THE EFFECT OF SLOPE ON THE EROSION COEFFICIENT OF UMINGAN, MAASIN AND MALITBOG CLAYS

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ABSTRACT

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The effect of percent slopes on the erosion coefficient of Umingan, Maasin and Malitbog clays was found to be highly significant. For all the soil types, erosion coefficient had a positive relationship with the slope. Third degree polynomial equations described the slope-erosion coefficient relationship for Umingan and Malitbog clays, and quadratic equation for Maasin clay.

Umingan clay had the highest erosion coefficient at all slope levels, *i.e.* from 2.5 to 50% at an increment of 2.5%, while Malitbog clay had a higher coefficient than Maasin clay only at slopes >17%.

KEYWORD: Erosion coefficient.

INTRODUCTION

About three-fourths of our farm lands are on slopes and 90% of them had been eroded by water in varying degrees resulting in nutrient losses, low productivity, low farm income, high cost of production and more destructive floods (Barrera and Tabayoyong, 1977; PCARR, 1977).

Soil erosion due to water arises from the effect of rainfall on the soil and is determined by rain erosivity, soil erodibility, management and land form. The length, steepness, shape and uniformity of shape of slopes, are factors under land form which have been little studied in the tropics (Hudson, 1977; Greenland and Lal, 1977).

Slope is a major factor in water-caused soil erosion (Ganapin, 1983). This kind of soil erosion is generally believed to increase as a power function of slope (Zing, 1940; Borst and Woodburn, 1940; Smith and Whitt, 1947; Smith and Wischmeier, 1957; Wischmeier and Smith, 1965; Chandra and

De, 1978; Singer and Blackard, 1982). However, the apparent interaction of slope with soil properties and the dissimilarity in soil erodibility are the likely causes of the differences in the erosion process at different slopes and soil (Wischmeier and Smith, 1978; Singer and Blackard, 1982).

Most of the methods for determining soil erodibility are quite unreliable and cumbersome, requiring commitments of large space, costly construction, time and tedious laboratory analyses, hence, a laboratory apparatus which is simple, inexpensive and fast in determining soil erodibility through an erosion coefficient had been designed and developed by Chandra and De (1978). This coefficient correlated well with erosion, dispersion and clay ratios as well as organic matter content, slope and other soil characteristics influencing soil erodibility (Chandra and De, 1978).

The slope-erosion coefficient relationships had not yet been established for Umingan, Maasin and Malitbog clays, the three soil types occupying large areas in Leyte, hence this study.

MATERIALS AND METHODS

Soil samples obtained from the Department of Horticulture experimental area, the water reservoir vicinity by the Department of Forestry and Barangay Bitanhu-an, Baybay, Leyte, were submitted to the Philippine Root Crop Research and Training Center Soil Laboratory, ViSCA, for soil analysis (see Tables 1-2 for results).

The laboratory erosion apparatus (Fig. 1), the test procedure developed by Chandra and De (1978) as described in the following paragraph, and regression analysis were used to determine the relationship of the erosion

Table 1. Textural analysis of the soil types.

Soil series	% Clay	% Silt	%Sand	Textural Classification
Umingan	48.506	10.927	40.567	clay
Maasin	77.333	7.040	15.627	clay
Malitbog	42.594	20.016	36.390	clay

Table 2. Physical proerties and organic matter content of the three soil types.

Soil type	Water holding capacity	Particle density (g/cm³)	Bulk density (g/cm³)	Organic matter %
Umingan clay	52.30	2.78	1.470	1.32
Maasin clay	55.40	2.20	1.495	2.03
Malitbog clay	48.33	2.60	1.319	4.32

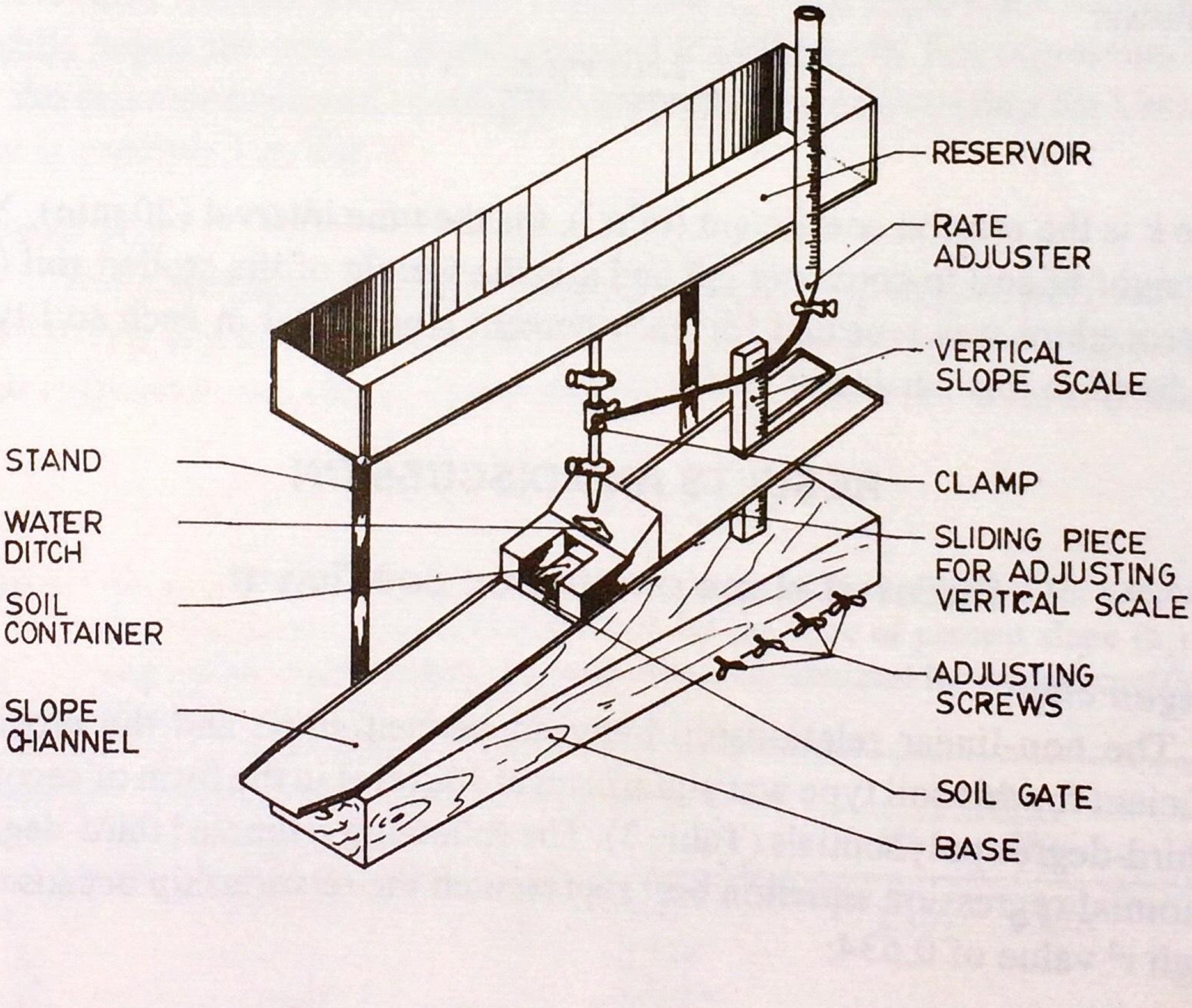


Figure 1. Apparatus developed by Chandra and De (1978) for the determination of the erosion coefficient of soils.

coefficient with slope for each of the soil types used in the study. The slopes used ranged from 2.5 to 50% at an increment of 2.5% with each slope level replicated three times. The developed regression equations were then tested for reliability.

Test Procedure for the Determination of Erosion Coefficient (Chandra and De, 1978)

Soil sample of about 30 g was brought to water holding capacity by adding distilled water. Wetted soil was transferred to the soil container of the laboratory erosion apparatus and was allowed to erode for 20 min at 15 mL/min water flow rate at a particular percent slope. Eroded soil was oven dried at 105°C for 8 h. The erosion coefficient was calculated using the relationship as follows:

$$k = \frac{2.303}{t} \log \frac{X}{X-x}$$

where k is the erosion coefficient (min^{-1}), t is the time interval (20 min), X is the weight of soil in container (g) and x is the weight of the eroded soil (g). The procedure was repeated for each percent slope level in each soil type considered in this particular study.

RESULTS AND DISCUSSION

Effect of slope on erosion coefficient

Umingan clay

The non-linear relationship between percent slope and the erosion coefficient for this soil type was significant at 1% level in the form of second- and third-degree polynomials (Table 3). The following estimated third-degree polynomial regression equation best represented the relationship because of its high r^2 value of 0.634:

$$\hat{Y}_{Um} = -2.99881 \times 10^{-3} + 1.41356 \times 10^{-3} X - 4.943 \times 10^{-5} X^2 + 5.7 \times 10^{-7} X^3$$

where: $\hat{Y}_{Um}$ = estimated erosion coefficient of Umingan clay

X = percent slope

Table 3. Regression equations obtained for erosion coefficient of Umingan clay on percent slope.

Regression equation	r^2 (decimal)
$\hat{Y} = 1.88693 \times 10^{-3} + 4.29571 \times 10^{-4}x - 4.157 \times 10^{-6}x^2$	0.5352
$\hat{Y} = -2.99881 \times 10^{-3} + 1.41356 \times 10^{-3}x - 4.943 \times 10^{-5}x^2 + 5.7 \times 10^{-7}x3$	0.6340

The relatively low r^2 value could be due to the short slope length of the apparatus (Singer and Blackard, 1982; Ganapin, 1983).

The test of significance of the partial regression coefficients of the third-degree polynomial showed that b_1 and b_2 were significant while b_3 was slightly below the level of significance of 5% (Table 4). The regression curve for the estimated erosion coefficient-percent slope relationship for Umingan clay is presented in Fig. 2.

Maasin clay

The coefficient of determination for the second-degree polynomial ($r^2 = 0.7305$) is higher than that obtained for the third-degree ($r^2 = 0.712$) although their regression equations were both highly significant at 1% level (Table 5).

Table 4. Value and test of significance of partial regression coefficients for percent slope (b_1), the square of percent slope (b_2) and the cube of percent slope (b_3) for the regression equation (third-degree polynomial) obtained for erosion coefficient of Umingan clay.

Parameter	Estimate of parameter (x 10^{-4})	Computed T-value	T-tabular 5%	T-tabular 1%
b_1	14.1356	2.767*	2.101	2.878
b_2	-0.4943	-2.214*		
b_3	0.0057	2.038^{ns}		

*significant
^{ns}not significant

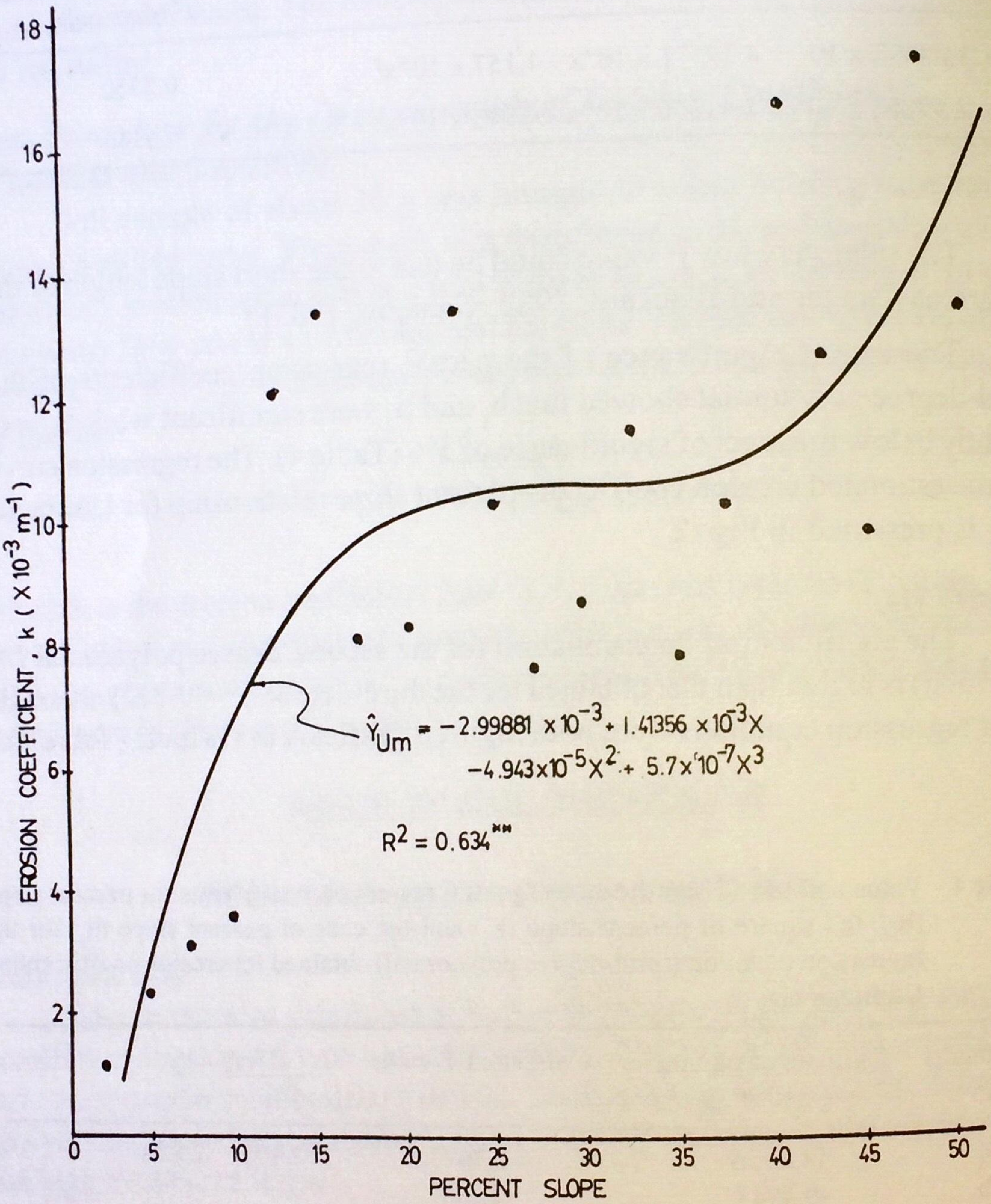


Figure 2. Relationship betweeen percent slope and the erosion coefficient of Umingan clay.

Table 5. Regression equations obtained for erosion coefficient of Maasin clay on percent slope.

Regression equation	r^2 (decimal)
$\hat{Y} = 7.39509 \times 10^{-4} + 1.7964 \times 10^{-5}x - 5.78561 \times 10^{-7}x^2$	0.7305
$\hat{Y} = -7.5532 \times 10^{-4} + 2.323 \times 10^{-5}x - 1.4 \times 10^{-7}x^2 + 1 \times 10^{-8}x3$	0.7120

Hence, the estimated erosion coefficient-percent slope relationship for Maasin clay is as follows:

$$\hat{Y}_{Maa} = 7.39509x10^{-4} + 1.7964x10^{-5}X + 5.78561x10^{-7}X^2$$

where: $\hat{Y}_{Maa}$ = estimated erosion coefficient of Maasin clay

The regression coefficients b_1 and b_2 were found to be significant at 5 and 1% levels, respectively (Table 6). Fig. 3 shows the regression curve for the estimated erosion coefficient-percent slope relationship for Maasin clay.

Malitbog clay.

The second- and third-degree polynomials were found to be significant at 1% level in describing the estimated erosion coefficient-percent slope relationship for Malitbog clay. However, the latter equation gave a higher r^2

Table 6. Value and test of significance of partial regression coefficients for percent slope (b_1), the square of percent slope (b_2) for the regression equation (second-degree polynomial) obtained for erosion coefficient of Maasin clay.

Parameter	Estimate of parameter ($\times 10^{-6}$)	Computed T-value	T-tabular 5%	T-tabular 1%
b_1	17.964	2.49*	2.101	2.878
b_2	0.578561	4.41**		

*significant
^{ns}not significant

value of 0.889 than the former with $r^2 = 0.7623$ (Table 7). Hence, the third-degree polynomial reflects better the relationship between the estimated erosion coefficient and percent slope for Malitbog clay:

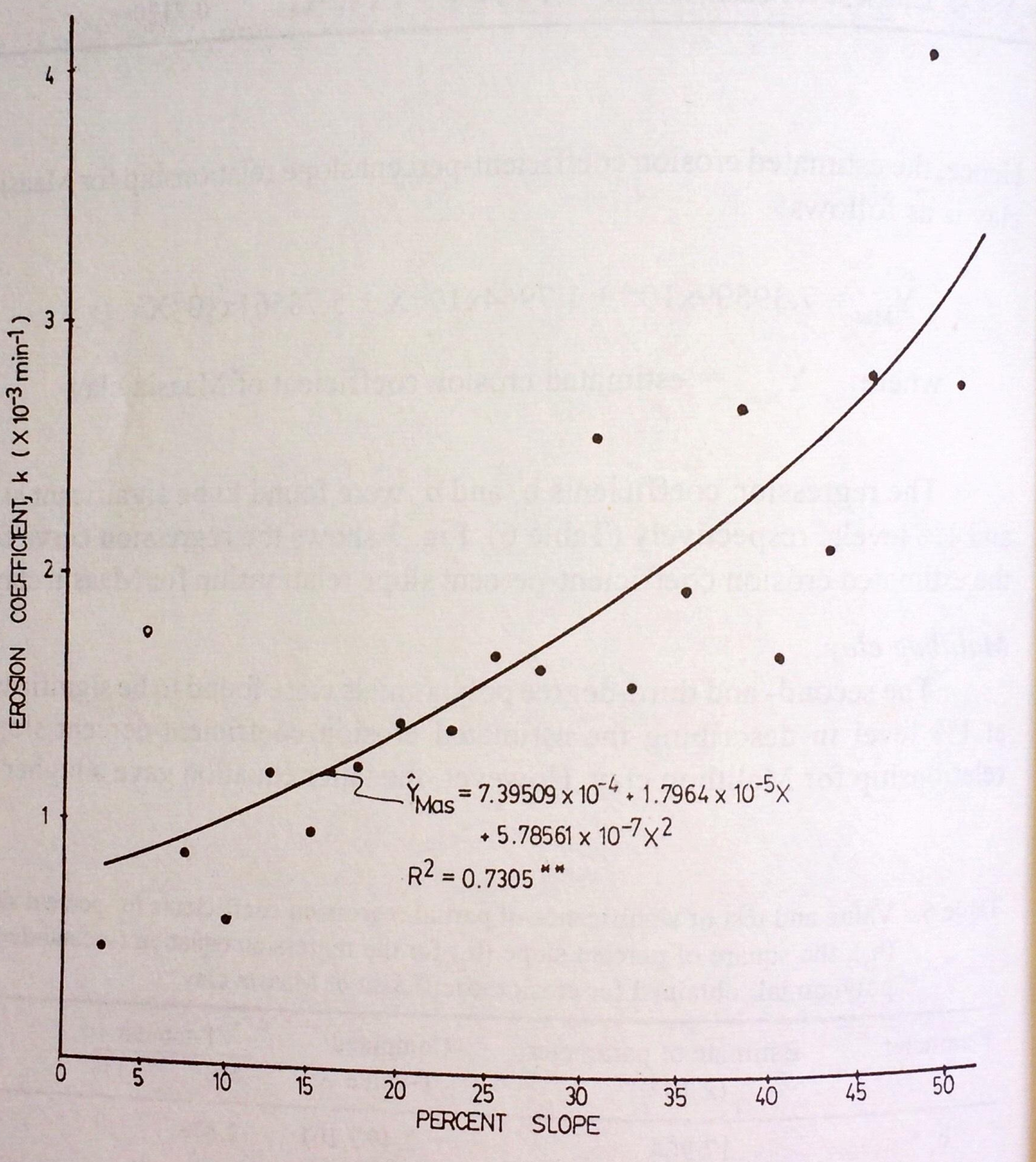


Figure 3. Relationship between percent slope and the erosion coefficient ofMaasin clay.

$\hat{Y}_{Mal}$ = estimated erosion coefficient of Malitbog clay.

Test of significance of the partial regression coefficients found both b_2 and b_3 to be significant at 1% level while b_1 was found insignificant (Table 8). The regression curve for the estimated erosion coefficient-percent slope relationship for Malitbog clay is presented in Fig. 4.

Table 7. Regression equations obtained for erosion coefficient of Malitbog clay on percent slope.

Regression equation	r^2 (decimal)
$Y = 1.0326 \times 10^{-3} + 1.78797 \times 10^{-4}x - 2.6539 \times 10^{-7}x^2$	0.7623
$Y = 1.37123 \times 10^{-3} + 3.0897 \times 10^{-4}x - 2.233 \times 10^{-5}x^2 - 2.9 \times 10^{-7}x^3$	0.8890

Table 8. Value and test of significance of partial regression coefficients for percent slope (b), the square of percent slope (b_2), and the cube of percent slope (b_3), for the regression equation (third-degree polynomial) obtained for erosion coefficient of Malitbog clay.

Parameter	Estimate of Parameter ($\times 10^{-4}$)	Computed T-value	T-tabular 5%	T-tabular 1%
b^1	-3.0897	-1.801^{ns}	2.101	2.878
b^2	0.2233	2.979^{**}		
b^3	-0.0029	-3.045^{**}		

**highly significant
^{ns}not significant

Comparison of estimated erosion coefficient-percent slope relationships

The regression curves for the estimated erosion coefficient-percent slope relationships for the three soil types used in this study are presented in Fig. 5. At all slope levels, Umingan clay shows a higher erosion coefficient than the other remaining soil types. This could have been due to its low organic

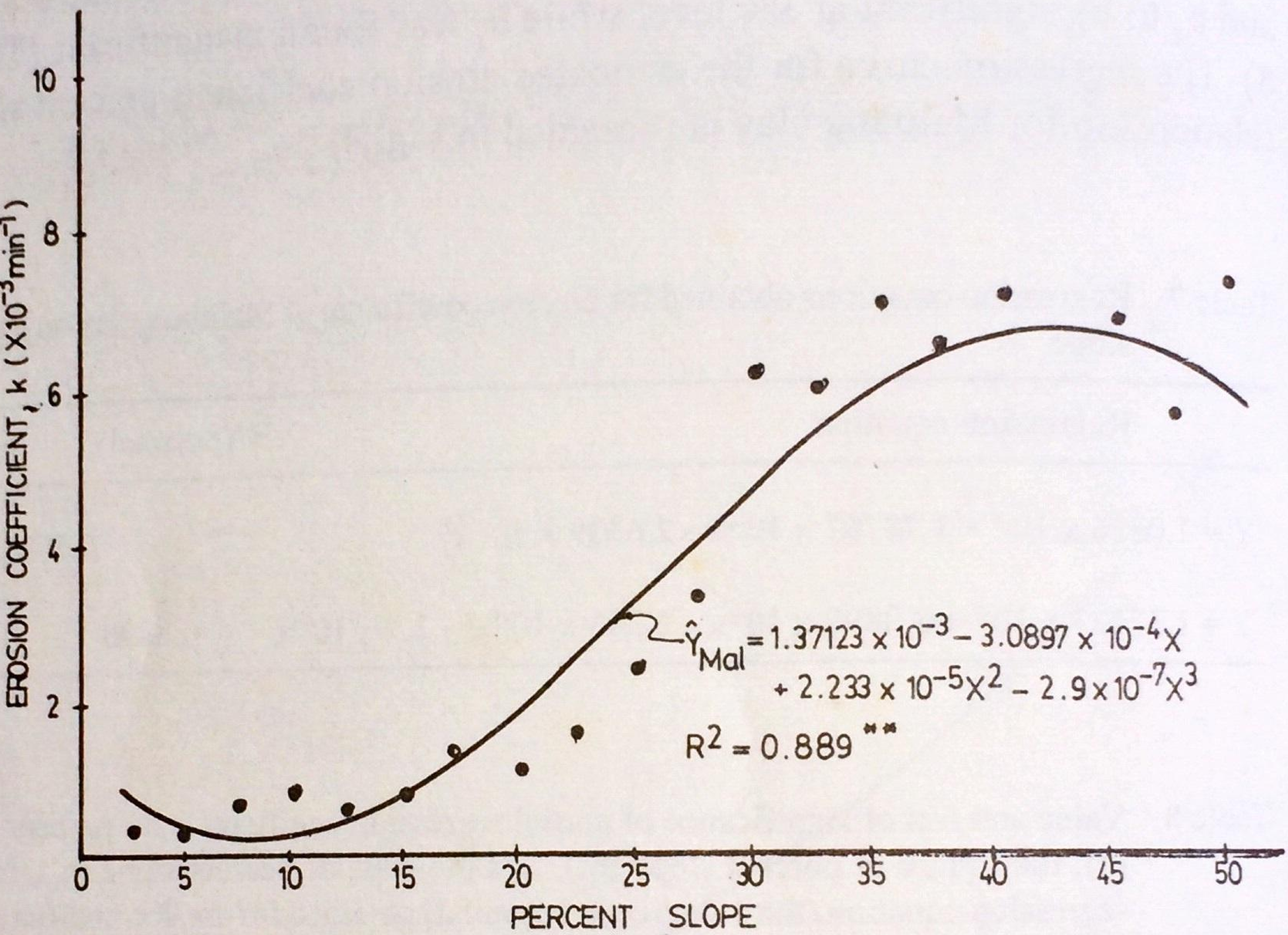
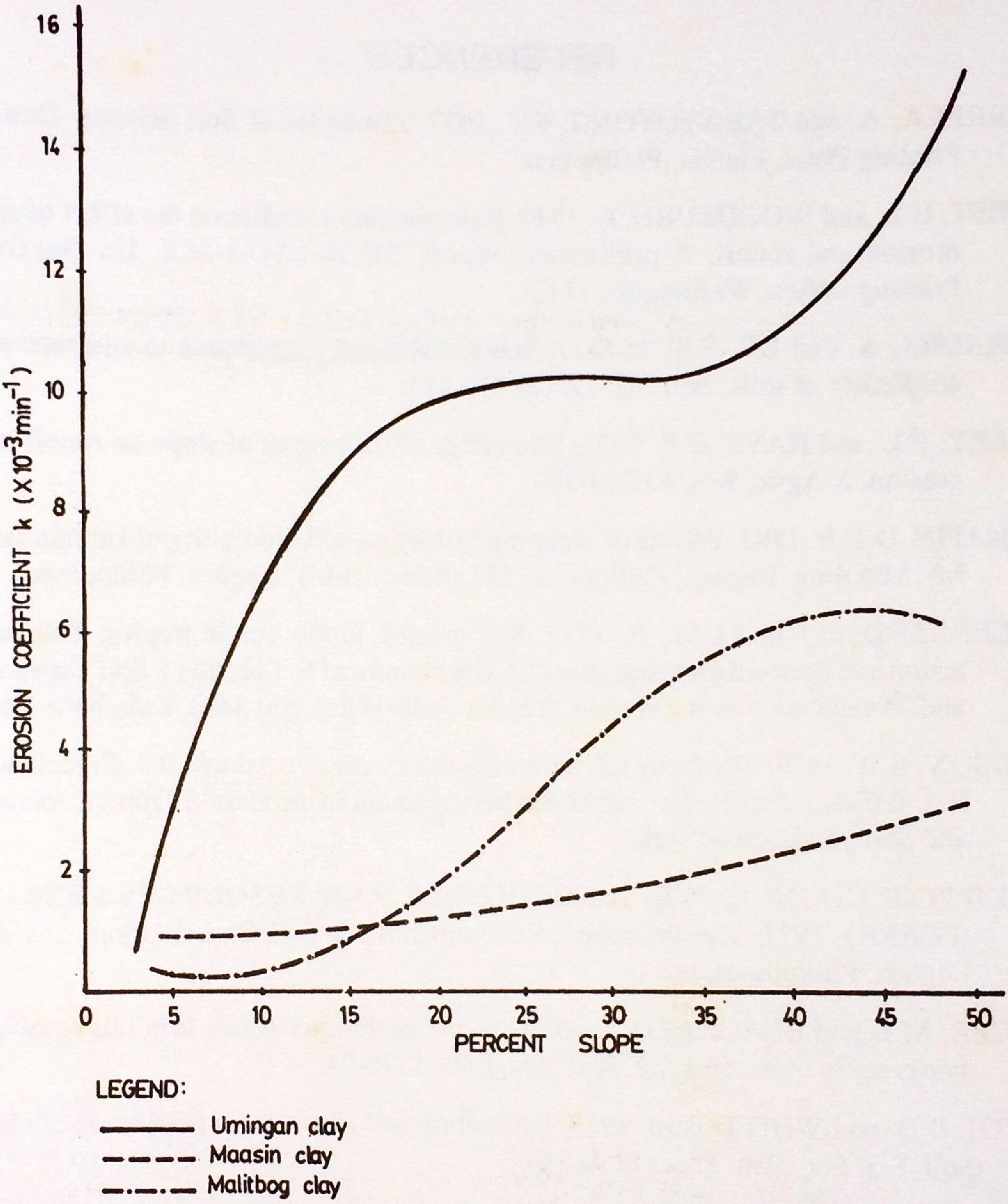


Figure 4. Relationship between percent slope and the erosion coefficient of Malitbog clay.

matter content and high sand fraction (Wischmeier and Mannering, 1969; Bruce-Okine and Lal, 1975 as cited by Ganapin, 1983).

The curve for Maasin clay shows a lower erosion coefficient than Malitbog clay only at slopes >17%. This could be due to the finer texture of Maasin clay compared to Malitbog clay. This result conforms with the findings of Duley and Hays (1932) that at higher slopes where flow rather than raindrop impact may dominate the erosion process, the finer textured soil may resist erosion since cohesiveness and shear strength increase with clay fraction content (Wischmeier and Mannering, 1969; Singer and Blackard, 1982).



The diversity and the non-parallel orientation of the regression curves in Fig. 5 tend to indicate that the rate of change in erosion coefficient due to change in slope differed among the three soil types. Umingan clay showed the highest rate of change in erosion coefficient followed by Malitbog and Maasin clays, respectively.

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