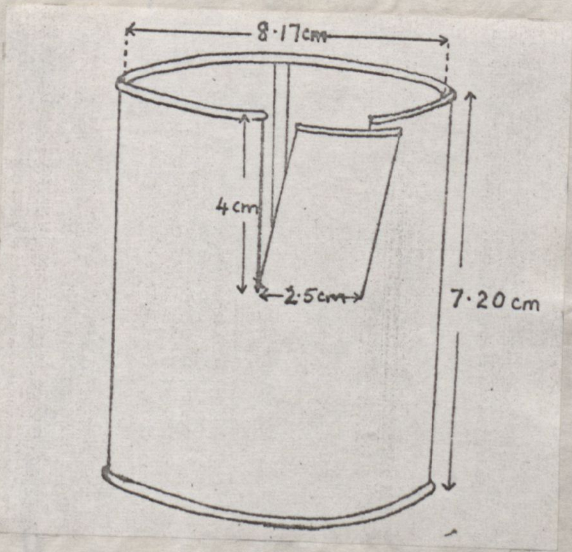

FIGURE 3 Sketch of a Cut Cylinder

SITES OF THE EXPERIMENTAL STATIONS

At the Rubber Estate Slope, a systematic pattern was intended. Transects upslope were made from the points A, B, C, D and E shown in Figure 4. The distance of 20 feet (6.096 m) between successive points was arbitrarily chosen and the profile along these points is shown in Figure 5. The profiles along the transects are shown in

[1] For preparation of the cylinder, see Appendix II

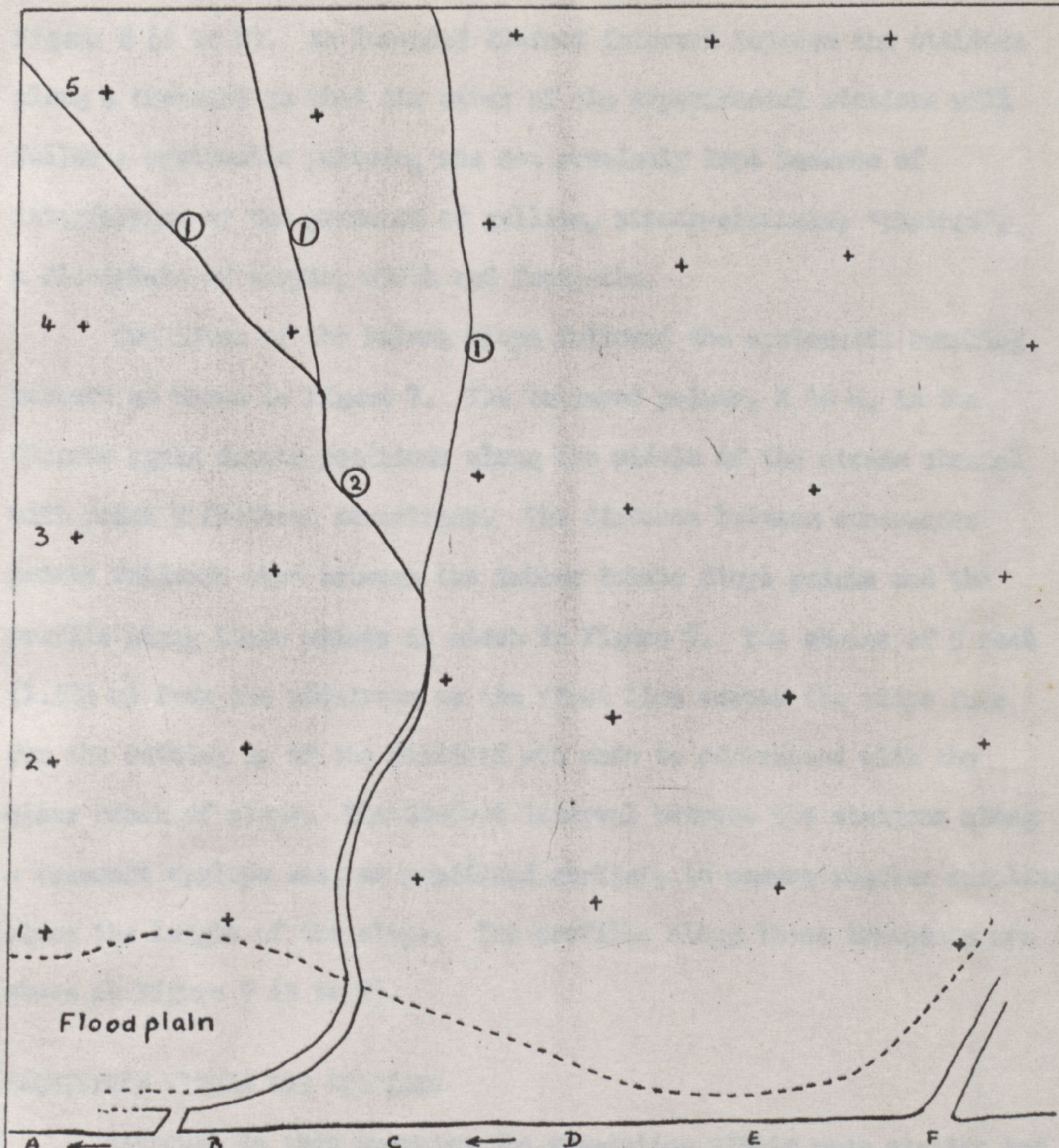

Figure 4 *Sites of Experimental Stations*
(Rubber Estate Slope)

① Stream-order

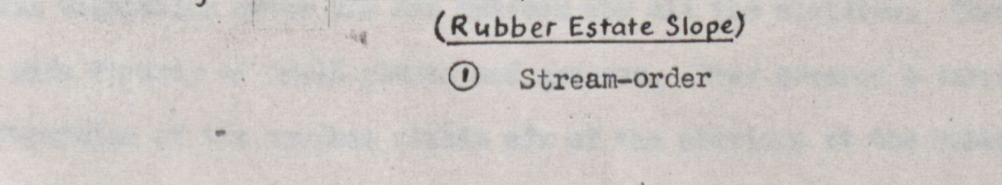

Figure 5 *Stream-bed Profile (A to F)*

Figure 6 (A to F). An intended 20-foot interval between the stations along a transect so that the sites of the experimental stations will follow a systematic pattern, was not precisely kept because of interference by the presence of gullies, stream-channels, "pipings", a floodplain of varying width and footpaths.

The sites of the Lalang Slope followed the systematic sampling pattern as shown in Figure 7. The lettered points, R to W, in the diagram again denote positions along the middle of the stream channel with point R farthest downstream. The distance between successive points followed that between the Rubber Estate Slope points and the profile along these points is shown in Figure 8. The choice of 5 feet (1.524 m) from the midstream as the first line across the slope face for the setting up of the stations was made to correspond with the clear break of slope. The 20-foot interval between the stations along a transect upslope was, as mentioned earlier, to ensure regular sampling along the length of the slope. The profiles along these transects are shown in Figure 9 (R to W).

VEGETATION WITHIN THE STATIONS

Although in this exercise the vegetation within each station had not been included as a variable it must, however, be pointed out that this vegetation cover was not uniform for all the stations. There was a wide variety of small plants and grasses. Moss covered a varying proportion of the surface within six of the stations at the Rubber Estate Slope. These were A1, 3 and 5, B2, C3 and D3[1]. Dead lalang

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[1] See Figures 4 and 7.

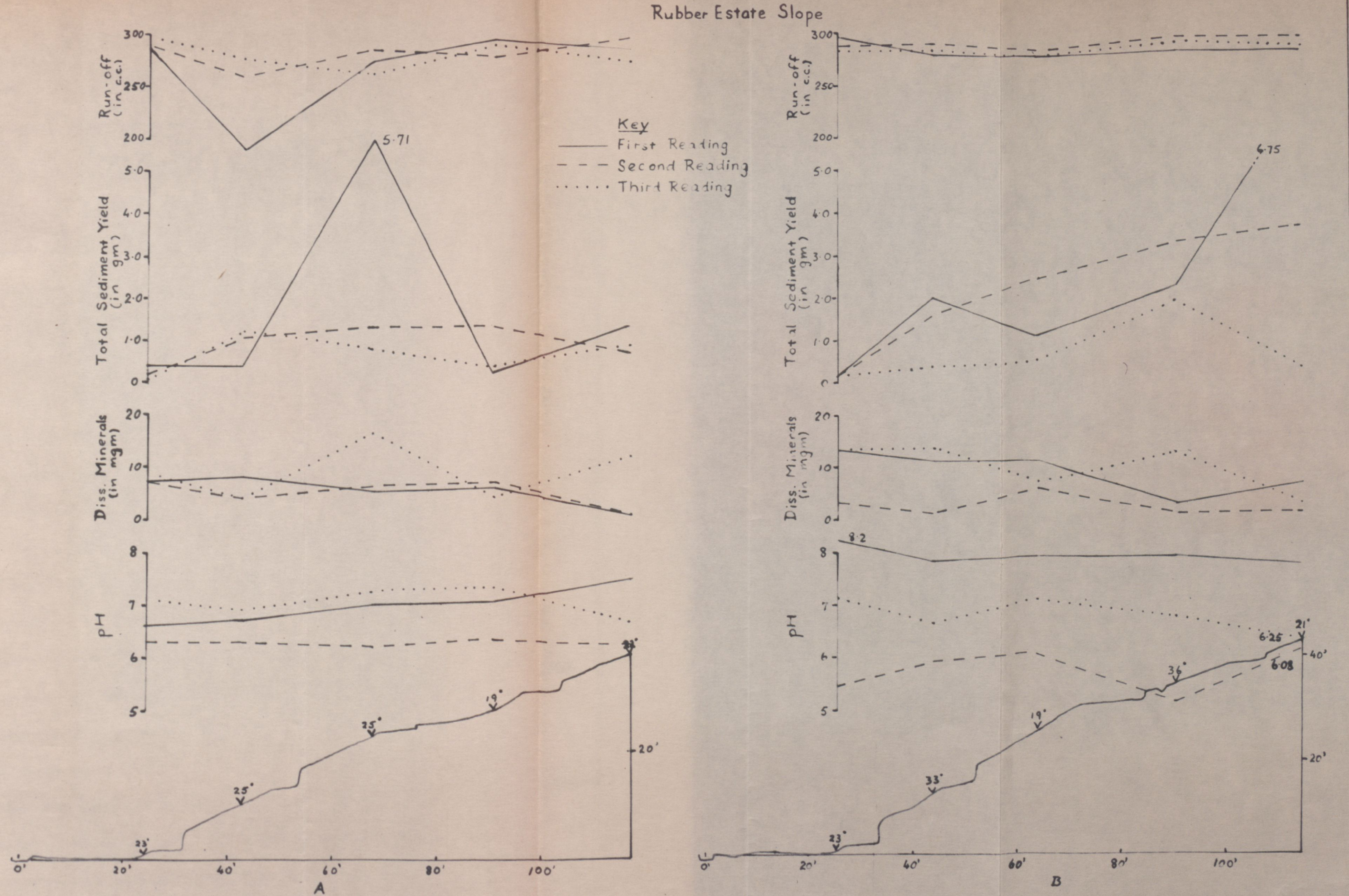

Figure 6 Slope Profiles and Data

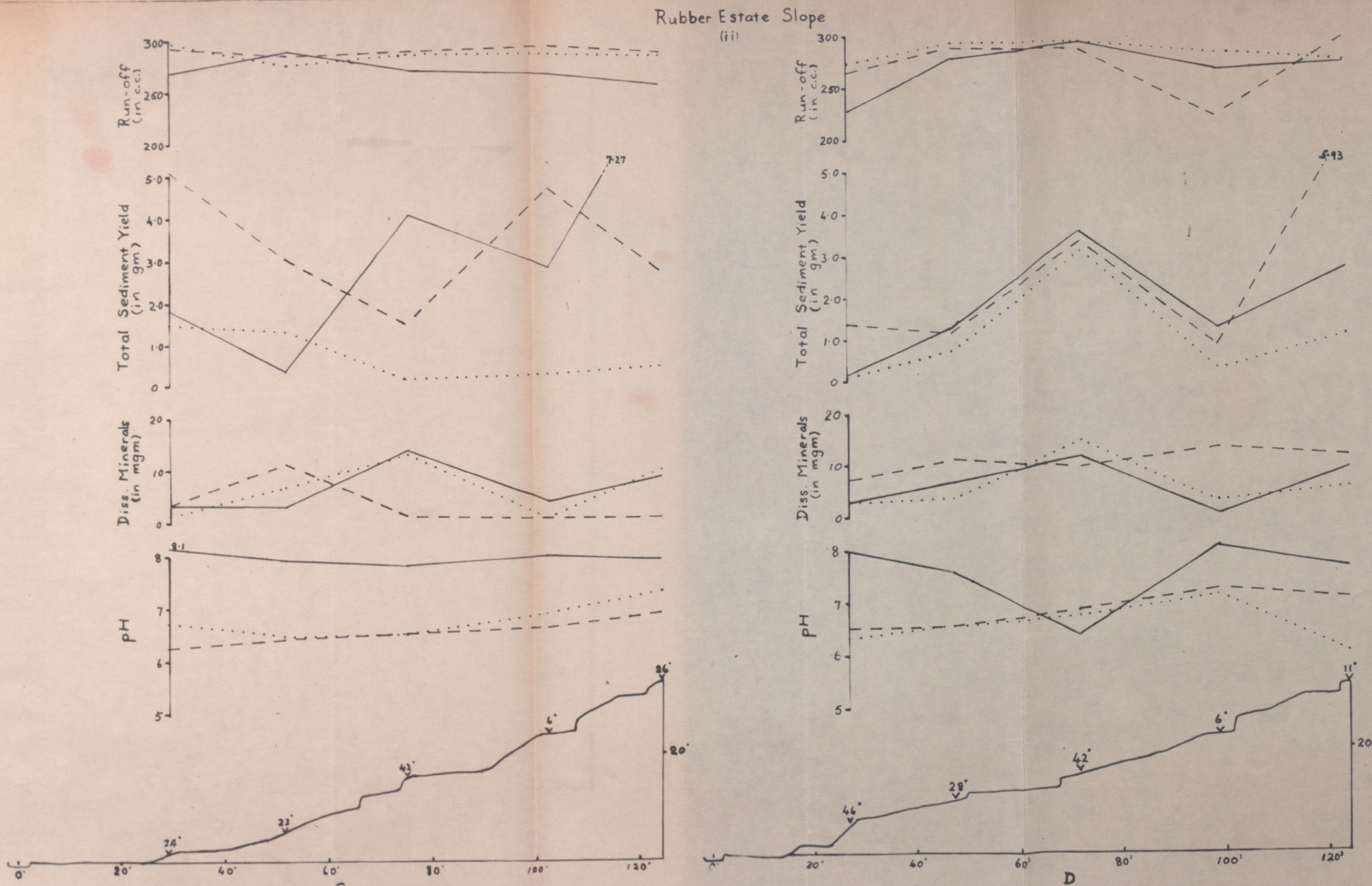

Figure 6 Slope Profiles and Data

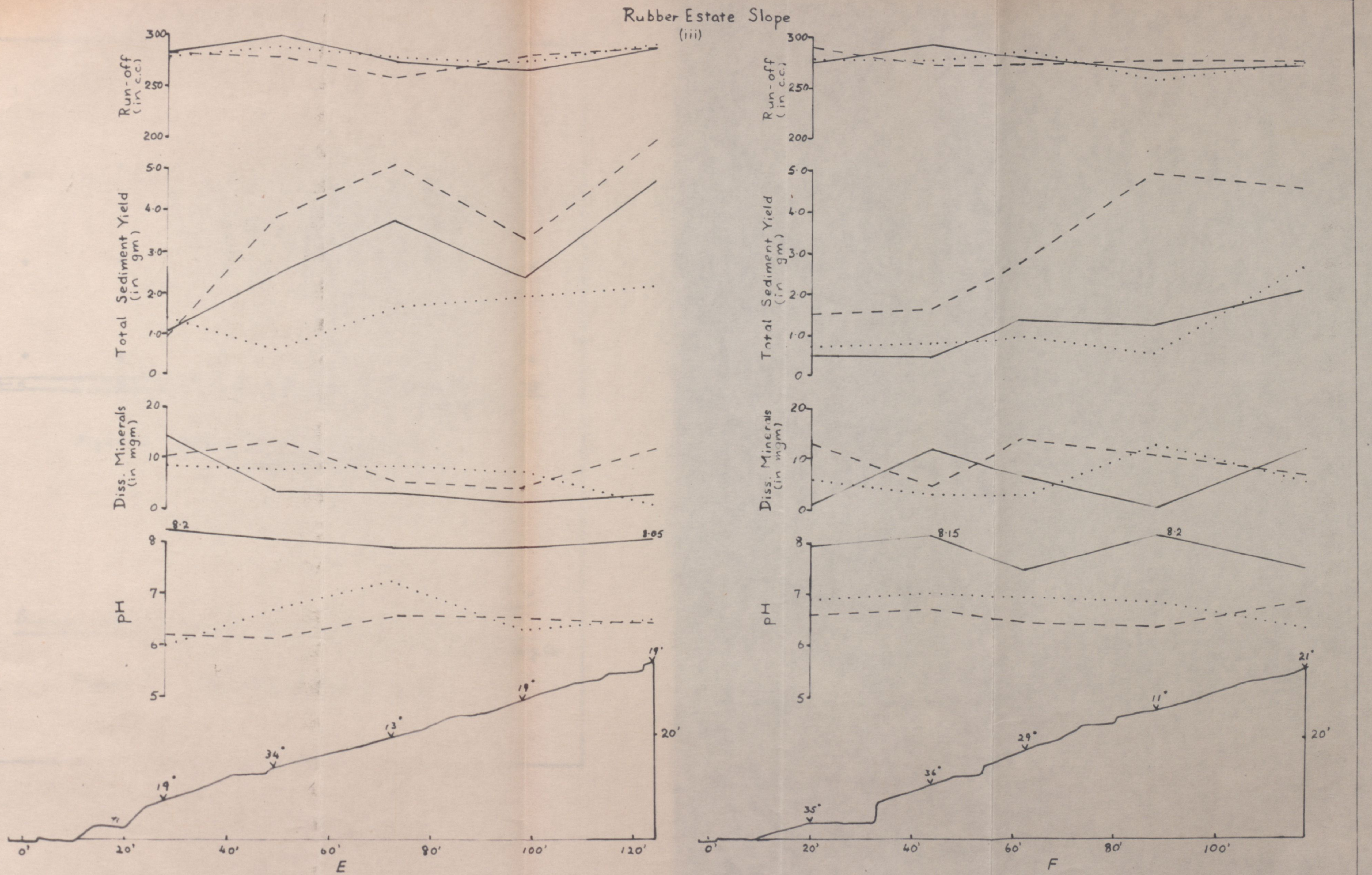

Figure 6 Slope Profiles and Data

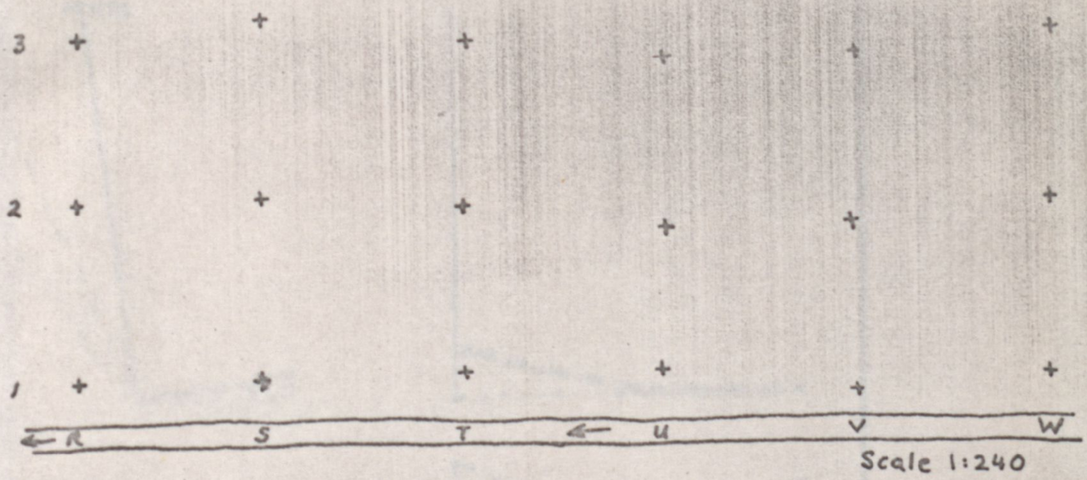

Figure 7 Sites of Experimental Stations
(Lalang Slope)

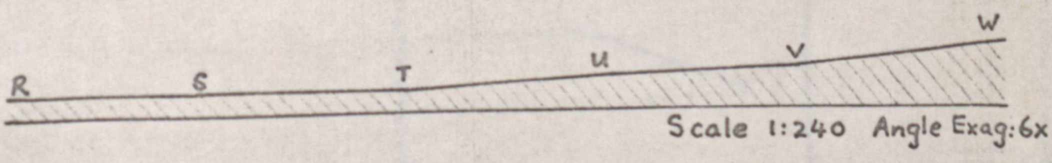

Figure 8 Stream-bed Profile (R to W)

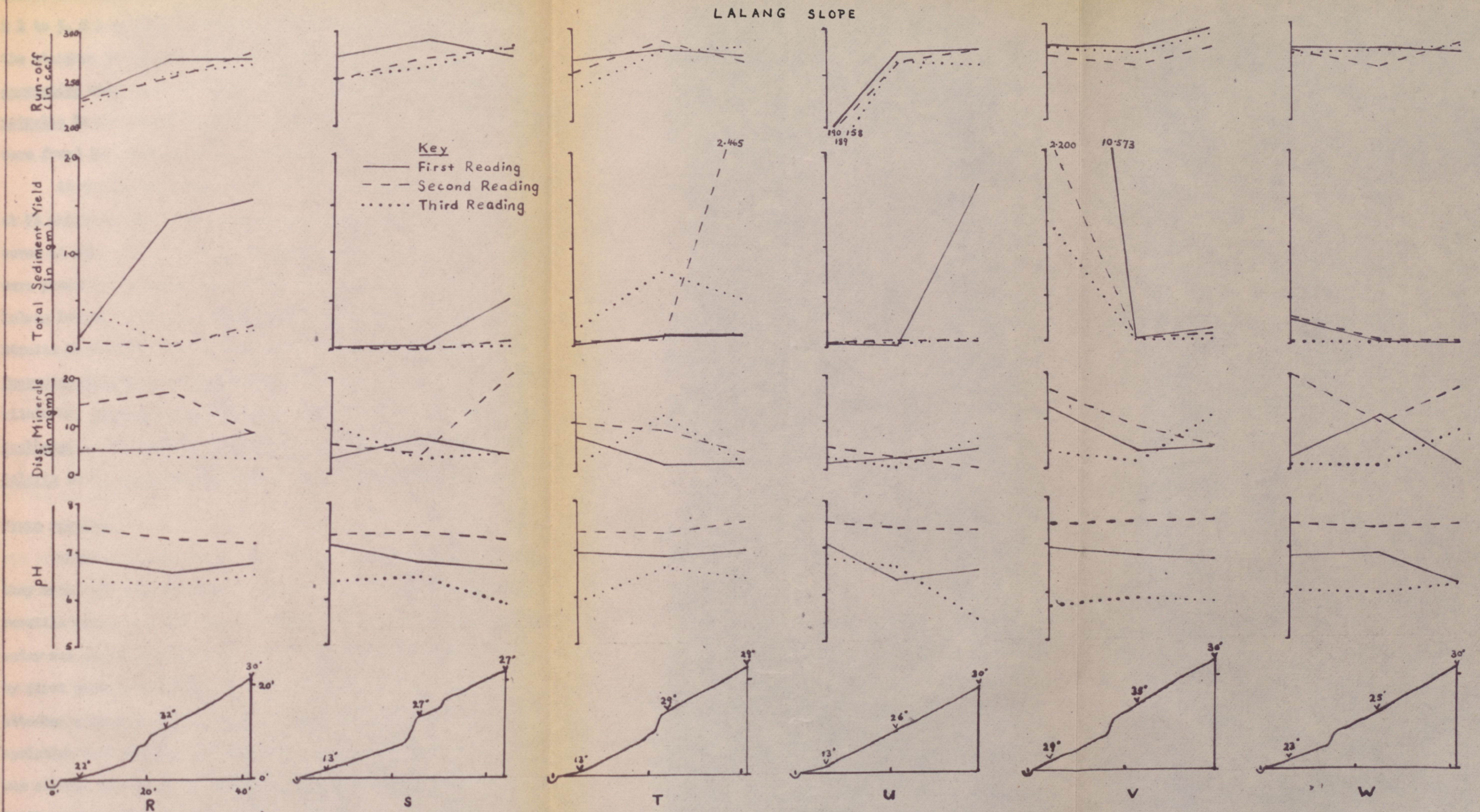

Fig 9 Showing Slope Profiles and Data Readings

leaves or stalks were seen in nineteen of the stations (A 1 to 5, B 1 to 5, C 1 to 3, D 1 to 4 and E 1 and 2) in that area. Further, the stations in the same area had three other plants. Ageratum canyzoides were found in B1 and C1, Scoparia dulces in B3 and Zoysia matrella in C4. Two plants, the Mikania cordata and the Pamcum nodosum were found just outside of the station wall of A3.

At the Lalang Slope the barest surface within a station was that at V1 which had only two plants of Sacciolepis myosuroides and no moss cover at all. In the rest of the stations dead lalang leaves or stalks were present. In some, other plants were found in addition to the lalang leaves or stalks. Cyperus zallingeri was found in S1, a young Straits Rhododendron in S3, very young shoots of Alternanthera in U1, Desmodium capitatum and Lycopodium practically covered the soil surface within U2, Oldenlandria pinifolia was found in U2 and 3, Fimbrislylis spathecea in V2, Borreria laevicaulis in V3, Borreria setideas and Soleria in W1, Desmodium bifolium in W2 and Croton hirtus in W3.

FIELD TECHNIQUE

After the cylinders had been set in their respective positions they were left untouched for 10 days to allow the soil particles to resettle within the stations. Then 300 c.c., a tinful, of distilled water was poured onto the soil within each station. This was done by first pouring the water into a funnel at the end of which was attached a tightly clipped rubber tube. The rubber tube had a small sprinkler head (about 4.2 cm diameter) at the other end. The water was allowed to flow from the funnel only on releasing the spring clip on the rubber tube. Before this was carried out an open polythene bag was held under the spout and as tightly to the cylinder as possible,

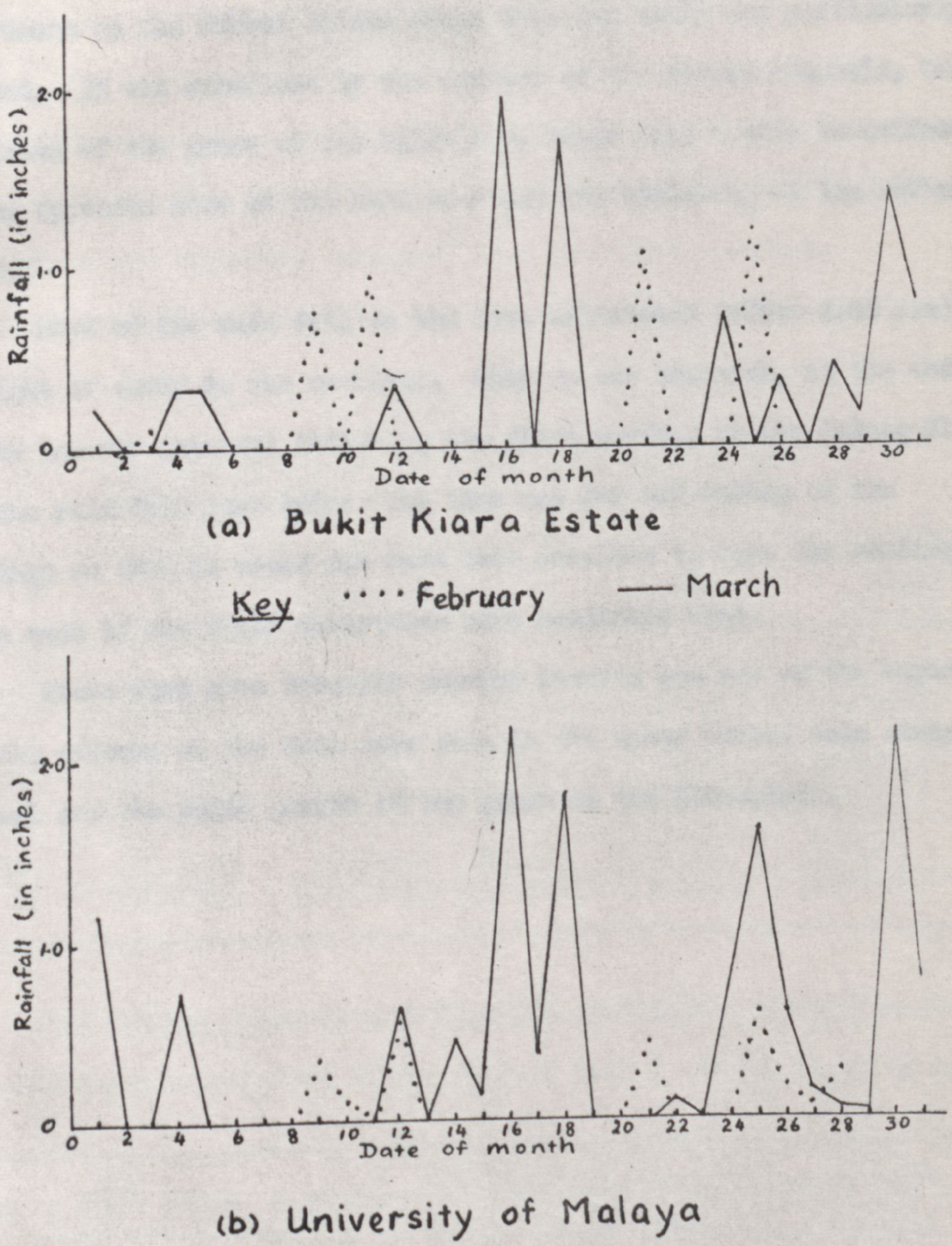

Figure 10 Rainfall Records

Another feature is the drier February and at the start of the experiment at the Rubber Estate Slope this dry spell was particularly noticed. It was evidenced by the dryness of the stream channels, the parchness of the grass at the hillslopes about half a mile downstream on the opposite side of the main road and the wintering of the rubber trees.

Most of the rain fell in the late afternoons (after 4.00 p.m), at night or early in the mornings. Only on one occasion, at the end of the ten-day interval following the first reading at the Lalang Slope, did the rain fall just before the time due for the taking of the readings so that it would not have been possible to have the readings taken even if the field assistants were available then.

There were more frequent showers towards the end of the experiment and the effects of the rain were seen in the water filled main stream channel and the rapid growth of the grass at the floodplain.

CHAPTER III

RESULTS AND DISCUSSION OF RUBBER ESTATE SLOPE OBSERVATIONS

MEAN VALUES

Table I shows the means[1] and the standard deviations[2] of the data for each of the variables analysed[3] from the three readings. A graphical representation of the raw data is shown in Figure 6 (A to F)

TABLE I

MEAN VALUES AND THE STANDARD DEVIATIONS OF THE RUN-OFF ANALYSIS FROM THE RUBBER ESTATE SLOPE

Reading	Run-off (in c.c.)	Filtered Sediment (in gm)	pH	Diss. Min. (in mgm)	Total Sediment Yield (in gm)
First	274.0667 (±21.2764)	2.1805 (±1.9377)	7.7067 (±0.4884)	6.50 (±4.37)	2.1550 (±1.9616)
Second	281.5667 (±13.8157	2.6466 (±1.7310)	6.3960 (±0.4413)	6.73 (±4.53)	2.6533 (±1.7316)
Third	281.5006 (±9.6267)	0.9523 (±0.7909)	6.7417 (±0.3611)	7.30 (±4.41)	0.9646 (±0.7911)

The results shown in both Figure 6 and Table I clearly indicate that there was a variation in the run-off from a uniform input of water.

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[1] Mean $m = \frac{\Sigma x}{n}$ where n = number of elementary units which is 30 in the Rubber Estate Slope and 18 in the Lalang Slope, and x = value of each elementary unit.

[2] Standard deviation $= \sqrt{\frac{\Sigma(x - m)^2}{n}}$ See also footnote 1 above

[3] See Appendix III for details of the analytical procedure

This variation indicates either experimental errors through a faulty technique or an actual variation in the soil conditions between readings. The high levels of significance in the inter-reading correlation[1] tests as shown later in Table II, however, suggest that these variations indicate changes of soil conditions. Further these variations can be explained.

Run-off

The low mean value for the first run-off reading may be due to the high infiltration capacity caused by the presence of disturbed soil (Bryan, 1969, p.149) at the stations and to the dry spell preceding the experiment which probably caused a low moisture contents within the soil. Both contributed to a higher capacity of the soil to hold water resulting in a small volume of run-off. The similarity of the volume of run-off for the second and the third readings suggests a similarity of soil conditions at these two readings. Both indicate a higher volume of run-off and a smaller water absorbing capacity in the soil.

Filtered Sediment

In the readings of the filtered sediment the small amount at the first reading could have been the result of a smaller volume of run-off. The increase in the amount of filtered sediment for the second reading could be correspondingly attributed to the increase in the run-off. The drop in the amount of filtered sediment at the third reading could be due to the decrease in the amount of disturbed soil within

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[1] Linear correlation $r = \dfrac{n\Sigma xy - \Sigma x \Sigma y}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$ where $y = f(x)$

and $t = r\sqrt{\dfrac{n-2}{1-r^2}}$ with $(n - 2)$ degrees of freedom the stations. This decrease in the soil is the result of the latter's removal with each shower of distilled water.

Acidity

The fluctuation in the pH values appears to reflect further the variation of the moisture contents of the soil. At the first reading the preceding dry spell probably had resulted in a low soil moisture contents. Thus when the distilled water was showered onto the soil there was insufficient time for the water to dissolve the minerals in the soil. At the second reading an increased antecedent moisture content had dissolved more acidic minerals so that the run-off from the shower of distilled water became more acidic through the displacement of soil water. The slight decrease in the acidity of the run-off at the third reading could have been due to a combination of an increase in the amount of distilled water in the soil from previous applications and a decrease in the amount of acidic minerals present. Surprisingly, this decrease in the acidity of the soil water apparently did not mean a decrease in the capacity of the soil water to dissolve the minerals present in the soil.

Dissolved minerals

The mean values for the dissolved minerals, show an increase throughout the three readings. A similarity of the standard deviation for each of the three readings can be seen. The increase in the mean values was not uniform, with the increase from the second reading to the third reading more than twice that from the first to the second. This appears to be partly due the increase in the amount of run-off and partly due to more moisture in the soil, especially between the second and the third readings, which would have increased the capacity of the soil water to dissolve the minerals present in the soil.

Total sediment yield

The mean values for the total sediment yield show a fluctuation similar to that for the filtered sediment. This is not surprising as the filtered sediment was the main component of the total sediment yield.

INTER-READING LINEAR CORRELATION TESTS

The data for four of the variables from each of the readings were tested for their coefficients of linear correlation between readings. The results are shown in Table II.

TABLE II

COEFFICIENTS OF LINEAR CORRELATION BETWEEN READINGS OF VARIABLES AT THE RUBBER ESTATE SLOPE (WITH THE PROBABILITY LEVEL WITHIN BRACKETS)

No.	Variable	Readings		
		1st vs 2nd	1st vs 3rd	2nd vs 3rd
4	Run-off	0.4036 (0.025)	0.2097 (0.15)	0.2252 (0.10)
5	Filtered Sediment	0.3979 (0.025)	0.1364 (0.25)	0.4868 (0.005)
7	Dissolved Minerals	-0.1950 (0.20)	0.2353 (0.15)	-0.2287 (0.15)
8	Total Sediment Yield	0.3961 (0.025)	0.1377 (0.25)	0.4856 (0.005)

In the test between the first reading and the second reading results, three of the variables showed correlation coefficients at the significant level of 0.025. The correlation coefficient for the dissolved minerals although recorded at the 0.20 level of significance was very close to the 0.15 level of significance with the "t" value being 0.004 below that for the 0.15 level of significance. The correlation coefficient for this variable was the only negative correlation in this first test, and one of the two in the inter-reading correlation tests.

In the test between the first and the third reading none of the coefficients of correlation was significant at the 0.10 level or better. All the coefficients of correlation were positive and below 0.5.

In the test between the second reading and the third reading for the four variables, three of the variables gave inter-reading coefficients of correlation significant at the 0.10 level or better. Only the coefficient for the dissolved minerals was significant at the 0.15 level. This coefficient was the other of the negative coefficients of correlation.

The above results suggest that there was a gradual change in the soil conditions and this affected the run-off, the amount of filtered sediment and the total sediment yield. This also resulted in the first readings being closer to those of the second, and the second readings closer to those of the third. But the conditions giving the first readings were sufficiently different from those giving the third to give coefficients of correlation at levels of significance of less than 0.10.

INTER-VARIABLE LINEAR CORRELATION TESTS

The inter-variable correlation test results together with their levels of significance are shown in Table III. One of the most striking

TABLE III

COEFFICIENTS OF LINEAR CORRELATION BETWEEN SOME OF THE VARIABLES AT THE RUBBER ESTATE SLOPES (PROBABILITY LEVEL IS INDICATED WITHIN THE BRACKETS)

No.	Dependent Variable*	Independent Variables*						
		1 Slope Angle	2 Altitude	3 Dist from Strm	4 Run-off	5 Filt.Sediment	6 pH	7 Diss.Minerals
4.	Run-off	-0.0099 (<0.25)	0.0550 (<0.25)	0.0544 (<0.25)	-	-	-	-
		0.1300 (0.25)	0.1647 (0.20)	0.1389 (0.25)	-	-	-	-
		0.1880 (0.20)	-0.1637 (0.20)	-0.1215 (<0.25)	-	-	-	-
5.	Filtered Sediment	-0.0407 (<0.25)	0.5806 (0.005)	0.5569 (0.005)	0.0519 (<0.25)	-	-0.0224 (<0.25)	-
		-0.3215 (0.05)	0.4337 (0.01)	0.4668 (0.005)	0.1945 (0.20)	-	0.1845 (0.20)	-
		0.0556 (<0.25)	0.2232 (0.15)	0.2337 (0.15)	0.0961 (<0.25)	-	-0.3014 (0.10)	-
7.	Dissolved Minerals	0.2468 (0.10)	-0.1545 (0.25)	-0.1348 (0.25)	0.1310 (0.25)	0.0515 (<0.25)	-0.1664 (0.20)	-
		-0.1049 (<0.25)	-0.1931 (0.20)	-0.1543 (0.25)	-0.3218 (0.05)	0.1145 (<0.25)	0.4196 (0.025)	-
		0.2515 (0.10)	0.0096 (<0.25)	-0.0064 (<0.25)	-0.3074 (0.05)	0.0548 (<0.25)	0.1413 (0.25)	-
8.	Total Sediment Yield	-0.0169 (<0.25)	0.5635 (0.005)	0.5378 (0.005)	0.0530 (<0.25)	0.9956 (0.0005)	-0.0417 (<0.25)	0.0754 (<0.25)
		-0.3216 (0.05)	0.4330 (0.01)	0.4662 (0.005)	0.1936 (0.20)	0.9999 (0.0005)	0.1856 (0.20)	0.1171 (<0.25)
		0.0570 (<0.25)	0.2231 (0.15)	0.2336 (0.15)	0.0943 (<0.25)	0.9999 (0.0005)	-0.3005 (0.10)	0.0604 (<0.25)

*The numbers attached to each variable will also be the same for Tables IV, VIII and IX.

features in the results is the general low level of significance of the coefficients. Of the 63 coefficients only 19 are significant at the 0.10 level or better. This suggests that there was no simple linear correlation between most of the pairs of the variables tested. The other features are discussed under the appropriate coefficients of correlation.

Run-off

In the correlation tests for the run-off, there was a higher correlation value at the second reading than at the first for each of the tests. The level of significance was also higher for these coefficients. There was a change to the negative correlation in the coefficients for the run-off - altitude and the run-off - distance from the stream tests, at the third reading. The coefficient of correlation between the run-off and the slope angle (or gradient) continued to improve at this reading. This suggests that the correlation between these two variables improved with the lessening of the amount of sediment yield, and that the amount of disturbed sediment at the first reading had a masking effect on the correlation between these two variables. It also appears that the relationship between the run-off and each of the other two variables was not a simple relationship.

Filtered sediment

The coefficients of correlation between the filtered sediment and each of the other variables listed show six coefficients significant at the 0.10 level or better. In the correlation test between the filtered sediment and the slope angle, the result from the second reading was negative but significant. This means the steeper the gradient, the less the filtered sediments. This suggests that in that area the steep slopes had less materials to be eroded than the gentle slopes.

The coefficients from the tests between the filtered sediment and the altitude and the filtered sediment and the distance from the stream show a similar pattern. The first reading gave the highest coefficients while the third gave the lowest. It appears that both the correlations (between the filtered sediments and the altitude, and between the filtered sediments and the distance from the stream) were similarly affected by the lessening of the disturbed sediments within the stations.

The coefficients of correlation between the filtered sediment and the run-off show a low value for each of the readings. This suggests that the amount of filtered sediment in the run-off did not depend solely on the amount of run-off. In the coefficients of correlation between the filtered sediment and the pH value the third reading gave a significant negative correlation. This suggests that the more acidic the run-off the more filtered sediments there would be.

Dissolved minerals

The coefficients of correlation between the dissolved minerals and the slope angle show a low positive, but significant correlation for the first and the third readings. This contrasts with the correlation between the filtered sediment and the slope angle. The correlations between the dissolved minerals and the altitude, and the dissolved minerals and the distance from the stream, show a similar contrast. These and the correlation between the dissolved minerals and the filtered sediments show the independence of the dissolved minerals from the latter.

The correlations between the dissolved minerals and the run-off show a negative but significant correlation at the second and the third readings. This suggests that the amount of dissolved minerals in the run-off varied inversely with the amount of run-off, but this needs further examination as there was a possible change in the antecedent moisture content of the soil at the second and the third readings.

In the last correlation test for the dissolved minerals, only the second reading gave a significant positive correlation. This again contrasts with that between the filtered sediment and the pH value.

Total sediment yield

In the coefficients of correlation between the total sediment yield and the variables listed, a noticeable feature is the similarity of pattern between these coefficients and those for the filtered sediment. This close relationship is further emphasised by the high correlation between the total sediment yield and the filtered sediment. This is not surprising as the filtered sediment was the major component of the total sediment yield. But this does not mean that the other component, the dissolved minerals, had no effects on the total sediment yield at all. Their effect is seen in the lowering of the correlation values generally. There was, however, no significant correlation between the total sediment yield and the dissolved minerals. Thus the reasons suggested for the fluctuations of the coefficients of correlation for the filtered sediment may well apply here.

MULTIPLE CORRELATION[1] TESTS

The data were tested for their multiple -correlations. This is because of the general low correlations in Table III and also in nature it is seldom, if ever, that one variable is affected directly and solely by another. The results are shown in Table IV. The coefficients of correlation are generally higher and the relative effects of the acidity and the filtered sediment can be seen.

In the correlation $R_{4.123}$, that is, between the run-off and the combination of gradient, altitude and distance from the stream, the coefficient at each reading is of a higher value than the individual linear correlation for the same variables as shown in Table III.

The correlation figures for the filtered sediment show a decreasing value. The first reading gave the highest correlation while the third the lowest. The amount of decrease was not uniform. This pattern is similar to the figures for the filtered sediment and altitude, and filtered sediment and distance from the stream correlations shown in Table III, suggesting the importance of altitude and distance from the stream. A surprising feature in the results in Table IV is that the first readings give correlations at a higher level of significance in spite of the presence of disturbed soil at the stations. The results also show small but significant increases from one combination to another.

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[1] $R_{Y.12\ldots n} = \sqrt{\frac{\Sigma(Y_c - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2}}$ where $Y_c = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$ and $x_1, x_2 \ldots x_n$ are independent variables. (Yamane, 1967, p.764)

TABLE IV

COEFFICIENTS OF MULTIPLE CORRELATION BETWEEN SOME OF THE VARIABLES AT THE RUBBER ESTATE SLOPE (WITH LEVELS OF SIGNIFICANCE WITHIN THE BRACKETS)

No.	Dependent Variable (x)	Combination of Variables					
		x. 123*	x. 1234	x. 12345	x. 123456	x. 123456	x. 1234567
4.	Run-off	0.05676 (<0.50)	-	-	-	-	-
		0.26408 (<0.50)	-	-	-	-	-
		0.29791 (<0.50)	-	-	-	-	-
5.	Filtered Sediment	0.61120 (0.01)	0.61145 (0.025)	-	0.61151 (0.05)	-	-
		0.48782 (0.10)	0.51574 (0.10)	-	0.52507 (0.25)	-	-
		0.29603 (<0.50)	0.30948 (<0.50)	-	0.41879 (0.50)	-	-
7.	Dissolved Minerals	0.28898 (<0.50)	0.31948 (<0.50)	0.34150 (<0.50)	0.34597 (<0.50)	0.36689 (<0.50)	-
		0.28158 (<0.50)	0.38236 (0.50)	0.44659 (0.50)	0.53561 (0.25)	0.56793 (0.25)	-
		0.27591 (<0.50)	0.45786 (0.25)	0.45995 (0.50)	0.49155 (0.25)	0.50191 (0.50)	-
8.	Total Sediment Yield	0.60098 (0.01)	0.60130 (0.025)	0.99594 (0.005)	0.60136 (0.05)	0.99609 (0.005)	0.99625 (0.005)
		0.48746 (0.10)	0.51517 (0.10)	0.99999 (0.005)	0.52468 (0.25)	0.99999 (0.005)	0.99999 (0.005)
		0.29681 (0.50)	0.30963 (<0.50)	0.99998 (0.005)	0.41617 (0.50)	0.99998 (0.005)	0.99999 (0.005)

*See note at Table III

The correlation figures for the dissolved minerals show fluctuations which reflect the different effects of the additional variable on the combinations of the other variables. They further show the complexity of dissoved minerals as a function of the other variables. For example, while the correlation $R_{7.123}$ show a decreasing value for the three readings, both $R_{7.1234}$ and $R_{7.12345}$ show an increasing value. This increase with each reading, however, was not continued with the addition of the pH variable in the combinations.

In the correlation figures for the total sediment yield the dominance of the filtered sediment as a component can be seen in the correlations $R_{8.12345}$, $R_{8.123456}$ and $R_{8.1234567}$ in which $R_{8.12345}$ can be considered to be 1.0 already. The remaining correlation figures also show a pattern similar to that for the filtered sediment in the same table.

TWO-WAY VARIANCE ANALYSIS

Two-way variance analysis[1] tests were carried out on five of the variables for the three readings and the results are shown in Table V.

Run-off

The run-off showed significant results for the "between altitudes"

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1 $$F_{row} = \frac{\frac{S_{row}}{(a-1)}}{\frac{S_{error}}{(a-1)(b-1)}}$$ where a = number of rows

b = number of columns

and S = sum of squares

(Yamane, 1967, p.707)

$$F_{col} = \frac{\frac{S_{col}}{(b-1)}}{\frac{S_{error}}{(a-1)(b-1)}}$$

TABLE V

LEVELS OF SIGNIFICANCE OF TWO-WAY VARIANCE ANALYSIS OF DATA FROM THE RUBBER ESTATE SLOPE

Variable	1st Reading		2nd Reading		3rd Reading	
	Alt.	Trans.	Alt.	Trans.	Alt.	Trans.
Run-off	0.25	0.25	0.25	0.25	0.10	0.50
Filtered Sediment	0.005	0.25	0.10	0.10	0.50	0.025
pH	0.25	0.005	0.10	0.005	0.50	0.25
Dissolved Minerals	0.25	0.50	0.025	0.005	0.50	0.50
Total Sediment Yield	0.005	0.25	0.10	0.10	0.50	0.50

tests in two of the three readings. The first at the 0.025 level of significance however is misleading because there was a large residual variance estimate and not a large variance estimate for altitude. This result is therefore not a contradiction to the low linear correlation between the run-off and the altitude. The other significant result was from the third reading at the 0.10 level of significance. This again was due to a large residual variance estimate.

In the tests for "between transects" for the run-off, there were no significant results suggesting a lack of a pattern for the run-off in the area.

Filtered sediment

The filtered sediment showed significant results in two of the three "between altitudes" tests. The first reading result suggests an accumulation of sediments and a greater erodibility at the upperslope stations. The second reading result was still significant but at the 0.10 level. The result from the third reading was not significant.

However, the results are still interesting in that in a pilot experiment[1] carried out at a slope within the University of Malaya campus to try out the method described in this graduation exercise, the results then obtained showed a greater erodibility at the foot slope stations. The bedrock of the campus pilot experiment is the same Kenny Hill Formation and the area still had rubber trees as the main vegetal cover. The only difference between the campus slope and the Rubber Estate Slope is the absence of a floodplain at the campus slope. As such, it is tempting to attribute the change in the erodibility pattenn to the presence of the floodplain.

Of the "between transects" tests, the results from the second and the third readings were significant with the result from the third reading at the higher level of significance at 0.025. These results suggest that greater erodibility took place at the upstream transects.

Acidity

In the "between altitudes" tests of the pH values only the second reading showed a result at a significant level. This result suggests a greater acidity downslope.

The "between transects" tests showed that two of the readings gave significant results. These were the first and the second readings both of which were at the 0.005 level. These results suggest that the run-off from the downstream transects were more acidic.

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[1]See Appendix IV

Dissolved minerals

The dissolved minerals showed only the second reading gave significant results. In this reading both the "between altitude" and the "between transects" tests showed results significant at the 0.025 and the 0.005 levels respectively. These results suggest that there was an greater amount of dissolved minerals at the footslope stations especially those at the upstream transects.

Total sediment yield

Of the tests on the total sediment yield the first and the second readings showed significant difference in the "between altitudes" tests and only the second reading showed a significant difference in the "between transects". The pattern was similar to that for the filtered sediment. This again shows the influence of the filtered sediment as the major component of the total sediment yield.

SUMMARY

The results of the tests show evidence that the conditions within the soil at the Rubber Estate Slope had changed from reading to reading. Further, there was no simple relationship between the variables and the run-off or the sediment yields.

Multiple correlations gave higher figures and the results suggest the importance of the effect of a combination of variables. The dissolved minerals and the acidity of the run-off appear to have complex effects on the amount of run-off and sediment yield.

The results of the two-way variance analysis on the sediment yield showed an interesting contrast to those of the same variable from a pilot project. This contrast suggests of the effect of a floodplain on the sediment yield, and deserves further investigation.

CHAPTER IV

RESULTS AND DISCUSSIONS OF LALANG SLOPE OBSERVATIONS

MEAN VALUES

Table VI shows the means[1] and the standard deviations of the data for each of the variables analysed from the three readings taken at the Lalang Slope. These results were obtained in the same way as that used for the Rubber Estate Slope and the same equipment were used. A graphical representation of the raw data from which these means were calculated is shown in Figure 8 (R to W).

Here again equal inputs of water have produced different outputs of run-off. Besides run-off, variations in the other variables are seen. While most of these variations may be explained, there are two

TABLE VI

MEAN VALUES AND THE STANDARD DEVIATIONS OF THE RUN-OFF ANALYSIS FROM THE LALANG SLOPE

Reading	Run-off (in c.c.)	Filtered Sediment (in gm)	pH	Diss. Min. (in mgm)	Total Sediment Yield (in gm)
First	267.778 (±22.6393)	0.9542 (±2.4642)	6.7389 (±0.2292)	4.83 (±3.26)	0.9168 (±2.4746)
Second	260.556 (±22.6618)	0.3129 (±0.7361)	7.4000 (±0.1029)	9.78 (±6.23)	0.3227 (±0.7361)
Third	258.9445 (±30.0166)	0.1973 (±0.3236)	6.1600 (±0.3683)	4.39 (±3.58)	0.2017 (±0.3238)

[1]The formulae used in the statistical tests in this chapter are the same as those used in Chapter III.

puzzling features. These will be discussed under the appropriate variables.

The mean values for the run-off show a higher infiltration capacity than that for the Rubber Estate Slope. The three readings also show an increasing infiltration capacity. This pattern differs from that for the Rubber Estate Slope and as the vegetal cover for this slope was mainly grass, it is probable that this increase in the infiltration was caused by the difference in the vegetal cover (Morgan, 1969, p.239) and the increasing infiltration was due to changes in the vegetation.

The filtered sediment show a decreasing mean value. This is not surprising and is to be expected. It reflects the decreasing amount of disturbed soil within the stations due to removal by the shower at each reading.

The pH figures show a fluctuation that is rather puzzling. It does not lend itself to the suggestion advanced for the same variable in the Rubber Estate Slope. As no analysis for the actual mineral contents of the run-off was carried out this feature of the Lalang Slope remains for further investigation. The higher figures for both the Lalang and the Rubber Estate Slope than those obtained for the Sungai Pasir (Douglas, 1967, p.36) may be attributed to the use of distilled water in the experiment.

The dissolved minerals show a fluctuation similar to that for the pH values. It is again puzzling and it is tempting to attribute this to the eluviation and the illuviation of the minerals in the soil (Carson, 1969, p.189).

The total sediment yield shows a decreasing mean value for the three readings. This pattern is only slightly different from that for the filtered sediment. This is again not surprising as the filtered sediment was again the major component of the total sediment yield. Thus the variation may again be attributed to a decreasing amount of disturbed sediment particles within the experimental stations.

INTER-READING LINEAR CORRELATION TESTS

Inter-reading linear correlation tests were conducted on the same four variables as in the Rubber Estate Slope inter-reading correlation tests. The results shown in Table VII indicate that except for the dissolved minerals the coefficients of correlation were high. These high correlations with the high levels of significance

TABLE VII

COEFFICIENTS OF LINEAR CORRELATION BETWEEN READINGS OF VARIABLES AT THE LALANG SLOPE (WITH THE PROBABILITY LEVEL WITHIN BRACKETS)

No.	Variable	Readings		
		1st vs 2nd	1st vs 3rd	2nd vs 3rd
4.	Run-off	0.8799 (0.0005)	0.9110 (0.0005)	0.9195 (0.0005)
5.	Filtered Sediment	0.6570 (0.005)	0.7837 (0.0005)	0.7004 (0.005)
7.	Dissolved Minerals	0.0821 (<0.25)	-0.2964 (0.15)	-0.1198 (<0.25)
8.	Total Sediment Yield	0.6070 (0.005)	0.7694 (0.0005)	0.6986 (0.005)

suggest that the experiment had been carried out with consistency and that the experimental errors arising from inconsistency of the method were very small. There was also some changes in the conditions within the soil. This was suggested by the inter-reading correlations for the dissolved minerals and the mean values shown in Table VI. The former results are interesting in that they are the only low correlations and are the only negative ones as shown in the correlation between the first and the third readings and between the second and the third readings. These results by themselves suggest that the dissolved minerals were different from the other variables and secondly that the results from the third reading were the reverse of those for the first and the second readings.

INTER-VARIABLE LINEAR CORRELATION TESTS

In the inter-variable linear correlation tests, the results of which are shown in Table VIII, the most significant results came from the tests for the run-off.

Run-off

The correlation between the run-off and the slope-angle show improvement with each reading suggesting that the link between these two variables was better reflected with the lessening of the amount of disturbed soil within the experimental stations. The correlations between run-off and altitude, and run-off and distance from the stream show a similarity. In both, the first reading gave the lowest coefficient while the second gave the highest. The drop in the coefficients for the third reading is rather puzzling and deserves further observations and investigations.

TABLE VIII

COEFFICIENTS OF LINEAR CORRELATION BETWEEN SOME OF THE VARIABLES AT THE LALANG SLOPE (PROBABILITY LEVEL IS INDICATED WITHIN THE BRACKETS)

No.	Dependent Variable	Independent Variables						
		1 Slope Angle	2 Altitude	3 Dist from Strm	4 Run-off	5 Filt.Sediment	6 pH	7 Diss.Minerals
4.	Run-off	0.5444 (0.005)	0.4478 (0.025)	0.4261 (0.05)	-	-	-	-
		0.6318 (0.0005)	0.6181((0.005)	0.6117 (0.005)	-	-	-	-
		0.7045 (0.0005)	0.6011 (0.005)	0.5658 (0.005)	-	-	-	-
5.	Filtered Sediment	0.2130 (0.20)	-0.1830 (0.25)	-0.1945 (0.25)	0.0786 (<0.25)	-	0.1232 (<0.25)	-
		0.1999 (0.25)	0.0451 (<0.25)	-0.0088 (<0.25)	0.0709 (<0.25)	-	0.1721 (0.25)	-
		0.1671 (<0.25)	-0.2452 (0.20)	-0.2901 (0.15)	0.1232 (<0.25)	-	-0.0972 (<0.25)	-
7.	Dissolved Minerals	0.0398 (<0.25)	-0.1712 (0.25)	-0.1438 (<0.25)	0.2148 (0.20)	0.5852 (0.005)	0.1510 (<0.25)	-
		0.0740 (<0.25)	-0.2569 (0.20)	-0.2496 (0.20)	0.1185 (<0.25)	0.0088 (<0.25)	-0.1744 (0.25)	-
		0.0285 (<0.25)	0.1870 (0.25)	0.1706 (0.25)	0.1211 (<0.25)	0.0584 (<0.25)	0.0553 (<0.25)	-
8.	Total Sediment Yield	0.2020 (0.25)	-0.2056 (0.25)	-0.2132 (0.20)	0.0998 (<0.25)	0.9973 (0.0005)	0.1102 (<0.25)	0.6053 (0.005)
		0.2005 (0.25)	0.0429 (<0.25)	-0.0109 (<0.25)	0.0719 (<0.25)	0.9999 (0.0005)	0.1707 (0.25)	-0.0003 (<0.25)
		0.1673 (<0.25)	-0.2429 (0.20)	-0.2880 (0.15)	0.1244 (<0.25)	0.9999 (0.0005)	0.0965 (<0.25)	0.0695 (<0.25)

Filtered sediment

The coefficients of correlation for the filtered sediments are generally low and the highest level of significance reached was 0.15. These low correlations suggest that there was no simple linear relationship between the filtered sediments and the five variables against which the former was tested. This belief appears to be supported by the results from the multiple correlation tests.

Dissolved minerals

The results of the linear correlation tests for the dissolved minerals show only one coefficient at a significant level. This is from the first reading in the dissolved minerals - filtered sediment test. The high correlation appeared to be influenced by the presence within the experimental stations of disturbed soil in which the soluble minerals must have been more exposed to the shower of water. The remaining coefficients suggest again that there was no simple linear correlation between the dissolved minerals and the other variables.

Total sediment yield

The coefficients for the total sediment yield show a pattern similar to that for the filtered sediment. This pattern and the high correlation between the total sediment yield and the filtered sediment suggest the dominance of the filtered sediment as a component of the former. Further support of this is seen in the correlation results between the total sediment yield and the dissolved minerals. In these results only the first reading gave a high correlation which as suggested earlier could have been influenced by the presence of disturbed soil within the stations.

MULTIPLE CORRELATION TESTS

The results of the multiple correlation tests are shown in Table IX.

A notable feature of the results is that the correlation values are higher though in most cases a lower level of significance than those for the linear correlation. These higher values suggest the influence of the combined effects of the variables. The correlation for the run-off $R_{4.123}$ shows an increasing value with each reading. This suggests an improving reflection of the link between run-off and the combination of slope-angle, altitude and distance from the stream as the amount of disturbed soil within each experimental station lessened with each shower of water.

The correlation figures for the filtered sediment show that in the three combinations against which the filtered sediment was tested, the second reading gave the lowest values. This feature is somewhat similar to that in the linear correlation test for the same variable. The results for the first reading in Table IX however indicate the importance of the acidity of the run-off. The coefficient for $R_{5.1234}$ is much lower than that for $R_{5.12346}$ The second reading shows a similar increase, but the third reading, though still showing an increase, does not show as great an increase as the other two readings. This small difference in the third reading could have been due to the low mean pH value for the third reading.

The correlations for the dissolved minerals show two main features. The first is that the correlations for $R_{7.123}$ and $R_{7.1234}$ show a pattern which contrasts with that for $R_{5.123}$ and $R_{5.1234}$. The second reading for $R_{7.123}$ and $R_{7.1234}$ shows the highest correlation

TABLE IX

COEFFICIENTS OF MULTIPLE CORRELATION BETWEEN SOME OF THE VARIABLES AT THE LALANG SLOPE (WITH LEVELS OF SIGNIFICANCE WITHIN THE BRACKETS)

No.	Dependent Variable (x)	Combination of Variables					
		x. 123*	x. 1234	x. 12345	x. 12346	x. 123456	x. 1234567
4.	Run-off	0.55442 (0.25)	-	-	-	-	-
		0.68779 (0.05)	-	-	-	-	-
		0.72680 (0.025)	-	-	-	-	-
5.	Filtered Sediment	0.49975 (0.25)	0.50105 (0.50)	-	0.57700 (0.50)	-	-
		0.37656 (<0.50)	0.37659 (<0.50)	-	0.39756 (<0.50)	-	-
		0.55227 (0.25)	0.56242 (0.25)	-	0.56489 (0.50)	-	-
7.	Dissolved Minerals	0.36254 (<0.50)	0.45183 (<0.50)	0.67488 (0.25)	0.62450 (0.25)	0.73111 (0.25)	-
		0.44697 (0.50)	0.50278 (0.50)	0.50451 (<0.50)	0.51680 (<0.50)	0.51743 (<0.50)	-
		0.26922 (<0.50)	0.28030 (<0.50)	0.32270 (<0.50)	0.30261 (<0.50)	0.33907 (<0.50)	-
8.	Total Sediment Yield	0.51684 (0.25)	0.51904 (0.50)	0.99810 (0.005)	0.58401 (0.50)	0.99822 (0.005)	0.99850 (0.005)
		0.37724 (<0.50)	0.37730 (<0.50)	0.99997 (0.005)	0.39792 (<0.50)	0.99997 (0.005)	0.99999 (0.005)
		0.55024 (0.25)	0.56058 (0.50)	0.99994 (0.005)	0.56317 (0.50)	0.99994 (0.005)	0.99999 (0.005)

*See note at Table III

values and the third the lowest. The second feature is that with the addition of the filtered sediment or the acidity value or both, the correlation figures show a gradual decrease from the first reading to the third. These two features show that the dissolved minerals is linked to the other variables in a unique function of its own.

The results of the correlation tests on the total sediment yield again show the dominance of the filtered sediment as a component of the former. This is again supported by the correlation $R_{8.12345}$ in which the addition of the filtered sediment to the combination of slope angle, altitude, distance from the stream and run-off, caused the correlation value to be practically 1.0.

TWO-WAY VARIANCE ANALYSIS

Two-way variance analysis were also carried out from the data of five variables and the results are shown in Table X.

TABLE X

LEVELS OF SIGNIFICANCE OF TWO-WAY VARIANCE ANALYSIS OF DATA FROM THE LALANG SLOPE

Variables	1st Reading		2nd Reading		3rd Reading	
	Alt.	Trans.	Alt.	Trans.	Alt.	Trans.
Run-off	0.25	0.50	0.25	0.50	0.025	0.25
Filtered Sediment	0.50	0.50	0.50	0.50	0.50	0.50
pH	0.05	0.50	0.50	0.50	0.50	0.50
Dissolved Minerals	0.25	0.10	0.50	0.25	0.50	0.025
Total Sediment Yield	0.50	0.50	0.50	0.50	0.50	0.50

Run-off

Of the tests on the run-off only the "between altitude" test at the third reading showed a significant result. This was at the 0.025 level. This result suggests an increase in the amount of run-off with an increase in altitude.

Filtered sediment

No significant results were obtained from the tests on this variable.

Acidity

Again no significant results were obtained from the tests.

Dissolved minerals

Two significant results were obtained, both from the "between transects" tests. The first result at the 0.10 level was from the first reading while the second at the 0.025 level was from the third reading. Both results suggest an increase in the dissolved minerals downstream.

Total sediment yield

No significant results were obtained from the tests on this variable.

SUMMARY

The results of the tests show evidence that the soil at the Lalang Slope was dynamic and that the conditions within it had changed from reading to reading. Further there was no simple linear relationship among the variables. The relationship between the run-off and the variables of slope-angle, altitude and distance from the stream was better reflected as a multiple correlation.

The dissolved minerals appear to have its own function and the test results of that variable did not show any pattern that can be compared to any of those of the other variables.

The multiple correlations in most cases show a low level of significance although in many of these cases an improvement on the simple linear correlation results is seen.

The two-way variance analysis has not shown any distinct trend for the three readings although there were two significant results, one from the first reading and the other from the third reading.

CHAPTER V

DISCUSSION

SUMMARY OF RESULTS

From the results of Chapter III and IV it can be seen that at both the areas understudy, there were evidence of changes in the soil conditions from reading to reading. These changes were to be expected. (Bear et al, 1968, p.11) The dissolved minerals at both areas also appeared to have unique functions of their own as the patterns of their results did not seem to be similar to any of the others.

At both areas the linear correlations were generally low, but the multiple correlations gave higher correlation figures. This suggests the importance of the effects of combining the variables. It also suggests a complex relationship between run-off or sediment and the other variables considered in this exercise. This complex relationship especially between variables like run-off, sediment yield, slope angle and precipitation has been observed by other writers (Colby, 1964, p.A1; Einstein, 1964, p.17; Soon and Rainer, 1968, p.9; Allen, 1969, p.4)

There were also differences in the results, the most striking of which was the difference in the erodibility pattern between the two areas. At the Rubber Estate Slope there was greater erodibility at the upperslope stations while at the Lalang Slope no clear pattern emerged. Another difference is the higher multiple correlation at the Lalang Slope between run-off and the combination of slope angle, altitude and distance from the stream.

F-TEST

The results were further tested with the F-test[1] and the results of the tests are shown in Table XI. In these results a variation in the levels of significance can be seen.

TABLE XI

LEVELS OF SIGNIFICANCE ON COMPARING THE VARIABLES OF THE RUBBER ESTATE SLOPE AND THE LALANG SLOPE

No.	Variable Compared	1st Reading	2nd Reading	3rd Reading
1.	Slope Angle	0.05	-	-
2.	Altitude	0.25	-	-
3.	Distance from Stream	0.005	-	-
4.	Run-off	<0.25	0.01	0.005
5.	Filtered Sediment	0.25	0.005	0.005
6.	pH	0.005	0.005	<0.25
7.	Dissolved Minerals	0.25	0.10	0.25
8.	Total Sediment Yield	0.25	0.005	0.005

Slope Angle

The slope angles were tested once only as these did not change from reading to reading and the test result showed that the difference between the distributions of the slope angles was highly significant

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1

$$F = \frac{\dfrac{n_1 S_1^2}{(n_1-1)}}{\dfrac{n_2 S_2^2}{(n_2-1)}}$$

where n_1 = number of elements in the first sample
S_1 = Standard deviation of the first sample
n_2 = number of elements in the second sample
S_2 = Standard deviation of the second sample

(Yamane, 1967, p.652)

suggesting that the two distributions could not have been from the same universe (distribution)

Altitude

The altitudes of the stations from the two areas were also tested once only for the same reason. The result was significant only at the 0.25 level suggesting that the two distributions were not very different from one another.

Distance from stream

The distance from the stream distributions were similarly tested once only and this gave a highly significant difference suggesting that the two distributions could not have come from the same universe.

Run-off

Of the three tests, one for each reading, the first did not show any significant difference while the second and the third gave significant results. These suggest that the disturbed soil had a masking effect on the run-off at the first reading but the difference in the run-off between the two areas began to show up from the second reading.

Filtered sediment

The results from the three tests showed a low level of significance at the first reading and highly significant results at the second and the third readings. Here again the results suggest the masking effect of the disturbed soil at the first reading to give a low level of significance. The difference in the two distributions again began to show up from the second reading.

Acidity

A reverse pattern from that of the run-off was seen in the test results for the acidity. The significant difference at the first and the second reading could only be attributed is the effects of the weedicide used at the Rubber Estate Slope not long before the start of the experiment. The result from the third reading was not surprising as the soils of the two areas were derived from the same parent rock.

Dissolved minerals

The results from the three tests showed that only the second reading gave a significant (at the 0.10 level) result. No easy explanation could be had for this fluctuation in the results and this variable deserves further investigation into its uniqueness.

Total sediment yield

The results from the three tests were similar to those for the filtered sediment and here again the effect of the filtered sediment as the major component was further emphasised. The results further show the difference in the erodibility of the two areas.

VALIDITY OF METHOD

Thus from the results above it is not unreasonable to conclude that the technique used in this graduation exercise is basically acceptable. The supporting evidence for this lies in the consistently high inter-reading correlation results from the two areas and in the data obtained from the experiment which appear to conform to the findings of other writers many of whom have been quoted in this exercise.

A critic may point to the low levels of significance of some of the multiple correlation tests. These low levels of significance, however, do not invalidate the technique. They merely suggest that the technique has some limitations the most obvious of which are the short duration of the simulated rain and the small areas within the experimental stations. Another limitation is the narrowness of the opening to the spout which resulted in the blocking of the flow of the sediments especially where dead leaf-stalks were present within the experimental stations. A fourth limitation was the short duration of the observations.

Theselimitations are easily overcome by finding, through further experimentation, an optimum duration and amount of simulated rainfall, widening the opening to the spout and by having a longer period of observation.

In spite of these limitations, the technique has shown what it was intended to do in this exercise viz to show the local effects of a shower of water at different parts of a slope and the difference in the erodibility of a slope caused by a difference in land use and vegetal cover. It has also hinted at areas for further investigations. Thus if the technique could be given more exhaustive trials, more comprehensive results may yet be obtained.

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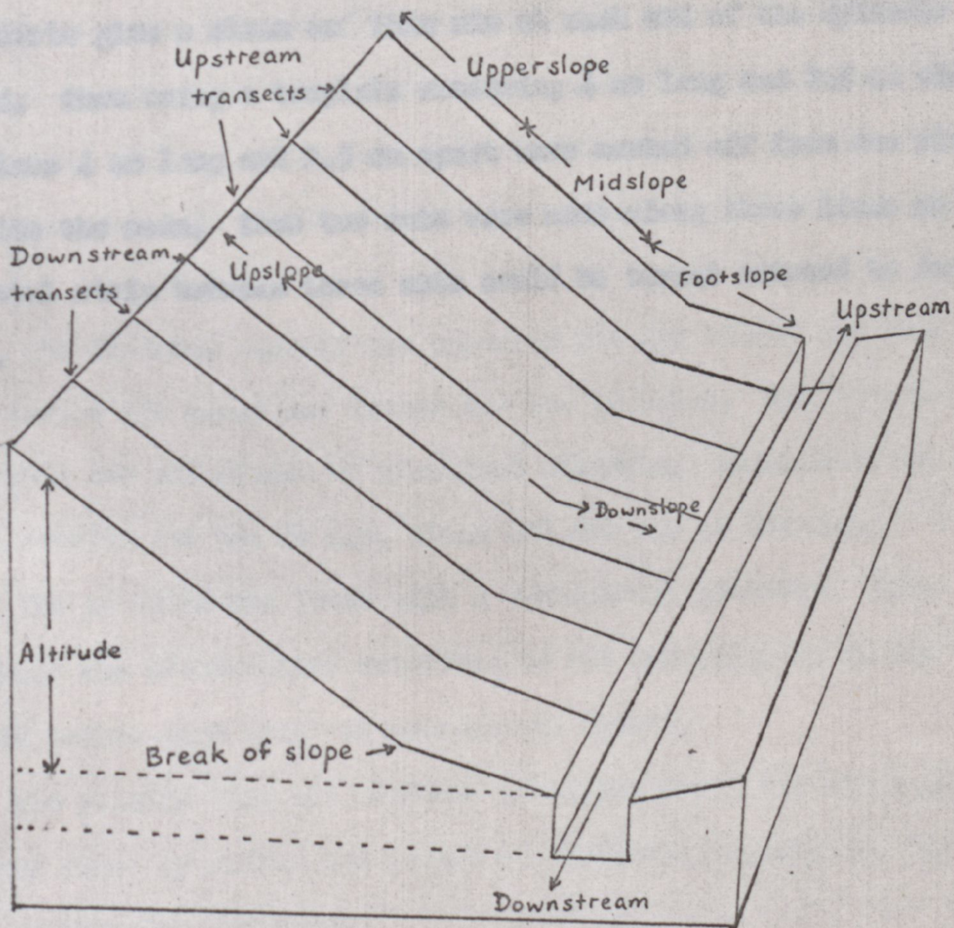
Appendix I

Some of the terms used in the text



APPENDIX II

PREPARATION OF THE MILK TINS

Discarded condensed milk tins were collected and measured for their internal diameters and their heights. Then a key type of tin-opener was used to remove both the tops and the bases of the tins. This was to give a clean and thin rim at each end of the cylinder so formed. Then using a template measuring 4 cm long and 2.5 cm wide, two lines 4 cm long and 2.5 cm apart were marked off from one rim and opposite the seam. Then two cuts were made along these lines so that the metal strip between these cuts could be turned outward to form a spout.

APPENDIX III

PROCEDURE FOR ANALYSING THE RUN-OFF

The run-off collected from each station was thoroughly shaken in its polythene bag. Then it was filtered with a No.1 filter paper which had been weighed before its use. The organic matters were visually removed from the filtered sediment. Then the filtered sediment together with the filter paper was dried in an oven for 24 hours at 200°F. After this, the former together with the filter paper was cooled in a desiccator before being weighed in a weighing balance.

The filtered run-off was measured for its volume and then a small sample (20 c.c.) was tested for its pH value. The rest was evaporated for the amount of dissolved minerals. Adjustment was made in the results for the 20 c.c. drawn off for the pH testing.

The pH value was found with a table-model pH-meter. This instrument was standardised according to the instructions in its handbook before each batch of samples was tested.

The results were all recorded immediately and the total sediment yield was found by adding the amount of dissolved minerals to the amount of filtered sediments.

APPENDIX IV

GEOMORPHOLOGY OF THE CAMPUS
by Khong Kah Yeong

ABSTRACT

An experiment at measuring the sediment yield of a slope was conducted at a stretch measuring 180 feet along the stream and 45 feet upslope, of the northern floodplainless bank of a stream flowing between the Geology Department and the Arts Block of the University of Malaya, Kuala Lumpur. The area was a rubber estate which had not been tapped for at least a decade. The soil was latosol soil derived from a sedimentary rock of alternating beds of shale and sandstone. In the experiment the run-off and sediment yield was induced with a carefully controlled 300 c.c. of simulated rainfall. The run-off and the sediment were collected from 25 sites, each marked by a pre-cut cylinder made from a discarded milk tin, along 10 transects. The latter were drawn from midstream points which were 20 feet apart. The distance between two stations along a transect was also 20 feet.

"Between altitude" variance analysis results from the sediment yield and the water lost suggested that there was an accumulation of sediment at the "footslope" stations and a greater infiltration at the "upperslope" stations.

Author