SEDIMENT PRODUCTION FROM A LAFAYETTE COUNTY MISSISSIPPI GULLY 1/

by

L. L. McDowell, G. C. Bolton, and M. E. Ryan 2/

INTRODUCTION

Gullies are a significant source of sediment in the Tallahatchie River watershed. In many areas the erosional processes have cut through the loessial mantle into the underlying Coastal Plains sands. This has resulted in the destruction of productive upland agricultural areas and downstream damages through channel aggradation, floodplain deposition, and reservoir sedimentation. A detailed study by Woodburn (4) 3/ revealed that one-third of the 294,000-acre Little Tallahatchie River watershed has been severely damaged by gullying.

Information on the rates of gully erosion and the significance of the contributed sediment to the total sediment delivery to downstream channels is essential in planning effective runoff and sediment control programs for agricultural watersheds. Quantitative data on the rates of sediment production from gullies in northern Mississippi have been obtained from studies by Woodburn (4) and Miller, Woodburn, and Turner (1). In these studies sediment production ranged from 1.45 to 6.77 inches per year per acre of exposed gully surface (Table 1). Production rates were highly variable, depending on gully size, relief, and the percentage of uncemented sands in the exposures. Practically no water flowed into the gullies, because the headcuts were very near the drainage divides. Thus, almost all of the erosion within the gullies could be attributed to raindrop impact and slope wash.

1/ A Contribution from the USDA Sedimentation Laboratory, Southern Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture, Oxford, Mississippi, in Cooperation with the Mississippi Agricultural Experiment Station and the University of Mississippi.

2/ Research Soil Scientist, Mathematician, and Chemist, respectively.

3/ Numbers in parentheses refer to Literature Cited -- at the end of the report.

TABLE 1.--Summary of Sediment Production Data from Gullies (Bare Surface) in Northern Mississippi.

Study Area	Study Period	Sediment Producing Area (Acres)	Maximum Relief (Feet)	Soil Loss		Reference
				Inches/Year	Tons 1/ / Acre-Year	
Lafayette County	1936-1949	0.7	40	1.85	310 2/	(6)
Lafayette County	1955-1960	0.54	27.7	1.45	245 3/	(2)
Tallahatchie County	1955-1960	0.30	21.1	3.00	506 3/	(2)
Carroll County	1955-1960	1.44	36.1	6.77	1142 3/	(2)

1/ Tons/acre based on bulk density of 1.5 g/cm^3 (93 lbs/ft^3).

2/ Concrete plugs were installed in the gully slopes and channel in 1936; the volume of soil removed by erosion was determined by surveys in 1937, 1939, and 1949.

3/ An earth dam with side spillway was installed at the lower end of the gully; the rate of gully erosion was determined by periodic surveys of the sediment pool behind the dam.

Previous studies on gullies in northern Mississippi have provided needed information on the rates of sediment production, but little quantitative data are available on the influence of rainfall characteristics on runoff and soil loss from gullies alone. In 1963 runoff and soil loss studies were initiated on a small gully near Oxford in Lafayette County, Mississippi. After three years of operation these investigations were terminated at the end of the 1966 water year. This report gives a summary of the data and an analysis and discussion of the influence of rainfall intensity and amount on runoff and sediment production.

EXPERIMENTAL PROCEDURE

This study was conducted on a small gully (0.15 acre and 5 to 15 feet deep) typical of many in Lafayette County. The gully drains into the ephemeral channel above Power Line Dam, a small detention reservoir located in the East Goose Creek watershed. The gully slopes are predominantly Coastal Plains sands varying from consolidated to extremely friable and overlain by 2 to 3 feet of loess and a thin layer of Lexington silt loam soil. The particle size distributions of the different sandy exposures within the gully are similar, having a median diameter (D_{50}) of about 0.2 mm.

Surface runoff entering the head of the gully was diverted at the beginning of the study. Therefore the measured runoff and soil losses resulted from rainfall within the gully perimeter area.

A recording-type rain gage was located at the site for precipitation measurements. In July 1963, the gully was equipped with a sediment basin to trap coarse sediments and a small H-flume and Coshocton-type N-2 sampler for measuring runoff and soil loss (see Figure 1). Runoff and soil loss measurements were made on a storm basis or at weekly intervals depending on the intensity and frequency of storms. The amount of coarse sediment trapped in the basin was determined by (a) weighing the sediment submerged in water and (b) subsequently converting these submerged values to dry-weight of soil in air, assuming a particle density of 2.65 g/cm^3 for the sediment.

The erosivity of the rainfall was evaluated as a function of the rainfall intensity (i) using the equation derived by Parsons [4], i.e.,

$$\bar{i} = \frac{\Sigma \Delta R i}{\Sigma \Delta R}$$

4/ Private Communication with D. A. Parsons, Director, USDA Sedimentation Laboratory.

where $\bar{i}$ is the weighted intensity for a storm or storm-period, $\Sigma\Delta Ri$ is the summation of the several intensity (i) intervals, weighted in accordance with their relative contributions to the total volume of rainfall (R) and $\Sigma\Delta R$ is the total rainfall for the period considered. Based on previous studies of sheet erosion, the sediment concentration in the runoff is proportional to a function of $\bar{i}$.

RESULTS AND DISCUSSION

Data collection began in October 1963. Therefore, the subsequent discussion is based on the results obtained in the water years 1964, 1965, and 1966. Yearly summaries illustrating the variability in rainfall, runoff and soil losses during the study are given in Table 2. The mean annual precipitation for the 47-year period 1920-1967 at University, Mississippi, is 53.21 inches. Annual precipitation during the study period was lower than the mean value by 3.2, 4.3, and 9.0 inches for 1964, 1965, and 1966, respectively. The percentage of annual rainfall measured as runoff (percent runoff) increased slightly from 25.5 to 32.1 percent. The relatively low values for runoff are attributed to the high infiltration rate of the gully sand bed channel.

Measured soil losses were 109.9, 93.5, and 88.1 tons per acre for 1964, 1965, and 1966, respectively, with corresponding concentration values of 8.6, 6.4, and 6.2 tons per acre-inch. Based on the measured concentration and percent runoff values (Table 2) the estimated annual soil losses are 116.8, 101.8, and 106.1 tons per acre for 1964, 1965, and 1966, respectively.

The annual sediment production rate for the gully is similar to that measured from sheet erosion on 0.022-acre fallow plots of Loring and Lexington soils at the North Mississippi Branch Experiment Station at Holly Springs [5]. However, the rate is only about 40 percent of the sediment production rates measured previously from gullies located in similar soil and geologic materials in Lafayette County (see Table 1). This lower rate is attributed to the relatively small area and relief of the gully.

A preliminary study of the monthly soil loss data and amount of runoff suggests that factors other than runoff volumes are involved in sediment production (see Figure 2). Previous studies (2) have illustrated that soil erosion is a complex process involving the erosivity of the rainfall, the flow of runoff over the soil surface, and the erodibility of the soil. The erosivity of rainfall is a function of both the rainfall volume and the intensity, and since erosion occurs

---

5/ Unpublished data, 1965 Annual Report, USDA Sedimentation Laboratory.

TABLE 2.--Annual Rainfall, Runoff, and Soil Loss Data for Gully No. 1, East Goose Creek Watershed.

	1964	1965	1966
Rainfall (inches)	50.03	48.88	44.18
Runoff	12.75	14.61	14.20
Runoff (percent of rainfall)	25.5	29.9	32.1
Soil loss (tons/acre)	109.9	93.5	88.1
Soil loss	0.65	0.55	0.52
Concentration (tons/acre-inch)	8.6	6.4	6.2
Weighted intensity (inches/hour)	0.94	0.96	1.11
Rainfall deficiency (inches)	3.2	4.3	9.0
Runoff deficiency (inches)	0.8	1.3	2.9
Estimated soil loss deficiency (tons/acre)	6.9	8.3	18.0
Estimated soil loss (tons/acre)	116.8	101.8	106.1
Estimated soil loss (inches)	0.69	0.60	0.62

only while runoff is occurring, then an analysis of soil erosion must include the applicable rainfall amount and intensity values concurrent with runoff. Assuming little change has occurred in the rate and volume of runoff, then the soil loss per unit area is proportional to the amount of runoff and the erosivity of the rainfall. Thus the concentration (C) of the sediment in the runoff (A) is proportional to the erosivity of the rainfall. Then the concentration is equal to a constant, K, times $f(\bar{i})$, a function of the weighted intensity; or $C = K f(\bar{i})$. The K value, may be regarded with some reservations to be indicative of the soil erodibility (3). The evaluation of concentration as a function of $\bar{i}$ in Figure 3 clearly reveals the decrease in the soil erodibility factor K, during the study period. Using the relationship $K = C/(\bar{i})^{0.76}$ this decrease in erodibility, along with its seasonal variation is more strikingly demonstrated in Figure 4.

Further examination of the concentration and weighted intensity values during the study period (see Figure 5) reveals two interesting factors: (1) the relatively close relationship between C and $\bar{i}$ throughout 1964 (the first year of study) and the winter months of 1965 and 1966, and (2) the decrease in C in relation to $\bar{i}$ during the summer months of 1965 and 1966 (periods of relatively high intensity storms). The apparent reduction in erodibility during 1965 and 1966 is attributed to the increase in plant cover observed on the lower slopes of the gully. Although the plant cover reduced the action of raindrop impact during the summer months, its effectiveness was greatly reduced by frost, and by freezing and thawing during the winter months.

The soil loss (SL) per unit area of the gully can be evaluated in relation to the product $A(\bar{i})^{0.76}$ (see Figure 6) since the soil loss is proportional to the amount of runoff and the erosivity of the rainfall. After correcting for changes in the soil erodibility, K, (see Figure 7) the significance of the $Af(\bar{i})$ product as an indicator of the erosion-producing potential of rainfall is clearly illustrated. Since runoff (A) is proportional to rainfall (R), the soil loss per unit area can be estimated from the product $R(\bar{i})^{0.76}$, but with greater dispersion of the data (see Figure 8).

SUMMARY

Based on a three-year study in Lafayette County, Mississippi, the annual sediment production from a small gully (0.15 acre and 5 to 15 feet in relief) is about 120 tons per acre. This suggests that an approximate rate of 0.7 inch per year from bare gully area is a reasonable value to apply in estimating gully sediment production from the many small (area and relief) gullies in Lafayette County. Previous studies by Woodburn (4), and Miller, Woodburn, and Turner (1) indicate that when relief is moderate (about 20 feet) the currently used value of 2 inches per year is a more accurate rate to apply in estimating soil losses.

The influence of the rainfall characteristics on runoff and soil loss from the gully were evaluated using the weighted intensity function ($\bar{i} = \Sigma\Delta Ri/\Sigma\Delta R$) proposed by Parsons as an indicator of the erosivity of rainfall. The concentration of sediment in the runoff was proportional to a function of the weighted intensity ($\bar{i}$), provided the soil erodibility remained constant during the study period. Based on the results of this study it is suggested that the $\bar{i}$ function be applied to the analysis of other watershed sediment production data as an indicator of the potential of rainfall to cause soil erosion.

LITERATURE CITED

1. Miller, Carl R., Russell Woodburn, and H. R. Turner. 1962. Upland Gully Sediment Production. Intl. Assoc. Sci. Hydrology. Symposium on Land Erosion 59:83-104.

2. Parsons, D. A. 1961. A Note on the Erosive Potential of Rainfall. U. S. Dept. Agri. Res. Report 347.

3. Parsons, D. A., R. P. Apmann, and C. H. Decker. 1964. The Determination of Sediment Yields from Flood Water Sampling. Intl. Assoc. Sci. Hydrology. Pub. No. 65. pp. 7-15.

4. Woodburn, Russell. 1949. Science Studies a Gully. Soil Conservation 15(1):11-13.

Figure 1.--Gully Instrumentation Included a Sediment Basin and Coshocton Sampler for Measuring Runoff and Soil Loss.

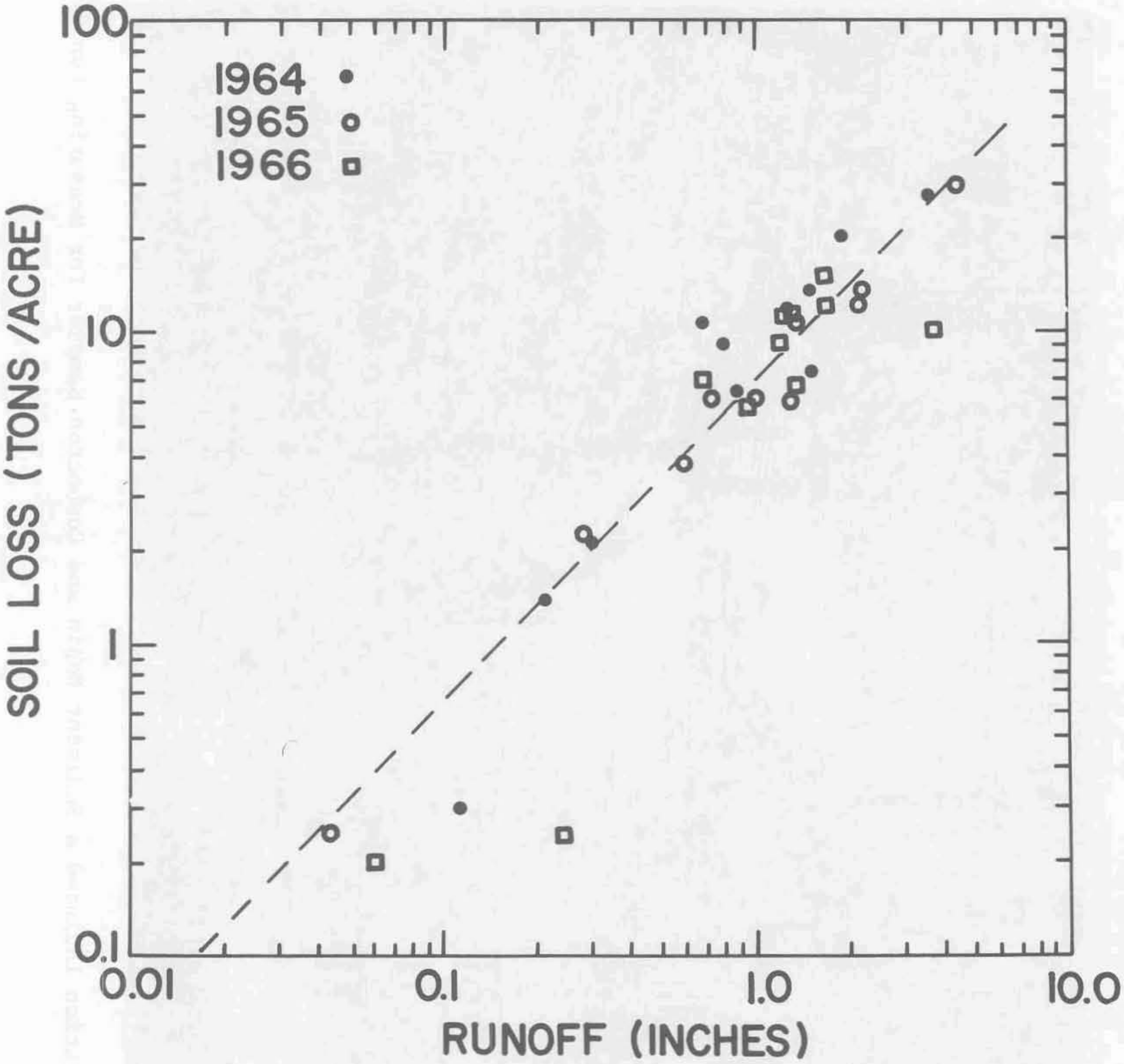

Figure 2.--Soil Loss as Related to the Amount of Runoff (Monthly Values).

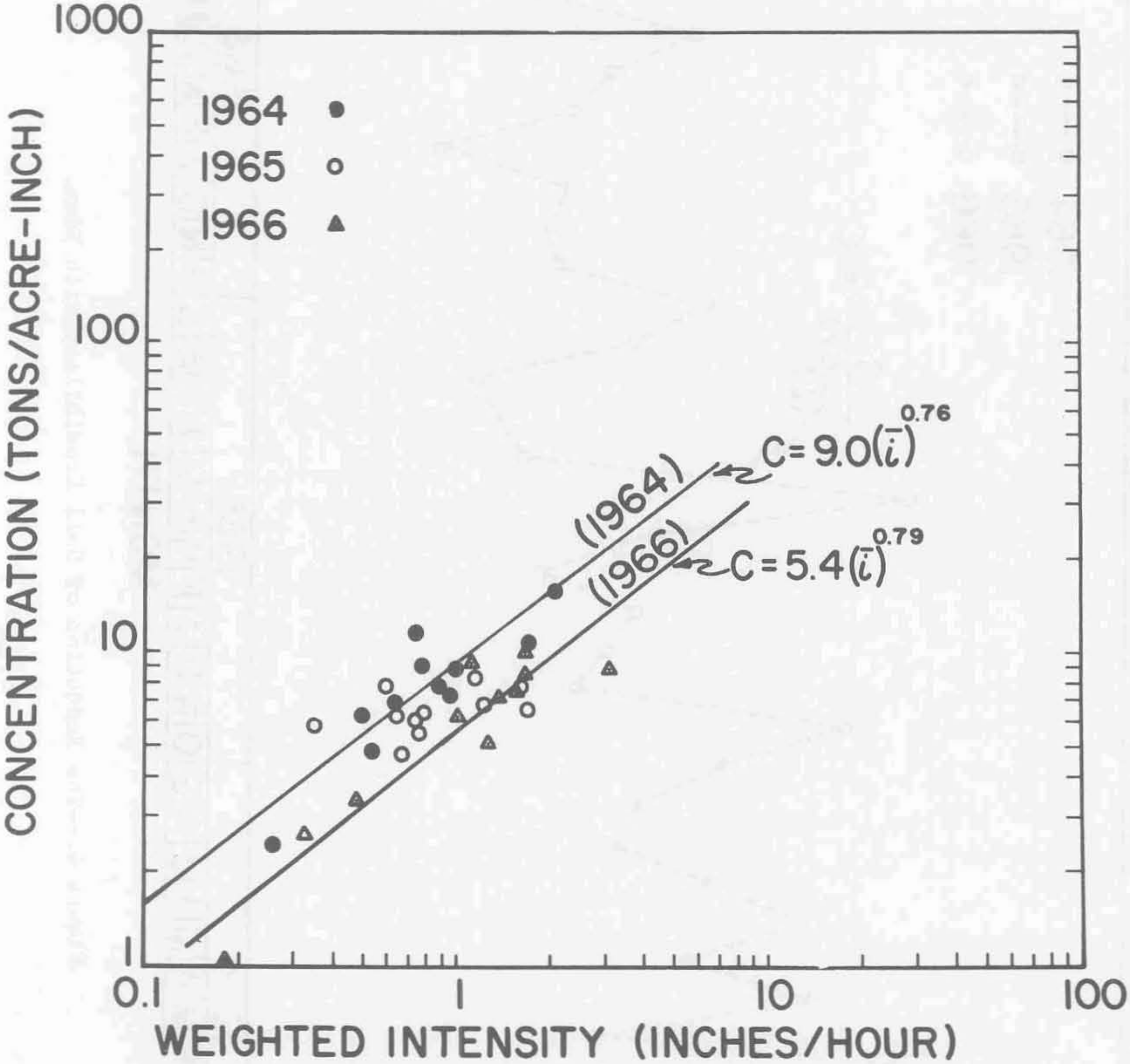

Figure 3.--Concentration as a Function of the Weighted Intensity of Rainfall (Monthly Values).

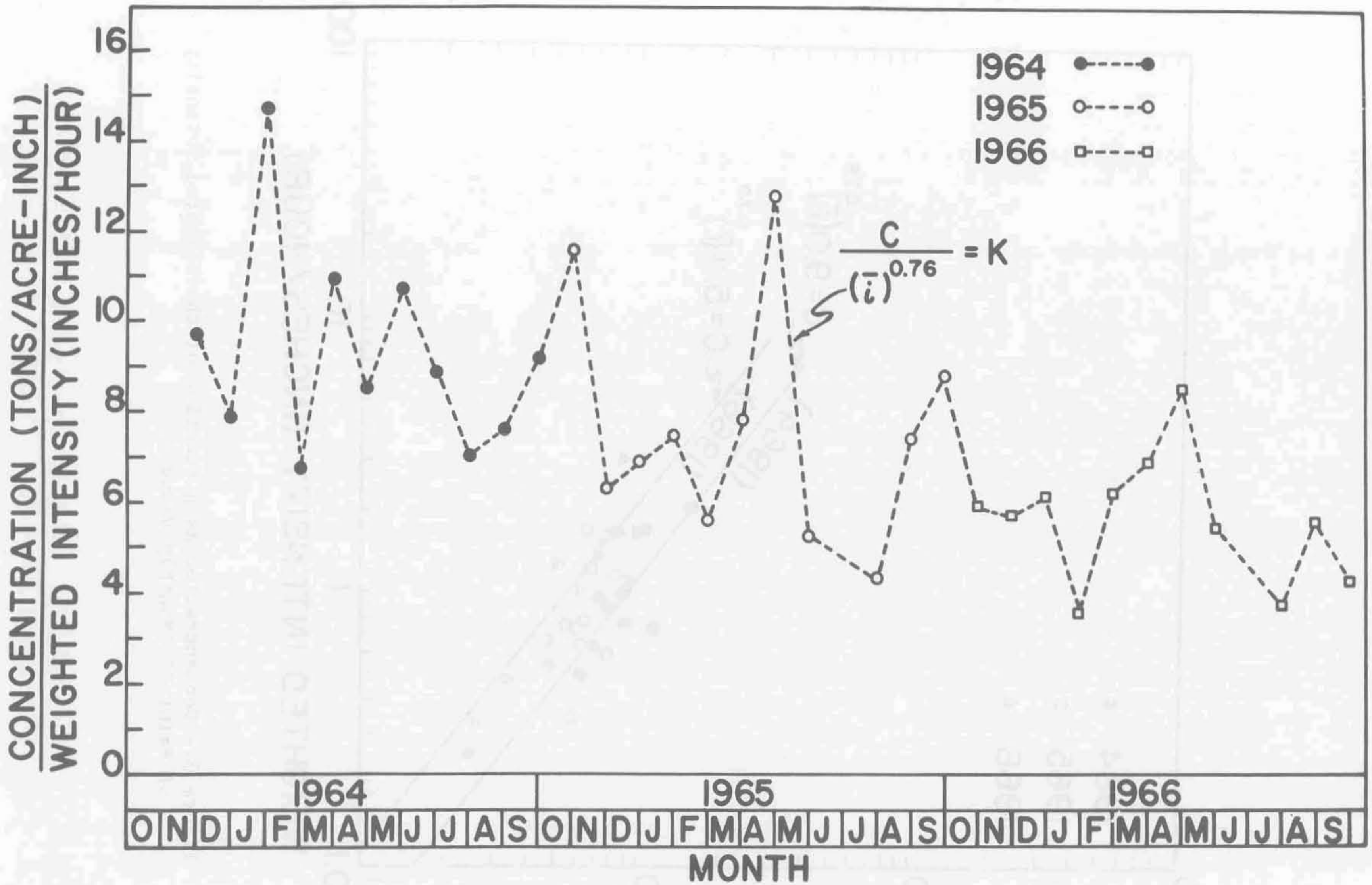

Figure 4.--The Reduction of Soil Erodibility with Time.

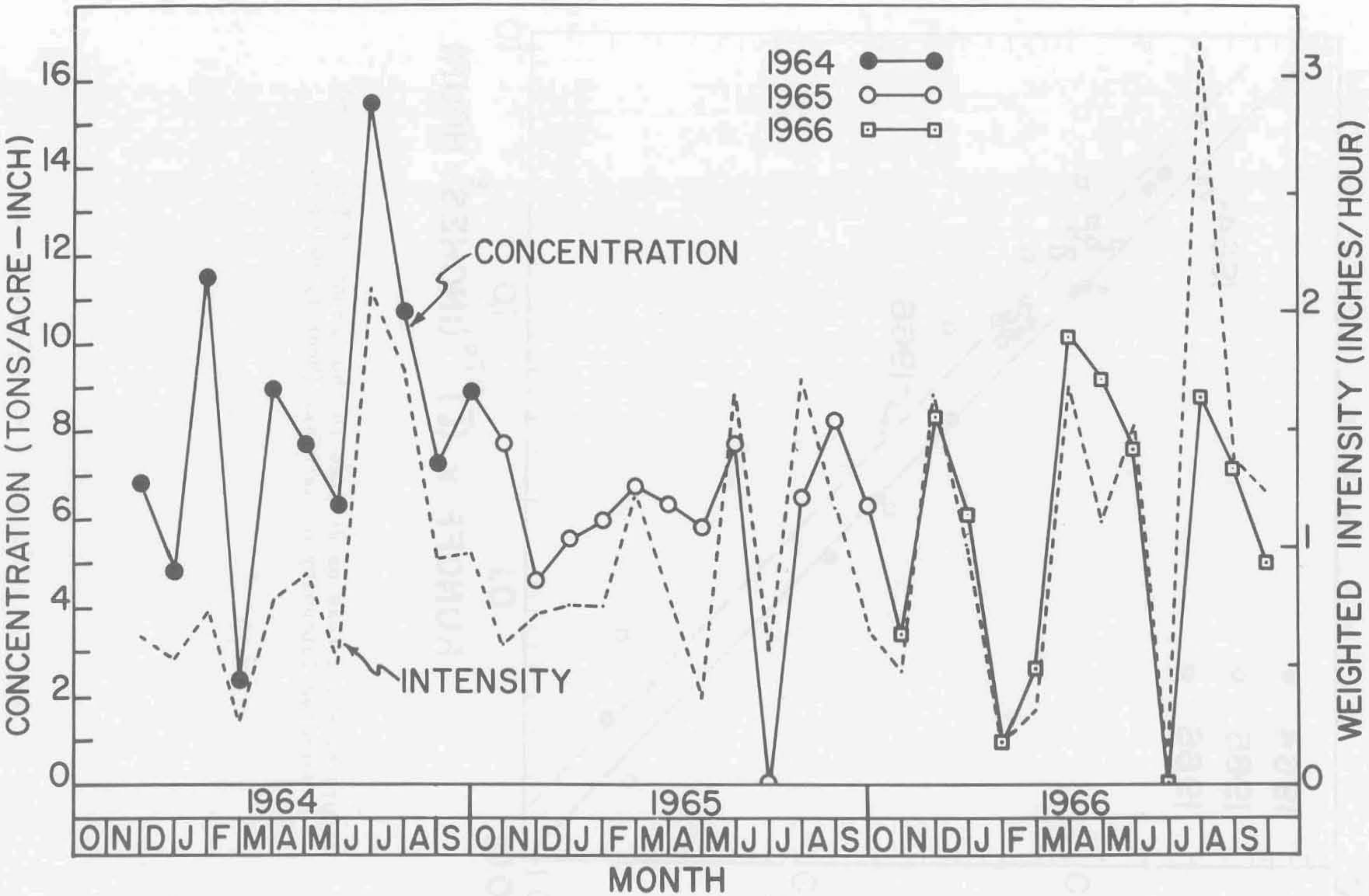

Figure 5.--Variation in Monthly Concentration and Weighted Intensity Values with Time (1964-1966).

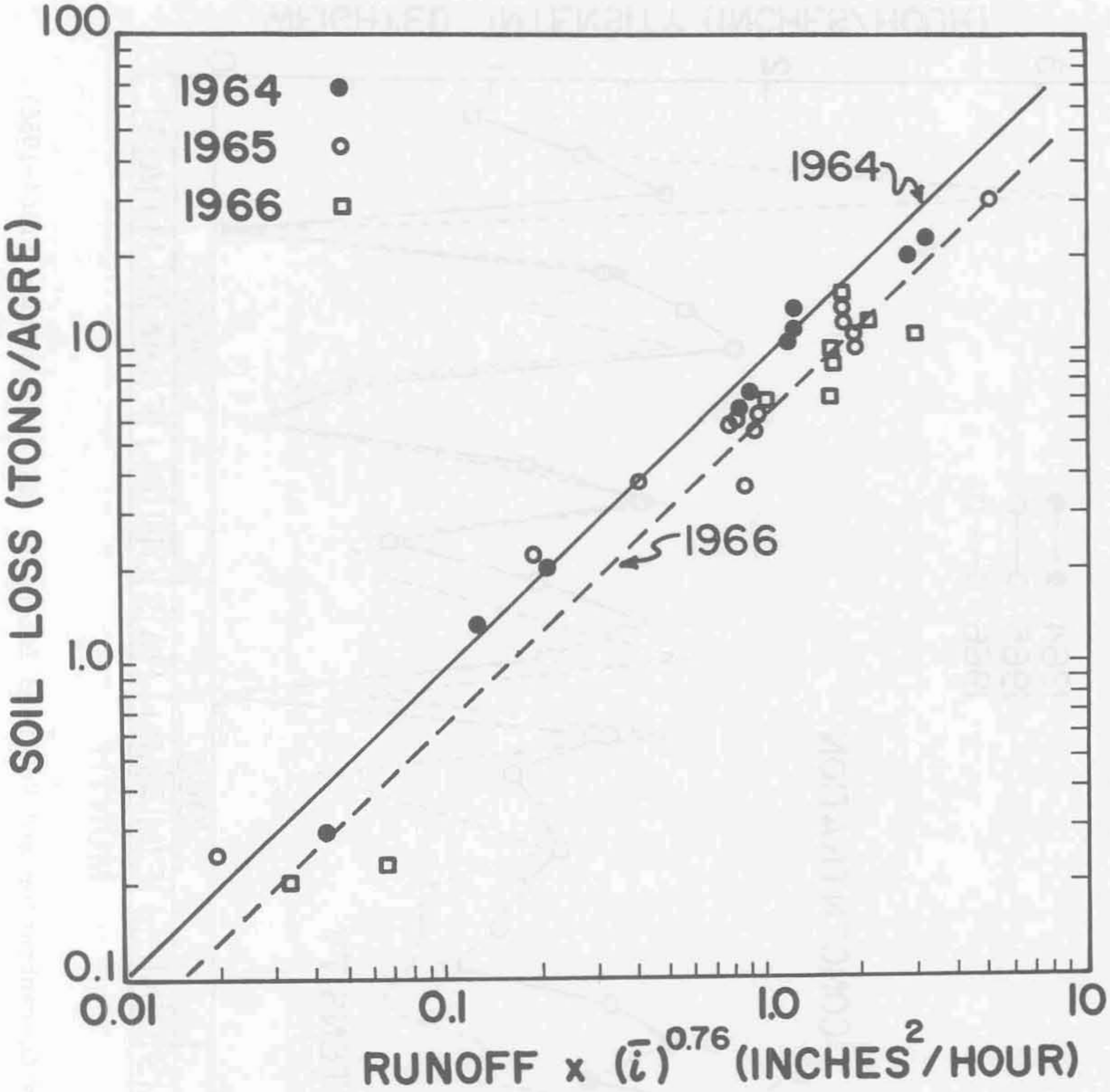

Figure 6.--Soil Loss as Related to the Amount of Runoff and Weighted Intensity of Rainfall (Monthly Values).

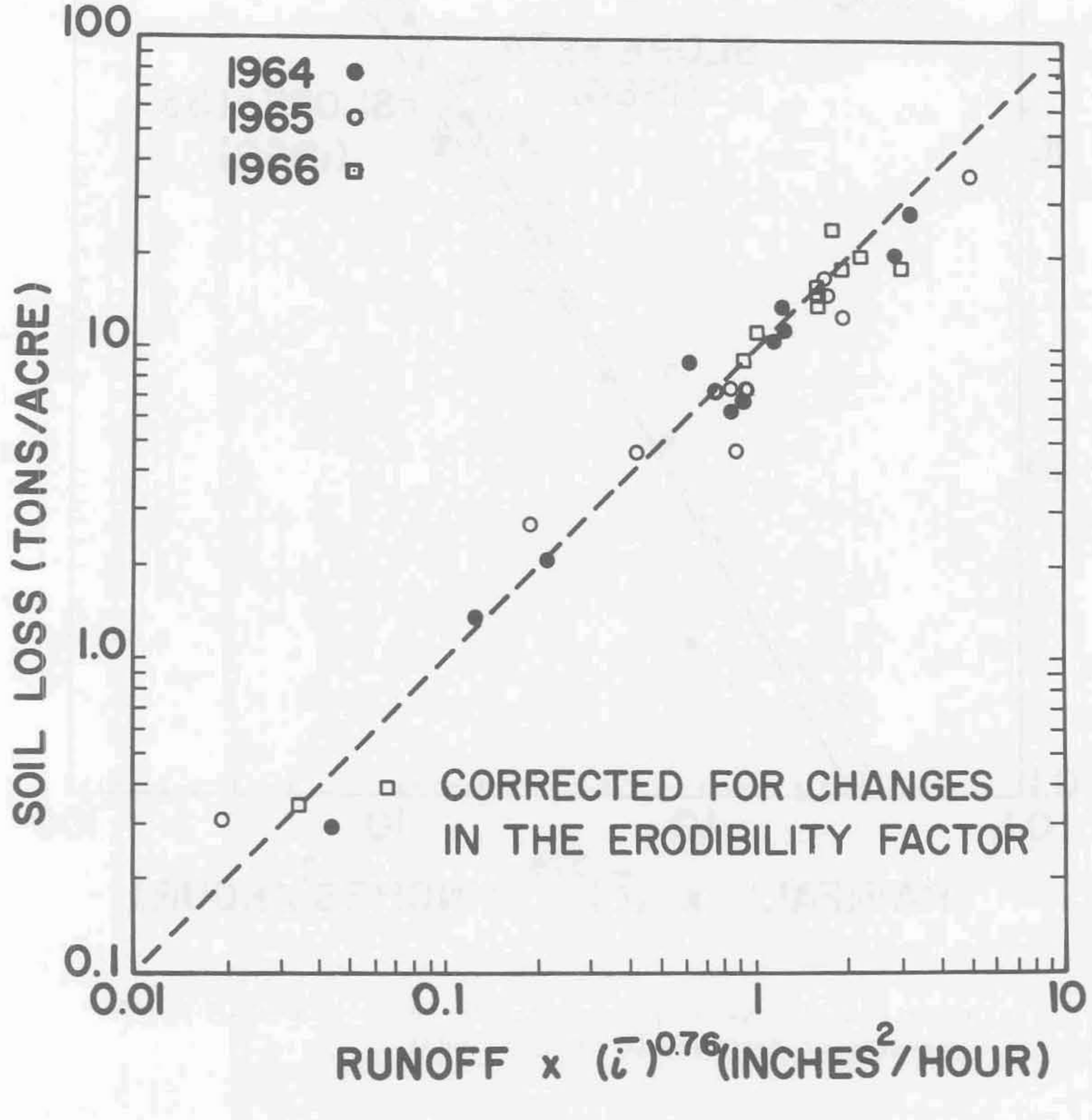

Figure 7.--Soil Loss as Related to the Amount of Runoff and Weighted Intensity of Rainfall (Monthly Values - corrected for Changes in Soil Erodibility).

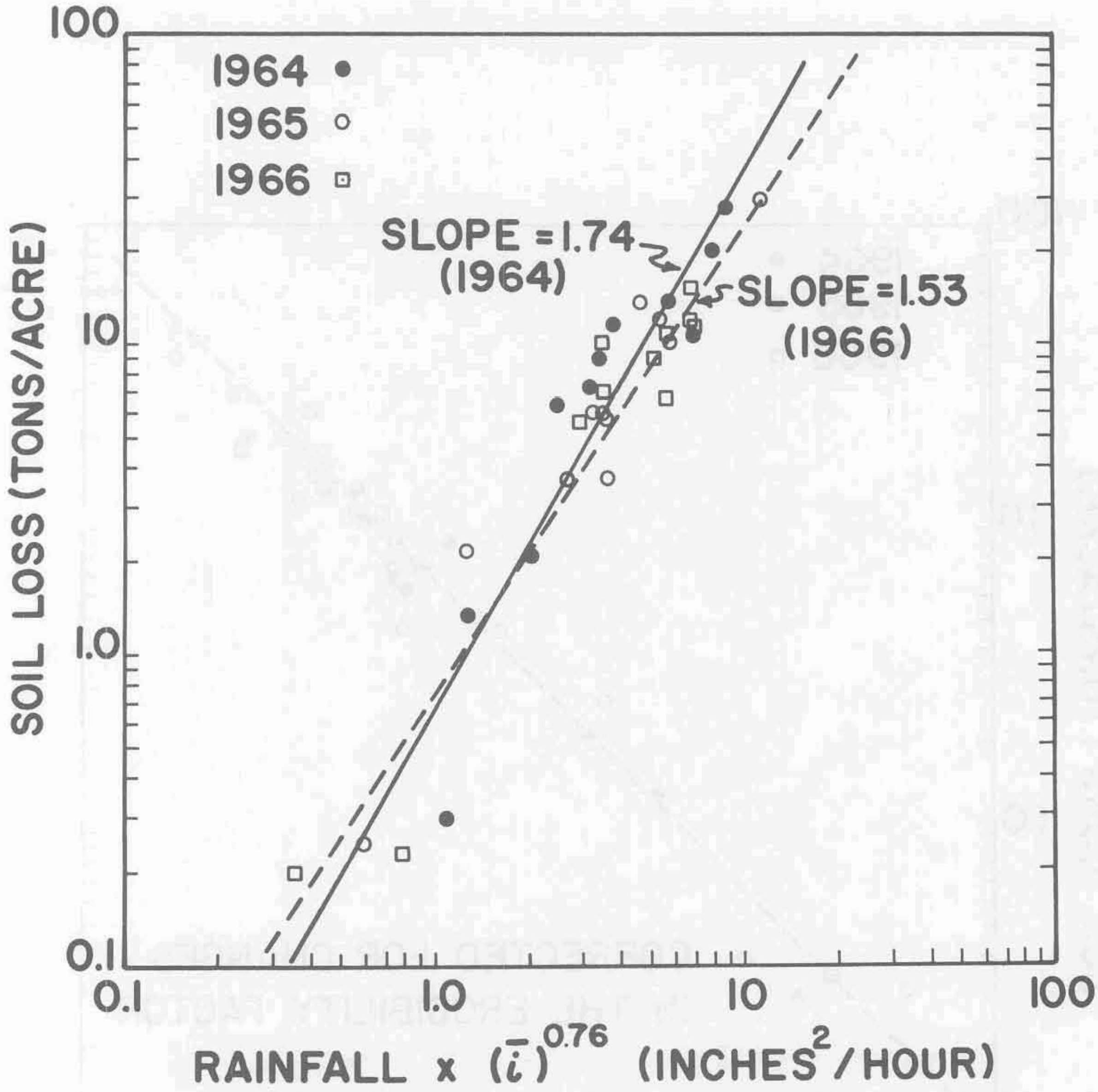

Figure 8.--Soil Loss as Related to the Amount and Weighted Intensity of Rainfall (Monthly Values).