soil erosion problems on an alfisol in western nigeria and their control

by

R. Lal

ONOGRAPH No.1

soil erosion problems on an alfisol in western nigeria and their control

by

R. Lal

ONOGRAPH No.1

soil erosion problems on an alfisol in western nigeria and their control

by

R. Lal

IITA MONOGRAPH NO. 1

APPROVED FOR PUBLICATION
(MAY, 1975)

1st Published 1976
Reprinted 1979

Table of Contents

List of illustrations (Plates)

List of illustrations (Figures)

List of Tables

List of Appendices

Foreword

Soil erosion is a major impediment to the development of successful, continuously productive farming systems for the humid tropics. The problem has been understood qualitatively for many years, but attempts to control erosion with measures successfully used in subtropical and temperate areas have often failed.

One reason is that the information on which the design of erosion-control systems must be based is not available in the humid tropics. Extrapolation of information gathered in other areas of the world is seldom satisfactory. The problem is further complicated by the fact that erosion-control measures developed for subtropical and temperate regions are based on relatively expensive land-development methods. The returns from production of food crops in the humid tropics are often not sufficient to bear the costs.

One alternative is to leave the agricultural lands of the humid tropics under the forest or tree crops. This solution, however, fails to respond to the need for more food to meet the demands of rapidly increasing populations.

In much of southern Asia, the response to the soil-erosion problem has been to leave the more erodible upland areas under forests or under limited cultivation and to develop valleys and estuarine areas for rice production, with careful water management. This, again, is a solution, but the problems involved in developing land for paddy rice production take many years to resolve. In Asia, as in many other parts of the humid tropics, there is an urgent need to develop methods for crop production on upland areas better able to control erosion.

The real choice is between acquiring the knowledge upon which sound land-use practices can be based or seeing the desperate need for food force people into unsatisfactory exploitative and degradative use of soils, with the result that they become unproductive and pressure on the land increases further.

To collect some of the information needed to develop economic methods of arable farming which are also free from erosion hazard of humid tropical areas, a detailed study of soil erosion in relation to food crop production was started at the International Institute of Tropical Agriculture, (IITA) Ibadan, Nigeria, in 1970. This monograph presents details of those experiments, including information on the relation between soil-management systems and soil loss. The results show clearly the superiority of no-tillage mulch-farming techniques and of intercropping, the practices widely used by indigenous farmers in these areas. It is now necessary to extend these results to other parts of the humid tropics, to determine how widely the Nigerian results can be generalized and what modifications may be necessary for other soil types and climates.

DENNIS J. GREENLAND
Director of Research, IITA

Acknowledgements

The author is grateful to Prof. D. J. Greenland for his helpful comments, suggestions and for reading the manuscript. My special thanks are due to Messrs R. A. Woodis and J. O. Oyekan for editing the report and to Mr. J. G. H. Craig for help in constructing the runoff plots. The help received from Drs. B. N. Okigbo, T. Little, M. Garber and T. L. Lawson is also acknowledged. Thanks also to the staffs of the Analytical Services Laboratory and the Communications and Information section of the International Institute of Tropical Agriculture (IITA). This monograph is dedicated to the field staff of soil physics section, who worked hard after every rain to collect the information which made this report possible.

Introduction

Soil erosion becomes a serious problem in the humid tropics when continuous farming replaces shifting cultivation and bush fallow. Soil erosion includes both physical removal of surface soil and deterioration in soil physical properties resulting in low productivity. Failure to appreciate the significance of the soil erosion problem can lead not only to large areas of shallow, badly eroded and unproductive soil in the tropics, but also to the replacement of forests by savannah.

The areas of West Africa where potential erosion problems exist are shown in Fig. 1.0. Areas with annual rainfall higher than 1000 mm. are subject to erosion when forests are removed for intensive and large-scale mechanized agriculture.

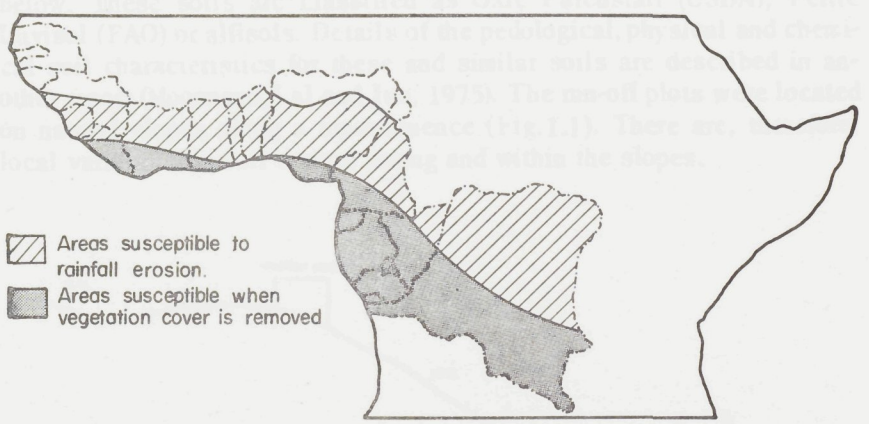


Fig. 1.0 Relationship of rainfall distribution with soil erosion hazard in West Africa.

This report describes in detail the results of a series of field experiments conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. These experiments were conducted on alfisols and the results may be applicable to similar soil and climatic conditions elsewhere in the tropics.

2

Runoff Plots: Location, Design and Construction

Western State of Nigeria lies roughly between longitudes 3° and 6° east and latitudes 6° and 8° north with an average rainfall of 1100 to 1300 mm. Because of the bimodal pattern of rainfall distribution there are two growing seasons. The first growing season, from late March to late July, ends in a short dry spell that lasts about one month; the shorter second season begins in late August and ends in December.

Run-off plots were constructed on well drained soils belonging to Egbeda series (Smyth and Montgomery, 1962). These soils are derived from fine-grained biotite gneiss and schist parent materials. They are medium-to-light textured near the surface, with sandy-clay to clay subsoil and a layer of angular and sub-angular quartz gravel immediately below. These soils are classified as Oxic Paleustalf (USDA), Ferric Luvisol (FAO) or alfisols. Details of the pedological, physical and chemical soil characteristics for these and similar soils are described in another report (Moormann, Lal and Juo, 1975). The run-off plots were located on natural slopes along a toposequence (Fig.1.1). There are, therefore, local variations in soil texture among and within the slopes.

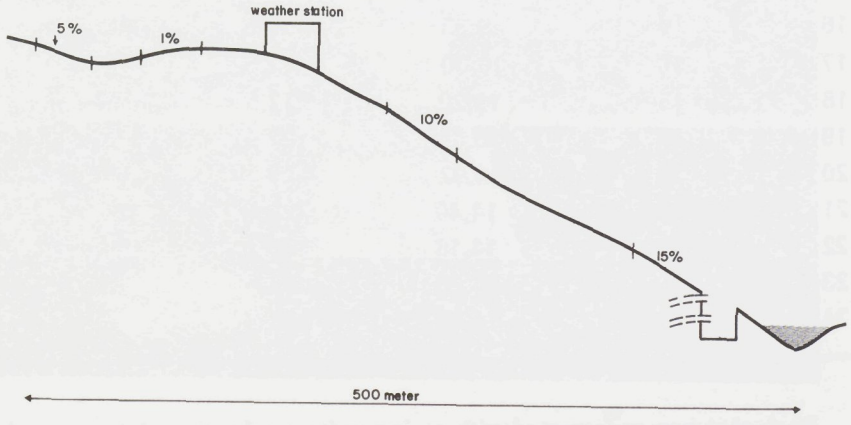


Fig. 1.1 The approximate locations of runoff plots of different slopes along a toposequence.

Run-off and Soil Loss Measuring System

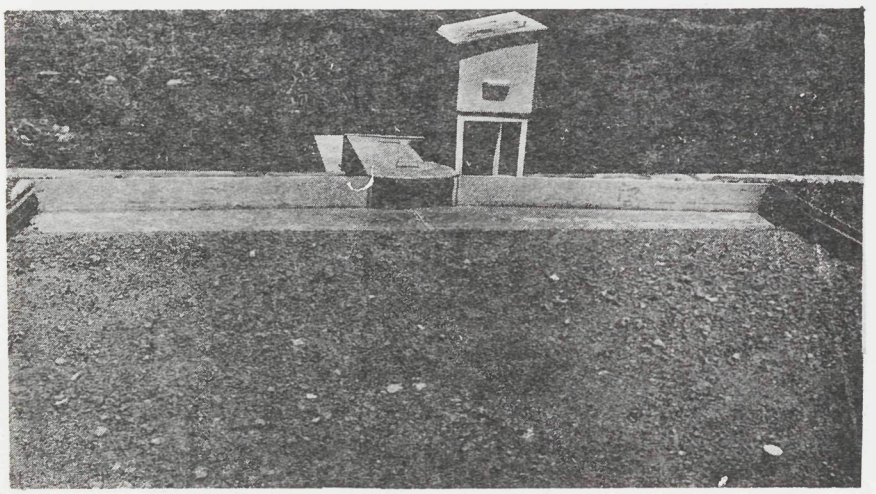
Four runoff plots were constructed on natural slopes of about 1, 5, 10 and 15%. The exact slopes for each of the plots are shown in Table 2.1. All plots were 25 x 4 m with a 1 m buffer zone between adjacent plots. There were five plots on each slope, with two additional plots 12.5 m and 37.5 m long on the 10 and 15% slopes.

Table 2.1. Slope characteristics of each run-off plots

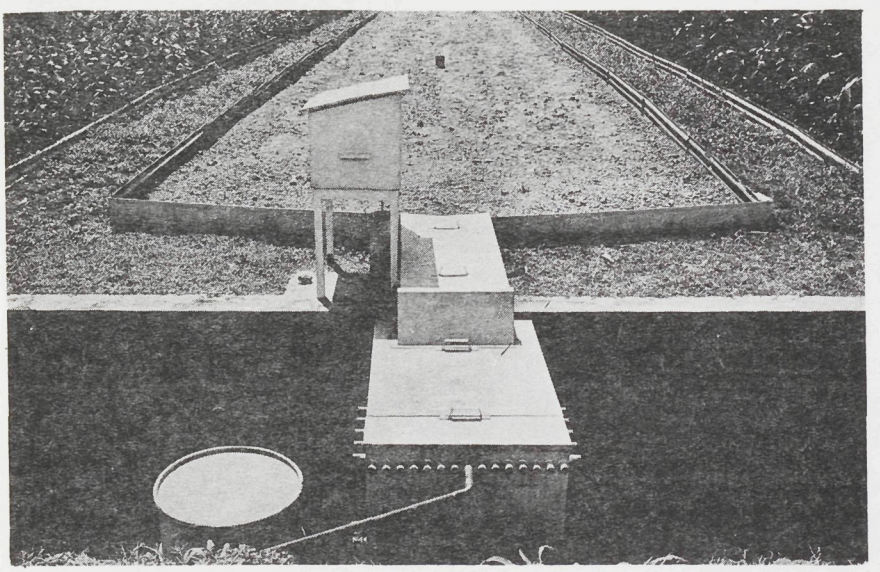
Plot No.	*Slope (%) Notation in the Text*	*Exact Slope %*	*Plot length (m)*	*Remarks*
1	1	1.80	25	–
2	1	1.30	25	–
3	1	1.10	25	–
4	1	1.00	25	–
5	1	0.88	25	–
6	5	4.72	25	–
7	5	5.12	25	–
8	5	5.48	25	–
9	5	5.68	25	–
10	5	5.68	25	–
11	10	8.76	25	–
12	10	9.28	25	–
13	10	9.72	25	–
14	10	9.88	25	–
15	10	10.12	25	Old termite hill covering 4 m^2 area
16	10	9.33	37.5	Complex slope
17	10	10.00	12.5	–
18	15	19.20	12.5	Concave slope
19	15	13.44	37.5	Complex slope
20	15	14.92	25	–
21	15	14.40	25	–
22	15	14.16	25	–
23	15	14.36	25	–
24	15	14.64	25	–

Each plot was constructed with an impervious asbestos edging extending 30 cm below and 15 cm above the ground on both sides to prevent runoff entering from outside. The top edging consisted of 30 cm asbestos

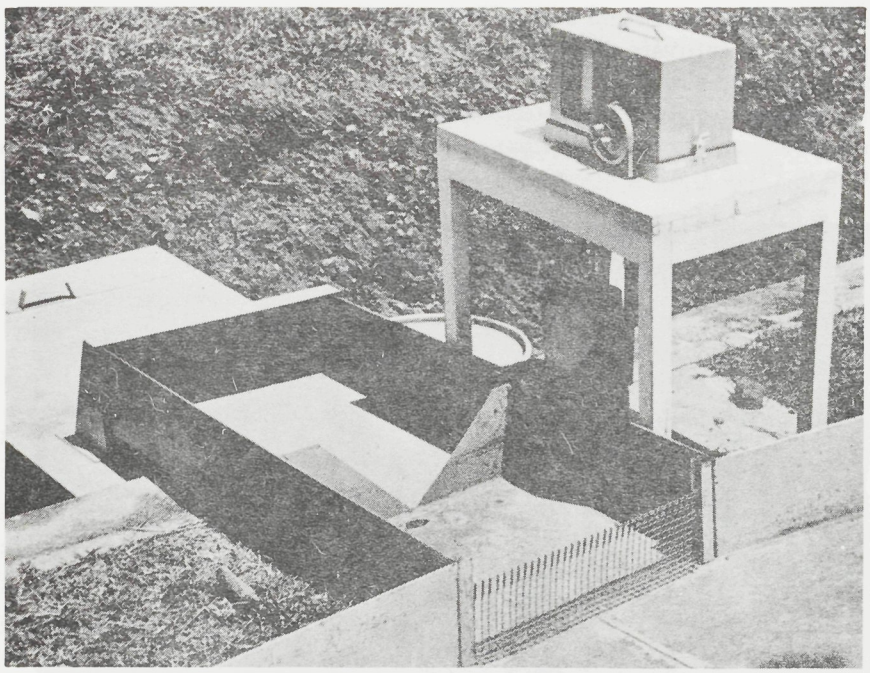
sheeting below the ground and a 15-cm-high earth embankment that made it possible to cultivate the soil with a small tractor. The plot edging was attached to the soil- and water-collection system at the lower side. The soil- and water-collection system was installed below the ground surface and was a modification of that described by Wiltshire (1947, 1948) and shown in Plate 1. a - g below:



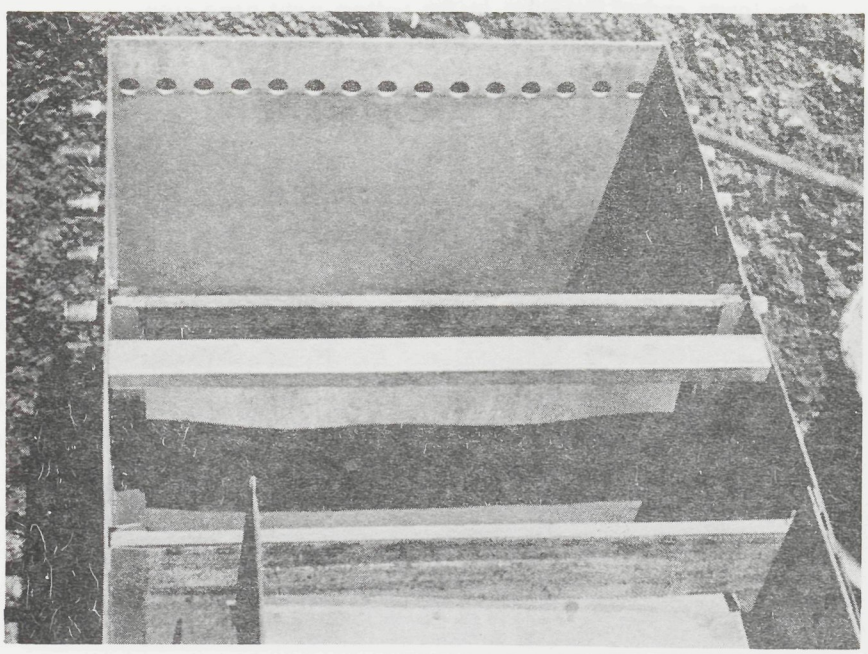
(a) Collection system with apron and sill installed toward the lower end of the plot. In the bottom right hand side in the upper portion of the Neutron Probe Access Tube.



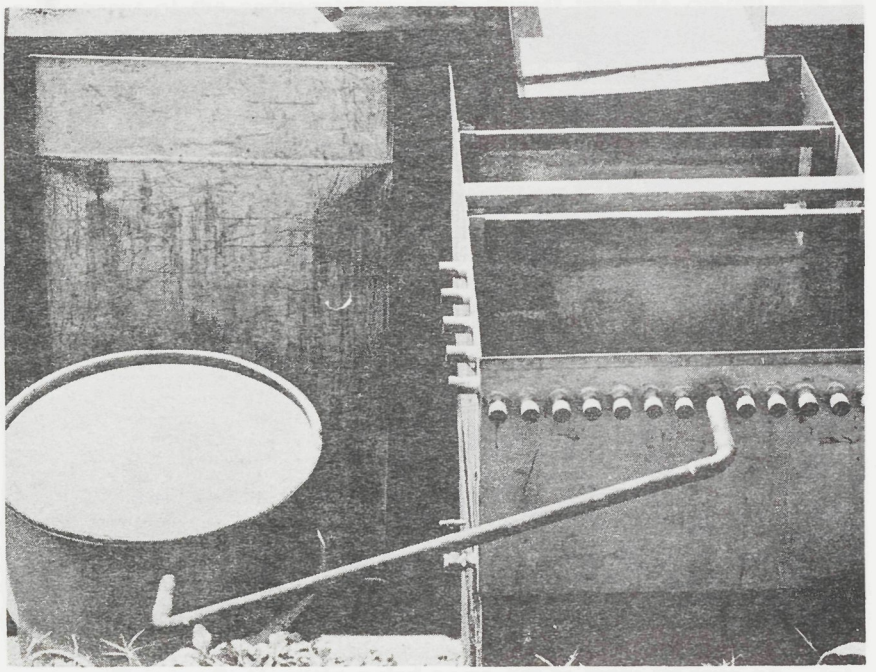
(b) Bare fallow plot with complex runoff collection system. In the center of the plot is a non-recording rain gauge.



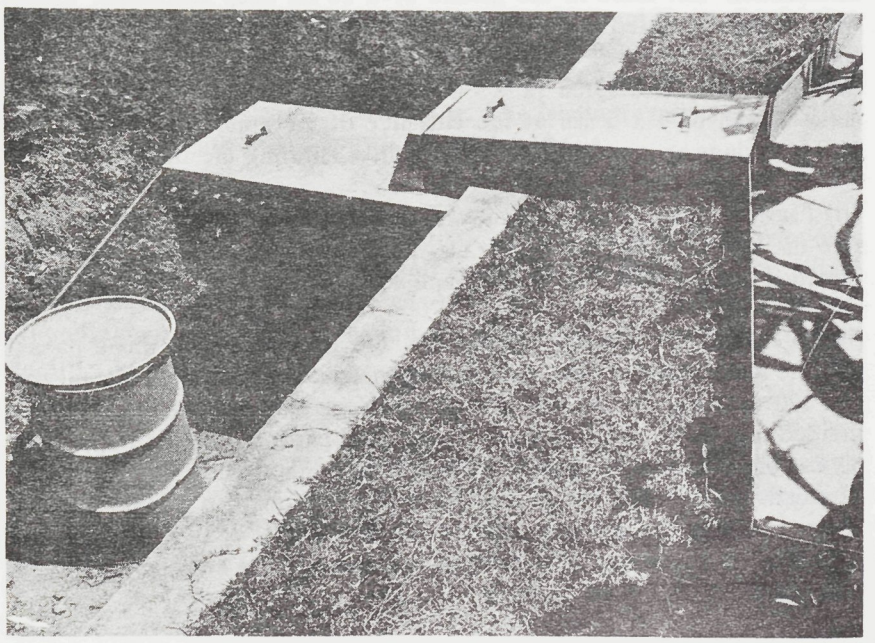
(c) Close up of the flume, a 90° V-notch, sill well and water level recorder.



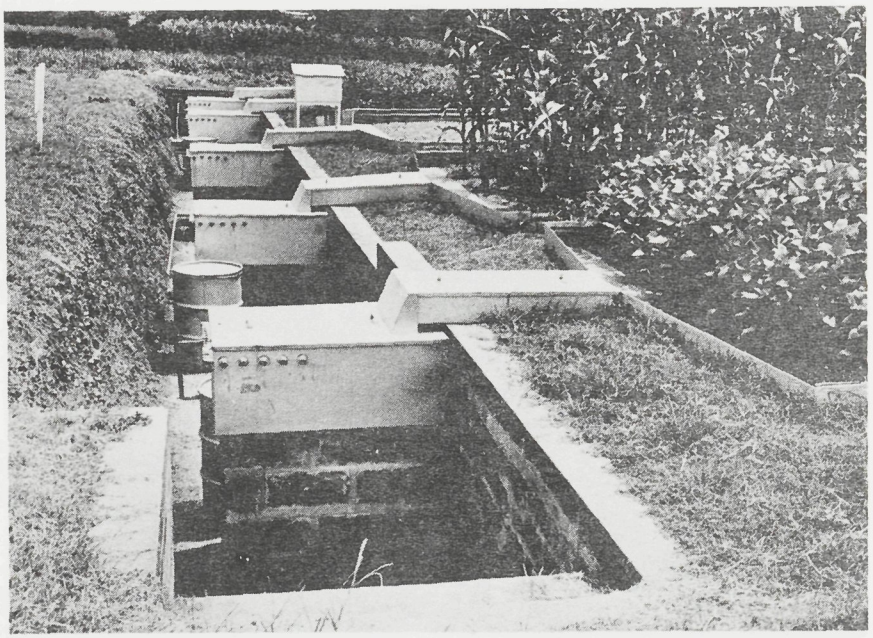
(d) Sedimentation and storage tank with two screens and a divisor system in the last compartment.



(e) Multi-divisor system and an over-flow tank.



(f) A complete over-view of the retaining wall, trench and collection system.



(g) An over-all view of the crops being grown in the runoff plots.

(i) Apron and Sill: Runoff and eroded soil pass over a 4 x 0.5-m level modification sill fixed in the ground by a 15-cm deep extension. Runoff water is concentrated in the center, from where it passes to an apron and flume. Some of the soil carried in the runoff water can be deposited over this level sill. The apron is 0.5 m wide, 1.0 m long and 15 cm high. A mesh screen of 5 x 5 mm at the entrance of the apron was installed to prevent stones or crop residue material from entering the flume.

(ii) Flume: A 90° V-notch flume was installed within the apron to measure the rate of flow. The height of water flowing through the V-notch is recorded using a still well system and an automatic water level recorder.

(iii) Sedimentation Tank: Runoff from the rate-measuring flume passes into the sedimentation tank. Sedimentation tank consists of a rectangular box 120 cm long, 70 cm wide and 50 cm deep. The sedimentation tank is divided into three equal portions. In the first portion is a silt trap, a tray 60 cm long, 30 cm wide and 30 cm deep. Also installed in the sedimentation tank are two screens of 5 and 8 mesh to an inch. After the water is filtered through the silt trap and the two screens, it passes into the last compartment consisting of a partitioning device. The sedimentation tank was installed on a level surface.

Runoff Partitioning Device: Twenty-five copper tubes 2.5 cm in diameter and 10 cm long were installed 40 cm above the bottom of the third

compartment of the sedimentation tank. Runoff from the central tube is collected into an overflow tank.

Overflow Tank: The overflow tank consists of an oil drum 58 cm in diameter and 90 cm deep. A drain pipe installed 5 cm above the tank bottom facilitates drainage of excess material.

Drainage System: Sedimentation and overflow tanks were installed in a trench dug across the lower end of the plots. The vertical surface toward the runoff plots is supported by a retaining wall. The trench base is cemented and has a 1% slope. The drainage is provided through an underground pipe.

Subsurface Water Collection System: The inter-flow water in the 15% slope plots can be collected at a depth of 1 m. Horizontal drain pipes were installed at the lower end of the plot at 100 and 150-cm depth. The collection of inter-flow water is facilitated by pipes 2.5 cm in diameter installed through the retaining wall.

Neutron Probe Access Tubes: Soil-moisture measurements in each plot are made with the help of the neutron moderation technique. Neutron probe access tubes were installed about 1 m from the upper and lower ends of the plots. In the experiments reported here soil-moisture contents were measured weekly at 30-cm intervals from the 30- to 120-cm depth. One field calibration was done for each of the four slope plots. Soil heterogeneity may introduce error in the calculations of absolute moisture content for various plots within each slope. The Neutron equipment used for these measurements was the Torxler Model 104–A.

Weather Station: A weather station was installed at the highest point within the same toposequence. A self-recording rain gauge (Belfort Model 5–780), an ordinary rain gauge, an American class A pan evaporimeter, a pyreliograph (Belfort), a hygrothermograph and an anemometer were installed in this station.

The plot sizes and the capacity and design of the soil- and water-collection system were based on preliminary experiments conducted on an adjacent location during 1970.

REFERENCES

1. Moormann, F. R., R. Lal, and A. S. R. Juo (1975) Soils of IITA. IITA Technical Bulletin No. 3, 1975.

2. Smyth, A. J., and R. F. Montgomery (1962). Soils and land use in Central Western Nigeria. Govt. Printer, Ibadan, Nigeria.

3. Wiltshire, G. R. (1947). Runoff plots and Standard Runoff and Soil loss measuring equipment used in the New South Wales Soil Conservation Service. J. Soil Conserv. Serv. N. S. W. 3 : 171–178.

4. Wiltshire, G. R. (1948). The measurements of runoff and Soil Loss from Plot experiments. J. Soil Conserv. Serv. N. S. W. 4 : 40–44.

3

Results of the Preliminary Experiments

Preliminary runoff experiments were conducted during 1970 on 25m x 3m plots on the four slopes mentioned in the previous section. The soil- and water- collection system was not installed. Runoff was collected in plastic-lined trenches at the lower end of the plots. The results, at best, are only approximate and of only relative importance.

The effects of different crops on runoff losses are shown in Table 3.1.

Soil losses under different treatments were not measured for all storms. Soil losses from different treatments relative to natural vegetation for two rainstorms are shown in Table 3.2.

About 60% of the eroded soil consisted of sand and gravels (Table 3.3).

Table 3.1. Effect of crop cover and mulching on run-off (cm), September–December, 1970. Total Rainfall = 29.5 cm.

Slope %	*Maize*	*Maize (Mulched)*	*Maize-Cowpea Alternate Strips*	*Bush Regrowth*
1	1.9	0.6	2.1	0.5
5	11.9	2.3	12.1	0.4
10	12.5	1.7	6.5	0.5
15	5.2	0.5	7.3	0.6

Table 3.2. Relative Soil Loss under Different Vegetation and Crop Cover (Relative to Natural Vegetation plot of 1% slope)

Slope %	*Maize*	*Maize (Mulched)*	*Maize-Cowpeas Alternate Strips*	*Bush Regrowth*
1	329	2	104	1.0
5	374	24	337	1.5
10	352	0.5	125	2.0
15	348	0.8	53	2.0

Average nutrient concentrations in the runoff water of two storms are shown in Table 3.4. The concentration of inorganic P was generally low; the concentrations of Ca and K, high. The average nutrient losses for all slopes and for all crops are given in Table 3.5.

Table 3.3 Particle size distribution of the composite samples of the eroded sediments.

Slope	*Gravel %*			*Sand*	*Silt*	*Clay*
%	*4 mm*	*2.38-4 mm*	*2-2.38 mm*	*%*	*%*	*%*
1	16	11	5	29	29	10
5	4	4	3	45	28	16
10	14	9	5	39	23	10
15	16	8	3	42	25	6

Table 3.4. Nutrient concentration in the run-off water (ppm) Average of two rain storms)

Slope	*Maize*				*Maize (mulch)*				*Maize-Cowpea*				*Bush regrowth*			
%	*P*	*Na*	*Ca*	*K*	*P*	*Na*	*Ca*	*K*	*P*	*Na*	*Ca*	*K*	*P*	*Na*	*Ca*	*K*
1	0.1	1.5	21.8	5.2	0.1	1.8	4.3	5.0	0.1	2.5	35.0	16.5	0.1	1.3	2.7	1.7
5	0.2	2.3	14.5	8.4	0.3	1.7	4.5	10.9	0.1	2.0	29.5	10.7	0.1	1.5	2.6	2.1
10	0.7	1.7	5.6	7.9	0.3	1.7	1,4	2.1	0.5	2.4	5.8	4.5	0.4	2,2	1.6	2.8
15	0.5	1.1	1.8	3.0	2.1	1.4	2.1	4.5	2.2	1.0	2.7	3.8	0.6	1.6	1.4	2.3

Table 3.5. Total nutrient loss in run-off water (kg/ha/season).

Crop	*PO_4-P*	*Ca*	*K*	*Na*
Maize	0.3	7.3	5.6	1.4
Maize (mulched)	0.2	0.4	0.8	0.2
Maize-Cowpea (Alternate strip)	0.5	12.4	5.5	1.3
Bush Regrowth	0.1	0.1	0.1	0.1

During one growing season 0.1 to 12 kg/ha of Ca and 0.1 to 6 kg/ha of K were lost. The maximum loss of inorganic P was 0.5 kg/ha.

The relative nutrient concentrations in eroded soil (Table 3.6) indicate that most of the nutrient loss in runoff water is associated with eroded sediments. The concentrations of P, Ca and K in the fine fraction

Table 3.6. Nutrient contents of the composite sample from eroded sediments (ppm)

Slope %	Coarse/ fine	Maize			Maize (mulch)			Maize-Cowpea			Bush Regrowth		
		P	Ca	K	P	Ca	K	P	Ca	K	P	Ca	K
1	C	4.4	390	25	4.0	450	60	4.6	563	53	1.4	410	53
	F	18.1	985	58	9.3	955	105	11.1	950	62	3.9	475	105
5	C	3.9	275	58	2.0	213	38	7.6	475	94	1.4	325	51
	F	18.1	788	98	2.3	775	101	28.1	1113	128	5.5	725	70
10	C	4.2	320	18	4.9	180	22	2.9	170	26	9.2	125	16
	F	28.1	995	102	13.5	775	132	9.2	745	90	8.2	790	90
15	C	33.4	248	58	4.6	204	35	9.8	234	51	4.7	138	21
	F	65.3	1515	154	10.9	1060	168	53.0	690	103	14.7	1135	82

C = Corse fraction
F = Fine fraction

(<2mm) were double those in the coarse fraction. The K content of the eroded soil from the mulched-maize plots was generally higher than that of the soil eroded from the unmulched-maize plots.

Conclusions: From these preliminary results, the following conclusions were drawn:

(i) The runoff plots should at least be 4m wide with a buffer zone of 1m between adjacent plots.

(ii) Runoff and erosion losses from mulched plots were significantly lower than those from unmulched plots and were equal to those from plots with bush regrowth.

(iii) Nutrient losses in runoff water were not high, though relative nutrient concentrations might present a potential pollution hazard.

(iv) Most of the nutrient losses occurred in eroded soil, particularly in the finer fraction of the eroded sediments.

Based on these conclusions, permanent runoff plots were designed and constructed during 1971. Plot design, construction and layout are shown in Chapter 3. It was also evident that straw mulching of the soil surface might be an erosion preventive practice and some techniques of managing residue to produce mulch *in-situ* may prove important cultural practices for farming systems in the tropics. The treatments designed for the permanent runoff plots were based on these preliminary findings.

4

Treatments

Experiments on the permanent runoff plots were conducted from 1972 to 1974. Soil- and crop-management treatments for the 1972 and 1973 experiments are shown in Table 4.1.

First-season crops were planted on 10 April; second season crops, on 10 August. Crops were planted in rows running up and down the slope. Maize was planted at 75 cm between and 25 cm within the rows and received 120 kg/ha of N (1/3 at planting and 2/3 four weeks after) and 60 kg/ha each of P and K. The mulched plots received 6 ton/ha of rice straw, applied on the surface after planting. No-tillage plots were treated with paraquat (1-1 dimethyl 1-4, 4-bypridinium ion) at the rate of 2.5 l/ha applied one week before planting. All other plots were disk-plowed and harrowed.

Because the soil had been disturbed during plot construction and there was no crop residue on the soil surface, the no-tillage plots were not effectively treated during the first season of 1972. The runoff and erosion results reported, therefore, have to be evaluated as results for disturbed, unmulched soil-surfaces.

Treatment allocations for 1972 and 1973 were randomized as shown in Table 4.2.

Table 4.1. Soil and crop management treatments for 1972-73.

Treatment No.	*First season*	*Second season*
1	Bare fallow	Bare fallow
2	Maize (mulch)	Maize (mulch)
3	Maize (conventional plowing)	Maize (conv. plowing)
4	Maize (no tillage)	Cowpeas (no tillage)
5	Cowpeas (conventional plowing)	Maize (conv. plowing)

Table 4.2. Treatment allocation to run-off plots for 1972-73.

Run-off plots no,	*Treatment No*	*Treatment description*
1	2	maize-maize (mulch)
2	3	maize-maize (conventional plowing)
3	1	bare fallow (conventional plowing)
4	4	maize-cowpeas (no tillage, herbicide weed control)
5	5	cowpeas-maize (conventional plowing)
6	4	maize-cowpeas (no tillage, herbicide weed control)
7	2	maize-maize (mulch)
8	3	maize-maize (conventional plowing)
9	4	cowpeas-maize (conventional plowing)
10	1	bare fallow (conventional plowing)
11	1	bare fallow (conventional plowing)
12	2	maize-maize (mulch)
13	4	maize-cowpeas (no tillage, herbicide weed control)
14	5	cowpeas-maize (conventional plowing)
15	3	maize-maize (conventional plowing)
16	6	maize-cowpeas (conventional plowing)
17	6	maize-cowpeas (conventional plowing)
18	6	maize-cowpeas (conventional plowing)
19	6	maize-cowpeas (conventional plowing)
20	4	maize-cowpeas (no tillage, herbicide weed control)
21	2	maize-maize (mulch)
22	4	cowpeas-maize (conventional plowing)
23	3	maise-maise (conventional plowing)
24	1	bare fallow (conventional plowing)

No crops were grown during 1974 and the plots received different rates of surface mulching. Runoff and soil losses from plots with mulch rates of 0, 2, 4 and 6 tons/ha were compared with those from the no-tillage plots. All 120 kg/ha of N and 60 kg/ha of each of P & K. These experiments were carried out for two consecutive seasons. Treatment allocations for 1974 are shown in Table 4.3.

Table 4.3. Treatment allocation for 1974.

Run-off plot No.	*Mulch treatment (tons/ha)*
1	6
2	2
3	0
4	No-tillage
5	4
6	No-tillage
7	6
8	2
9	4
10	0
11	0
12	6
13	No-tillage
14	4
15	2
16	0
17	0
18	0
19	0
20	No-tillage
21	6
22	4
23	2
24	0

Soil and runoff water from each of the plots were collected after every storm. Eroded sediments from each plot were dried and processed separately for physical and chemical analyses. A representative sample of the runoff water from each storm was collected to determine sediment density and nutrient concentration.

5

Rainfall Characteristics

In addition to rainfall amount, rainfall intensity, distribution of storm intensity, kinetic energy, momentum and drop size are important parameters affecting soil erosion.

Intensity: The frequency distribution of rainfall intensity for 1972 to 1974 is shown in Figure 5.1. The 7.5-minute maximum intensities of 61% of the rainstorms in 1972 and 57% of those during 1973 were between 25 and 75 mm hr^{-1} Seventy-six percent of the storms during 1972 and 66% of those during 1973 had maximum intensities greater than 25 mm hr^{-1}. Intensities exceeding 75 mm hr^{-1} were recorded for 15% of the rainstorms during 1972 and 10% of those during 1973. Intensities greater than 100 mm hr^{-1} were recorded for 7% of the storms during 1972 and 3% of those during 1973.

The 7.5-minute maximum intensities of 48.3% of the rainstorms during 1974 were greater than 50 mm hr^{-1} Twenty-one percent of the storms had maximum intensities greater than 75mm hr^{-1} About 14% of the rainstorms had intensities greater than 100mm hr^{-1}; half of those with intensities of 130 mm hr^{-1}

Rainstorm intensity rarely exceeds 75mm hr^{-1} in temperate climates. Tropical rainstorms, however, are more intense. As the data in Figure 5.1 indicate, 15, 10 and 30% of storms during 1972, 1973 and 1974 respectively, had intensities greater than 75mm hr^{-1}. Storms with rainfall intensities greater than 130 mm hr^{-1} were also observed.

Intensity Distribution: Some storms have their highest intensities in the beginning and lowest intensities during later stages. For example, an intensity of 213 mm hr^{-1} was recorded during the first five minutes of a storm on 26 April 1973. Most storms fit this pattern (Fig. 5.2).

Other storms begin with medium intensity and reach their peaks in the middle (Fig. 5.3). There are also composite storms with peak intensities within two to three hours of one another (Fig. 5.4). Each intensity distribution presents a different soil-erosion hazard. Interpreting the erosion data from composite storms is more difficult.

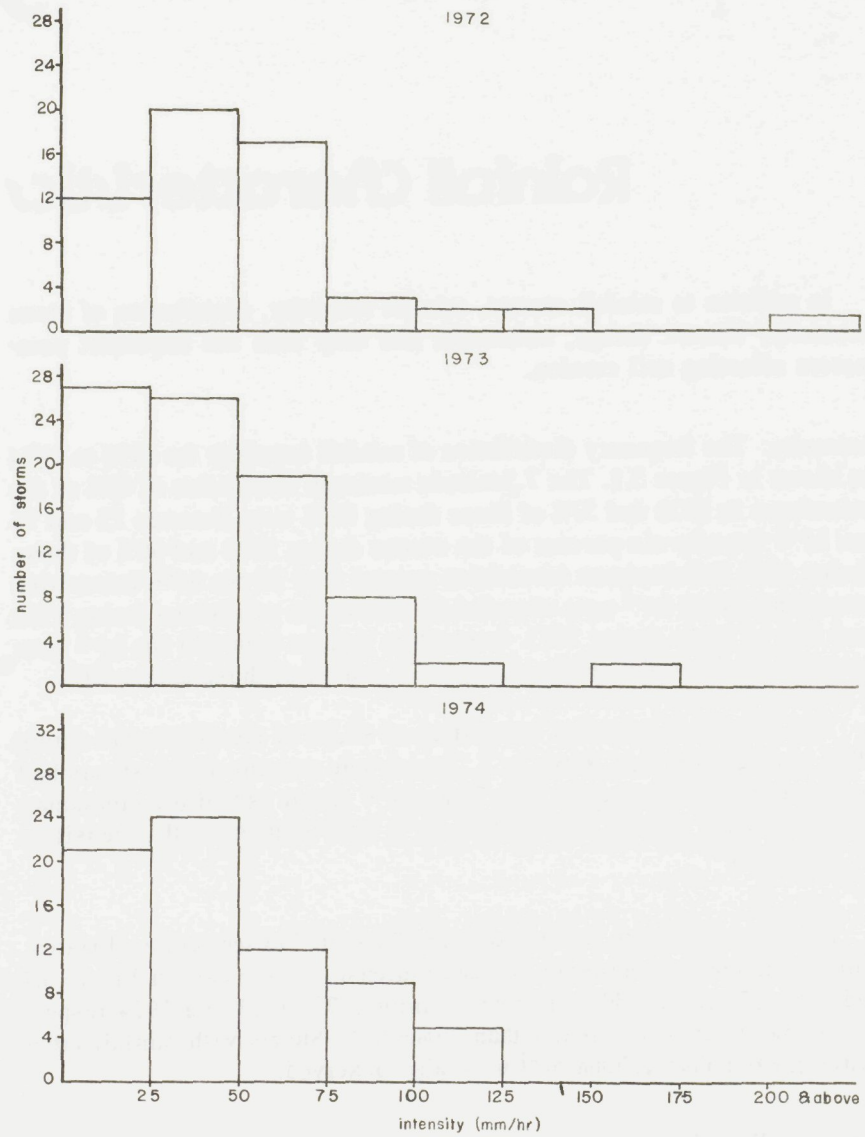


Fig. 5.1 Rainfall intensity distribution of storms from 1972 to 1974.

Rainfall Erosivity: Erosivity is the potential ability of rain to cause erosion. Energy to dislodge and detach soil particles in the erosion process is provided by the kinetic energy of the rain. Wischmeier (1955) and Wischmeier et al (1958) found that the EI_{30} index was most significantly correlated with the erosion. This index is a product of the kinetic energy of the storm and the 30-minute maximum intensity. The 30-minute intensity is the greatest average intensity recorded during any 30-minute period.

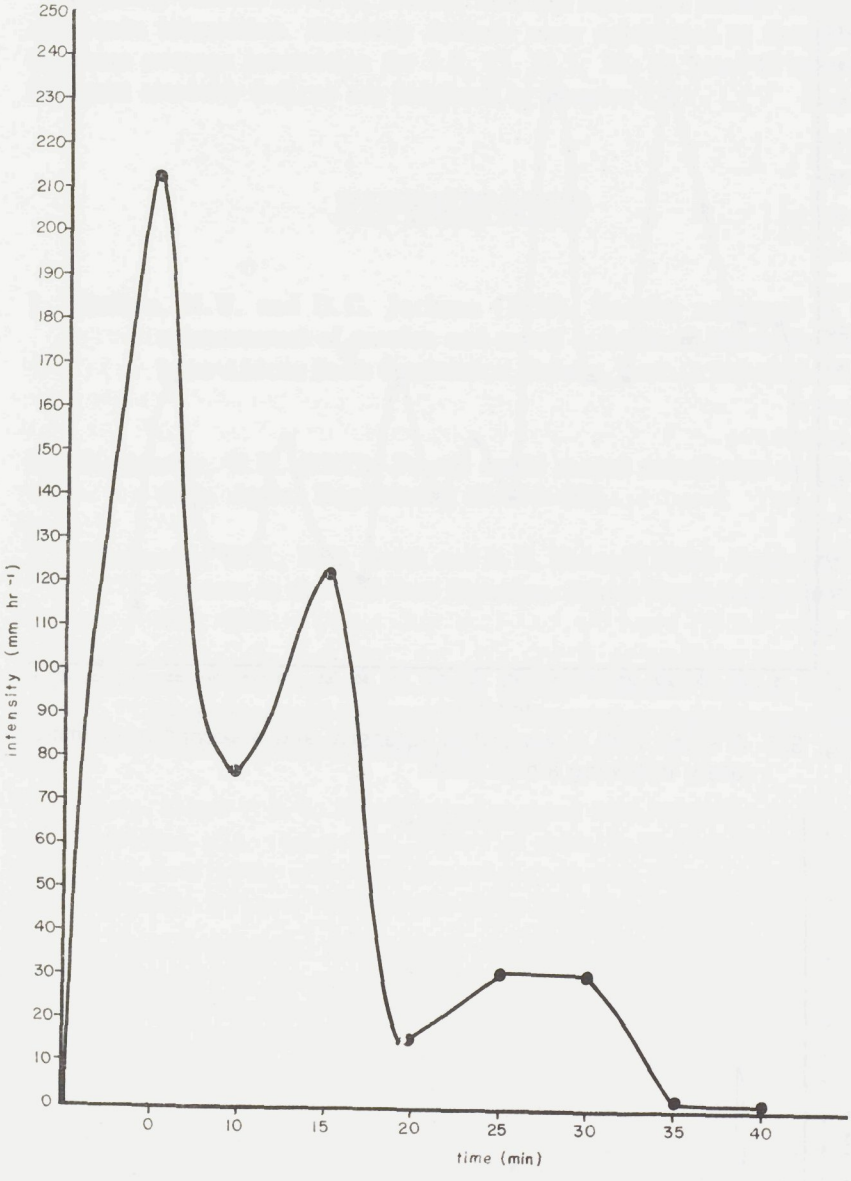


Fig. 5.2 Rainfall intensity distribution during a storm with the peak intensity occurring in its beginning.

Hudson and Jackson (1959) found from their studies in Rhodesia that although the EI_{30} index provided an accurate measure of erosivity of rainstorms in temperate America it was less effective in tropical Africa. He developed an alternate procedure based on the concept that there is a threshold intensity value at which rainfall becomes erosive (25mm per hour). This index is called KE >1.

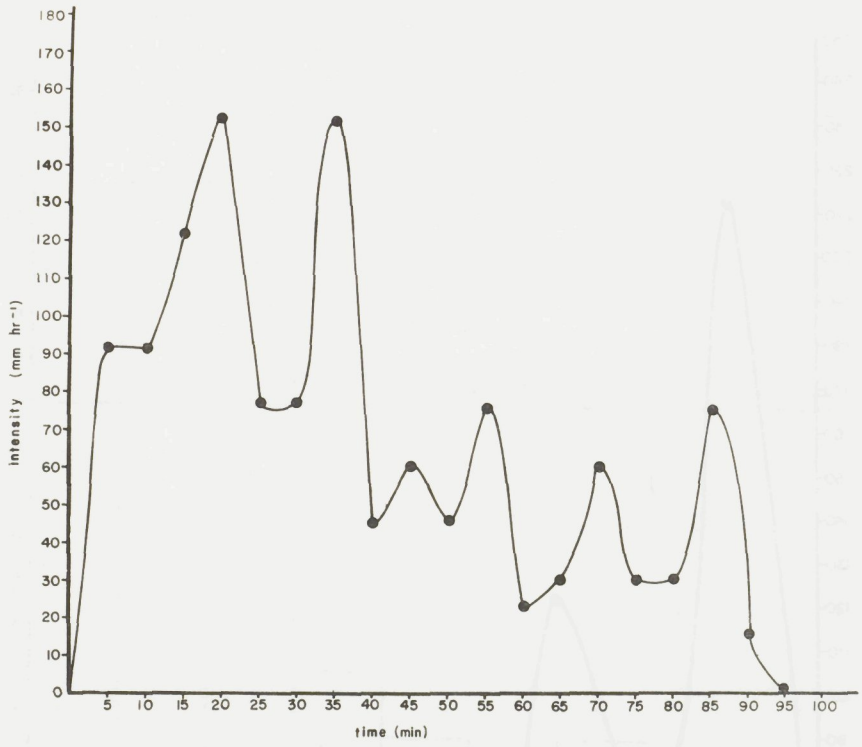


Fig. 5.3 A storm with a low initial intensity and a second peak immediately following a high peak.

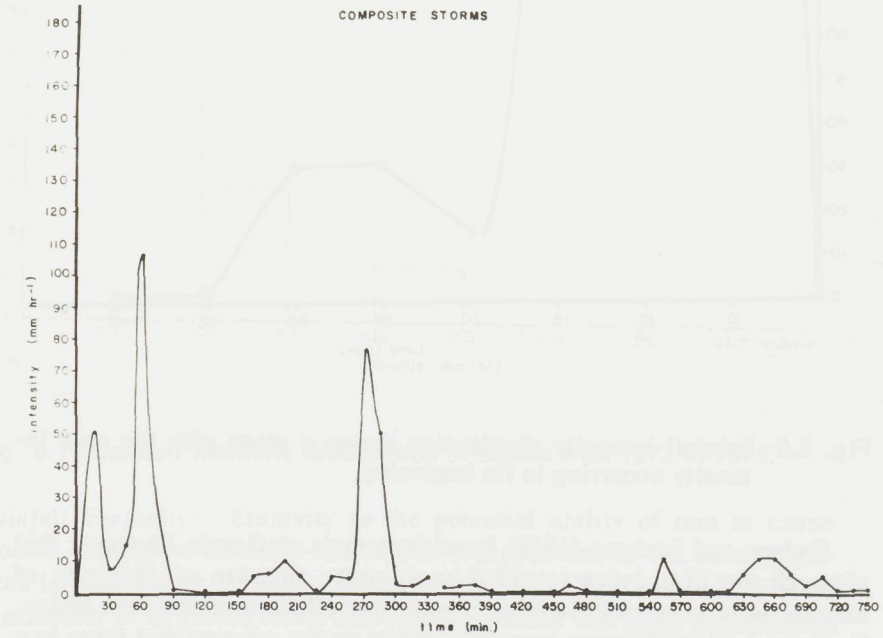


Fig. 5.4 A composite storm with two separate intensity peaks spaced widely apart.

Intensity records at IITA, Ibadan, indicate that most storms have high short-term intensities. Erosivity indices were calculated to incorporate maximum average intensities for 7.5, 15, 22.5, 30, 37.5 and 45 minutes. Different erosivity indices are compared in Chapter 7.

REFERENCES

1. Hudson, N.W. and D.C. Jackson (1959). Results achieved in the measurement of erosion and runoff in Southern Rhodesia. Third Inter-African Soils Conference, Dalaba. Proc. 2:575–584.

2. Wischmeier, W.H. (1955). Punch cards record runoff and soil loss data. Agric. Engineering 36:664–666.

3. Wischmeier, W.H., D.D. Smith and R.E. Uhland (1958). Evaluation of Factors in the Soil-loss Equation. Agric. Engineering 30:458–462, 474.

4. Wischmeier, W.H. and D.D. Smith (1965). Rainfall Erosion Losses from Cropland East of Rocky Mountains. Agricultural Handbook 282, USDA, Washington, D.C.

6

Soil and Water losses for different slopes and soil management practices

Exponential relationships between slope and erosion losses have been reported by various workers (Zingg, 1940; Wischmeier et al, 1958). Hudson and Jackson (1959) reported from their work in Rhodesia that for tropical soils the slope coefficient approaches a value of 2. Wischmeier (1966) reported the relation between slope and runoff loss to be logarithmic. Other studies have shown no relation between slope and runoff (Borst and Woodburn, 1942).

Use of crop residue as a mulch to reduce runoff and erosion losses has extensively been reported (Mannering and Meyer, 1961 and 1963). No-tillage or minimum tillage has also been used effectively to minimize runoff and erosion losses (Mannering and Burwell, 1962; Moldenhauer et al, 1967; Harrold, 1972). Some studies in West Africa have indicated greater runoff and erosion losses under minimum tillage (Charreau, 1966).

Minimum tillage results should be interpreted with reference to initial soil conditions, e.g. compaction, degree of erosion, and amount of crop residue because initial soil conditions under minimum tillage can significantly influence soil and water conservation and crop performance.

(i) Slope-Runoff Relation: The effects of slope and soil management on runoff losses for four seasons are shown in Tables 6.1, 6.2, 6.3 and 6.4. There are no significant differences in the runoff losses from bare fallow plots on slopes ranging from 1 to 15%. This may mean that runoff losses from bare soil are primarily governed by soil physical properties, e.g. infiltration rate and surface-sealing characteristics. Runoff losses under different crop rotations were of the order of maize-maize (mulch) < maize-cowpeas (no-tillage) < cowpeas-maize < maize-maize < bare fallow. This sequence does not apply to no-tillage treatments during the first season of 1972 because of the lack of crop residue as a surface mulch.

Mathematical relationships between runoff and slope based on the analysis of individual storms are shown in Tables 6.5, 6.6, 6.7 and 6.8. These results are the combined analyses of first- and second-season storms. Storms with less than 25 mm of rainfall (lowfall) and those with more than 25 mm of rainfall (high rainfall) were analyzed separately. The correlation coefficients between runoff and slope are generally low, except for mulched treatments.

Table 6.1. Effect of slope and soil management on run-off loss (mm).First season 1972 Total Rainfall–

Slope %	*Soil and crop management treatments*					*Mean*
	Bare fallow	*Maize-maize (mulch)*	*Maize-maize*	*Maize-cowpeas (no-tillage)*	*Cowpeas-maize*	
1	225.6	0.4	69.1	22.4	12.7	66.0
5	261.6	14.9	170.0	118.2	89.5	130.8
10	259.1	15.8	91.9	123.4	30.7	104.2
15	214.1	13.5	83.2	118.3	32.7	92.4
Mean	240.1	11.2	103.6	95.6	41.4	

Table 6.2. Effect of slope and soil management on run-off loss (mm). Second season 1972 Rainfall –

Slope %	*Soil and crop management treatments*					*Mean*
	Bare fallow	*Maize-maize (mulch)*	*Maize-maize*	*Maize-cowpeas (no-tillage)*	*Cowpeas-maize*	
1	22.7	0,0	4.5	2.2	5.1	6.9
5	39.0	1.9	15.2	4.0	27.7	17.6
10	27.6	4.2	9.6	5.2	6.9	10.7
15	25.5	3.2	9.4	5.3	17.6	12.2
Mean	28.7	2.3	9.7	4.2	14.3	

Table 6.3. Effect of slope and soil management on run-off loss (mm). First season 1973 Rainfall –

Slope %	*Soil and crop management treatments*					*Mean*
	Bare fallow	*Maize-maize (mulch)*	*Maize-maize*	*Maize-cowpeas (no-tillage)*	*Cowpeas-maize*	
1	315.7	0.0	55.1	11.4	19.8	80.4
5	347.3	6.9	158,7	11.8	81.2	121.2
10	311.0	20.3	52.4	20.3	51.4	91.1
15	316.5	16.8	89.9	21.0	46.1	116.3
Mean	322.6	11.0	89.0	16.1	49.6	

Table 6.4. Effect of slope and soil management on run-off loss (mm). Second season 1973 Rainfall –

Slope %	*Soil and crop management treatments*					*Mean*
	Bare fallow	*Maize-maize (mulch)*	*Maize-maize*	*Maize-cowpeas (no-tillage)*	*Cowpeas-maize*	
1	191.7	0.0	9.1	6.0	22.2	45.8
5	195.8	4.0	65.0	6.5	64.5	67.2
10	193.1	9.0	36.0	10.2	30.5	55.8
15	185.4	7.5	71.4	10.7	105.4	76.1
Mean	191.5	5.1	45.4	8.4	55.7	

Table 6.5. Run-off slope relation 1972. (a) High Rainfall

Treatment	R^2	*Equation*	*Average Runoff %*
Bare fallow	ns	ns	42.9
Mulch	0.11	$Y = -0.46 + 0.33\ S$	2.1
Maize-maize	0.19	$Y = -8.77 + 16.93\ S - 2.33\ S^2 + 0.09\ S^3$	16.7
Cowpea-maize	0.26	$Y = -6.32 + 11.83\ S - 1.79\ S^2 + 0.07\ S^3$	7.9
No-tillage	ns	ns	14.2

(b) Low Rainfall

Treatment	R^2	*Equation*	*Average Runoff %*
Bare fallow	ns	ns	14.8
Mulch	0.40	$Y = -0.79 + 0.58\ S - 0.03\ S^2$	1.5
Maize-maize	0.29	$Y = -2.97 + 5:88\ S - 0.83\ S^2 + 0.03\ S^3$	5.1
Cowpea-maize	0.24	$Y = -1.39 + 3.54\ S - 0.52\ S^2 + 0.02\ S^3$	3.8
No-tillage	0.19	$Y = -1.35 + 3.30\ S - 0.40\ S^2 + 0.01\ S^2$	5.1

Table 6.6. Run-off slope relations 1973. (a) High Rainfall

Treatment	R^2	*Equation*	*Average Runoff %*
Bare fallow	ns	ns	50.7
Mulch	0.69	$Y = 0.12 - 0.23\ S + 0.10\ S^2 - 0.005\ S^3$	1.3
Maize-maize	0.29	$Y = -10.77 + 15.57\ S - 2.27\ S^2 + 0.09\ S^3$	13.6
Cowpea-maize	0.15	$Y = -2.43 + 8.46\ S - 1.33\ S^2 + 0.06\ S^3$	10.7
No-tillage	0.40	$Y = 1.76 - 0.40\ S + 0.09\ S^2 - 0.004\ S^3$	2.0

(b) Low Rainfall

Treatment	R^2	*Equation*	*Average Runoff %*
Bare fallow	ns	ns	29.9
Mulch	0.45	$Y = -0.95 + 0.56\ S - 0.024\ S^2$	1.3
Maize-maize	0.17	$Y = -7.64 + 11.86\ S - 1.77\ S^2 + 0.07\ S^3$	8.6
Cowpeas-maize	0.10	$Y = -3.15 + 6.89\ S - 1.04\ S^2 + 0.04\ S^3$	6.3
No-tillage	0.13	$Y = 1.48 + 0.10\ S$	2.3

Combined analysis as shown in Tables 6.7 and 6.8 may be misleading because the crops grown during the first and second seasons were different for different tillage treatments. During the first season, maize was grown on the no-tillage plots and cowpeas grown on the plowed plots.

Table 6.7. Runoff - slope relations 1972. (a) High Rainfall

Treatment	*r*	*Equation*
Bare fallow	-0.01	$Y = 32.4\ S^{-0.01}$
Mulch	0.79	$Y = 0.0016\ S^{2.99}$
Maize-maize	0.09	$Y = 7.87\ S^{0.12}$
Cowpea-maize	0.42	$Y = 1.95\ S^{0.46}$
No-tillage	0.47	$Y = 0.39\ S^{0.58}$
	(b) Low Rainfall	
Treatment		*Equation*
Bare fallow	-0.01	$Y = 8.75\ S^{-0.01}$
Mulch	0.78	$Y = 0.008\ S^{2.38}$
Maize-maize	0.14	$Y = 3.2\ S^{0.13}$
Cowpea-maize	0.60	$Y = 1.18\ S^{0.51}$
No-tillage	0.55	$Y = 1.40\ S^{0.56}$

Table 6.8. Runoff - sloppe relations 1973. (a) High Rainfall

Treatment	*r*	*Equation*
Bare fallow	-0.03	$Y = 46.40\ S^{-0.02}$
Mulch	0.92	$Y = 0.0008\ S^{3.35}$
Maize-maize	0.39	$Y = 4.86\ S^{0.38}$
Cowpea-maize	0.50	$Y = 1.62\ S^{0.66}$
No-tillage	0.53	$Y = 1.23\ S^{0.24}$
	(a) Low Rainfall	
Treatment	*r*	*Equation*
Bare fallow	0.08	$Y = 23.10\ S^{-0.14}$
Mulch	0.84	$Y = 0.005\ S^{0.26}$
Maize-maize	0.15	$Y = 2.66\ S^{0.26}$
Cowpea-maize	0.35	$Y = 1.19\ S^{0.53}$
No-tillage	0.18	$Y = 1.15\ S^{0.20}$

During the second season the crops and treatments were reversed. The exponential function analysis was therefore run separately for each of the four seasons (Table 6.9).

Cumulative runoff factors for different crop rotations, averaged over the four growing seasons, are shown in Table 6.10. Those factors are computed as ratio of runoff or soil loss from a given treatment to that from bare fallow plots at a given stage of crop growth. Mulch and no-tillage are most effective in preventing runoff. The coefficients for different stages of crop growth are shown in Table 6.11. The four stages described in this table are as follows: Stage 1 – Plowing, seeding and three weeks after; Stage 2 – Crop establishment, from 3 to 6 weeks; Stage 3 – Establishment to maturity, 6 weeks to harvest; Stage 4 – Harvest until next plowing.

Table 6.9. Slope run-off relations for each season for maize-cowpea (no-tillage) and cowpea-maize (plowed) treatments

Treatment	*Year*	*Season*	*Rainfall*	*R*	*Equation*
Cowpea-maize (plowed)	1972	I	High	0.46	$Y = 2.11\ S^{0.41}$
		I	Low	0.57	$Y = 1.87\ S^{0.17}$
		II	High	0.40	$Y = 1.62\ S^{0.58}$
		II	Low	0.81	$Y = 1.18\ S^{0.52}$
	1973	I	High	0.46	$Y = 1.23\ S^{0.53}$
		I	Low	0.43	$Y = 1.27\ S^{0.54}$
		II	High	0.56	$Y = 1.92\ S^{0.74}$
		II	Low	0.27	$Y = 0.75\ S^{0.51}$
Maize-maize (no-tillage)	1972	I	High	0.66	$Y = 1.15\ S^{0.68}$
		I	Low	0.56	$Y = 1.50\ S^{0.62}$
		II	High	0.78	$Y = 0.90\ S^{0.36}$
		II	Low	0.75	$Y = 1.50\ S^{0.33}$
	1973	I	High	0.48	$Y = 1.21\ S^{0.21}$
		I	Low	0.26	$Y = 0.74\ S^{0.21}$
		II	High	0.56	$Y = 1.24\ S^{0.25}$
		II	Low	0.13	$Y = 0.08\ S^{0.21}$

(ii) Slope-Soil Loss Relations: Slope-soil loss relationships for different soil management and crop rotations are shown in Tables 6.12 to 6.15. The potential erodibility of a given slope and soil and crop management treatment is indicated by the erosion loss under bare fallow. The data for the four seasons investigated indicate three important factors that affect erosion losses: (i) slope, (ii) season and (iii) soil management. Erosion losses increased with increase in slope. By the second season of 1973, the bare-fallow plots on the 10 and 15% slopes had been eroded excessively and a decrease in erosion was recorded because gravel exposed on the soil surface acted as a mulch (Figs. 6.1 and 6.2).

Rainstorms during the first growing season at Ibadan are more erosive than those during second season. As a result, the erosion losses are lower during the second season. Mulching and no-tillage soil management practices were most effective in preventing soil erosion, regardless of slope. The erosion losses were in the order of maize-maize (mulch) < maize-cowpeas (no-tillage) < cowpeas-maize < maize-maize < bare fallow. No-tillage treatment during first season 1972 was not effective because of the lack of crop residue on the soil surface.

Table 6.10. Crop and soil management factor

Rotation	*First season*	*Second season*
Bare fallow	1.00	1.00
Maize-maize (mulch)	0.04	0.05
Maize-maize	0.35	0.29
Maize-cowpea (no-tillage)	0.05 *	0.10
Cowpea-maize	0.16	0.40

* Exluding the first season 1972 date in which case was no crop residue and the soil was disturbed.

Table 6.11. Crop and soil management factor for different stages of growth (based on 1973 records)

Rotation	*1*	*2*	*3*	*4*
Bare fallow	1.00	1.00	1.00	1.00
Maize-maize (mulch)	0.048	0.025	0.019	0.039
Maize-maize	0.70	0.27	0.29	0.114
Maize-maize (no-tillage)	0.075	0.037	0.035	0.051
Cowpea-maize	0.74	0.117	0.036	0.068

Table 6.12. Effect of slope and soil management on soil loss (tons/ha). First season 1972 Total Rainfall –

Slope %	Soil and crop management treatments: Bare fallow	Maize-maize (mulch)	Maize-maize	Maize-Cowpeas (no-tillage)	Cowpeas-maize	Mean
1	4.0	0.0	1.0	0.4	0.2	1.1
5	32.1	0.1	2.7	1.5	1.2	7.5
10	45.5	0.1	5.8	5.1	2.1	11.7
15	101.0	0.1	13.4	7.8	1.8	24.8
Mean	45.7	0.1	5.7	3.7	1.3	

Table 6.13. Effect of slope and soil management on soil loss (tons/ha) Second season 1972. Total Rainfall –

Slope %	Slope and Crop Management Treatments: Bare fallow	Maize-maize (mulch)	Maize-maize	Maize-cowpeas (no-tillage)	Cowpeas-maize	Mean
1	1.0	0.0	0.1	0.0	0.3	0.3
5	11.1	0.0	0.4	0.0	1.1	2.5
10	13.4	0.0	0.6	0.0	0.9	3.0
15	15.1	0.1	1.3	1.0	4.4	4.4
Mean	10.2	0.0	0.6	0.2	1.7	

Table 6.14. Effect of slope and soil management on soil loss (tons/ha). First season 1973 Total Rainfall –

Slope %	Soil and crop management treatments: Bare fallow	Maize-maize (mulch)	Maize-maize	Maize-Cowpeas (no-tillage)	Cowpeas-maize	Mean
1	7.5	0.0	1.2	0.0	0.6	1.9
5	80.4	0.0	8.2	0.2	5.6	18.9
10	152.9	0.1	4.4	0.1	3.3	32.2
15	155.3	0.0	23.6	0.1	7.6	37.3
Mean	99.0	0.0	9.4	0.1	4.3	

Table 6.15. Effect of slope and soil management on soil loss (tons/ha) Second season 1973. Total Rainfall –

Slope %	Soil and Crop Management Treatments: Bare fallow	Maize-maize (mulch)	Maize-maize	Maize-cowpeas (no-tillage)	Cowpeas-maize	Mean
1	3.7	0.0	0.4	0.0	0.3	0.9
5	75.8	0.0	2.8	0.0	4.0	16.5
10	79.7	0.1	2.8	0.1	3.0	17.1
15	73.9	0.0	17.1	0.0	35.4	25.3
Mean	58.3	0.0	5.8	0.0	10.7	

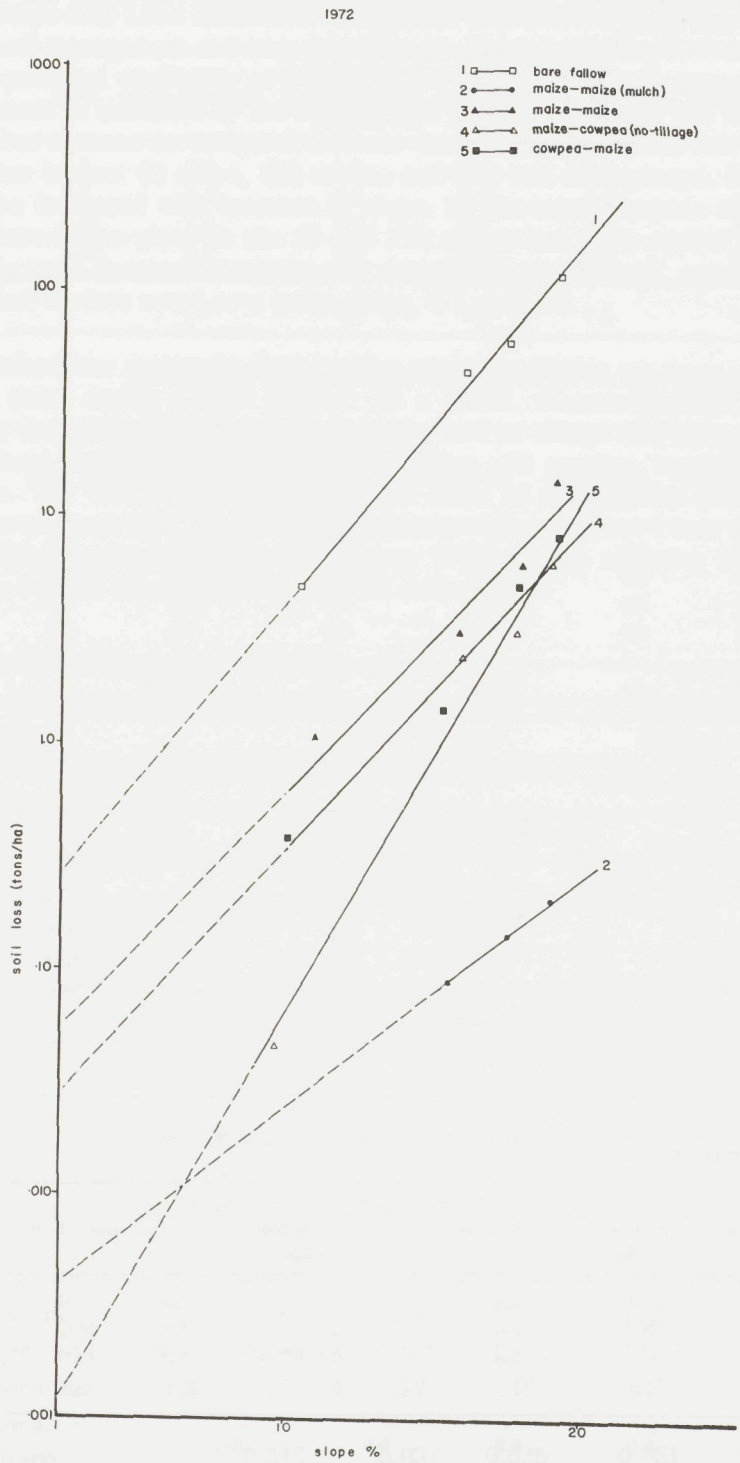


Fig. 6.1 Influence of soil management crop rotations and slope on soil erosion in 1972. Note that Y-axis is a log scale.

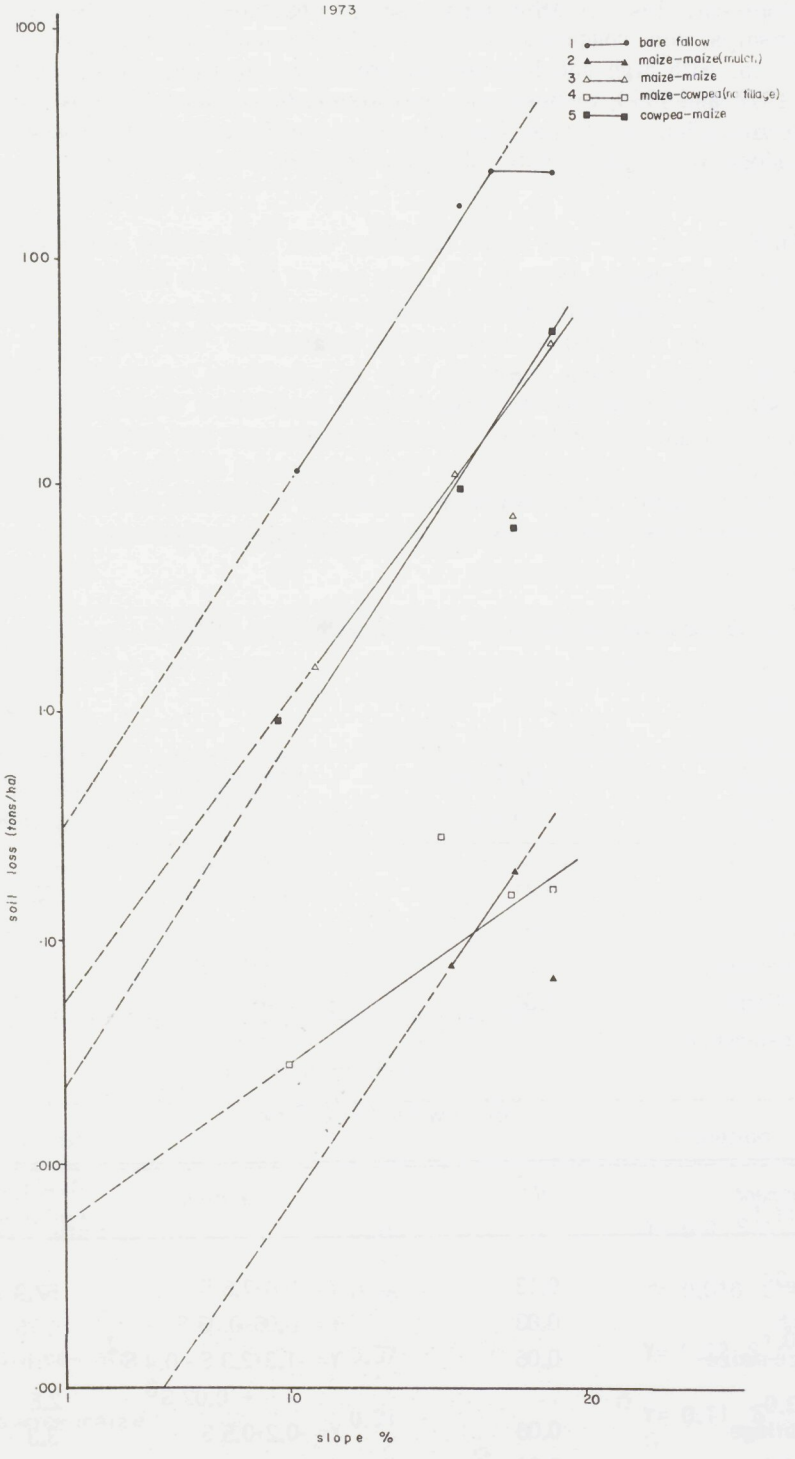


Fig. 6.2 Influence of soil management crop rotations and slope on soil erosion in 1973. Note that Y-axis is a log scale.

Slope-soil loss relationships, similar to those of runoff-slope relationships, were computed. Multiple regression analyses of soil loss with slope for both high and low rainfall are shown in Tables 6.16 and 6.17 for 1972 and 1973, respectively. Soil loss in the relation is expressed in units of kg/ha/mm of rain. The correlation coefficients between soil loss and slope were high for bare fallow and maize-maize treatments only.

Analyses of soil loss slope relations with exponential functions are indicated in Tables 6.18 and 6.19. This type of analysis fits the data from the bare-fallow and maize-maize treatments better than the data from other crop rotations and residue management treatments. The correlation coefficients were always generally high in rainstorms exceeding 25 mm. The slope exponents for the high rainfall bare-fallow treatments ranged between 1.1 and 1.2. Mulch and no-tillage treatments had the lowest slope exponents as well as coefficients. The exponential function of slope-soil loss did not apply to the mulch and no-tillage treatments and the correlation coefficients were the lowest for these management practices.

Table 6.16. Multiple regression of soil loss with slope, 1972.

(a) High Rainfall (25 mm)

Treatment	R^2	*Equation*	*Average Y kg/ha/mm*
Bare	0.41	Y= -2.1+11.2 S	82.3
Mulch	ns	ns	0.04
Maize-maize	0.29	Y= -3.8+1.7 S	9.7
No-tillage	0.34	Y= -2.4+1.1 S	5.8
Cowpea-maize	ns	ns	5.7

(b) Low Rainfall (25 mm)

Treatment	R^2	*Equation*	*Average Y kg/ha/mm*
Bare	0.13	Y= -0.6+7.6 S	57.0
Mulch	0.03	Y= -0.06+0.03 S	0.16
Maize-maize	0.05	Y= -1.3+2.3 S - 0.4 S^2 + 0.02 S^3	2.5
No-tillage	0.06	Y= -0.2+0.5 S	3.3
Cowpea–maize	0.04	Y= -0.09+0.3 S	2.3

Table 6.17. Soil Loss - Slope Relationships, 1973

(a) High Rainfall

Treatment	R^2	*Equation*	*Average Y kg/ha/mm*
Bare fallow	0.42	$Y= -33.5+40.2\ S - 1.65\ S^2$	136.9
Mulch	ns	ns	0.47
Maize-maize	0.42	$Y= -12.0+12.9\ S - 2.2\ S^2+ 0.1\ S^3$	15.1
No-tillage	ns	ns	0.12
Cowpea-maize	0.24	$Y= -6.6 - 4.6\ S + 0.5\ S$	16.7

(b) Low Rainfall

Treatment	R^2	*Equation*	*Average Y kg/ha/mm*
Bare fallow	0.31	$Y= -37.9+49.8\ S - 2.6\ S$	127.8
Mulch	ns	ns	0.24
Maize-maize	0.15	$Y= -5.1 - 2.1\ S + 0.2\ S$	9.2
No-tillage	0.05	$Y= -0.009+0.09\ S - 0.006\ S$	0.17
Cowpea-maize	0.04	$Y= -1.2+0.9\ S$	7.8

Table 6.18. Soil Loss - Slope Relationships, 1972

(a) High Rainfall

Treatment	*r*	*Equation*
Bare fallow	0.75	$Y= 6.0\ S^{1.11}$
Mulch	0.28	$Y= 0.016\ S^{0.50}$
Cowpea-maize	0.37	$Y= 0.32\ S^{1.02}$
Cowpea-maize	0.21	$Y= 0.11\ S^{0.52}$
No-tillage	0.46	$Y= 0.12\ S^{1.14}$

(b) Low Rainfall

Treatment	*r*	*Equation*
Bare fallow	0.30	$Y= 1.6\ S^{0.82}$
Mulch	0.14	$Y= 0.08\ S^{0.15}$
Maize-maize	0.76	$Y= 0.48\ S^{0.20}$
Cowpea-maize	0.20	$Y= 0.18\ S^{0.34}$
No-tillage	0.33	$Y= 0.18\ S^{0.63}$

Table 6.19. Soil Loss Slope Relationships, 1973
(a) High Rain fall

Treatment	*r*	*Equation*
Bare fallow	0.86	$Y= 9.57\ S^{1.21}$
Mulch	0.47	$Y= 0.02\ S^{0.66}$
Maize-maize	0.52	$Y= 0.59\ S^{1.13}$
Cowpea-cowpea	0.45	$Y= 0.13\ S^{1.19}$
No-tillage	0.17	$Y= 0.043\ S^{0.16}$

(b) Low Rainfall

Treatment	*r*	*Equation*
Bare fallow	0.48	$Y= 4.26\ S^{1.26}$
Mulch	0.14	$Y= 0.08\ S^{0.15}$
Maize-maize	0.29	$Y= 0.36\ S^{0.68}$
Cowpea-maize	0.41	$Y= 0.27\ S^{0.44}$
No-tillage	0.12	$Y= 0.10\ S^{0.09}$

The slope-soil loss relationships for first and second season maize-maize (no-tillage) and cowpeas-maize (plowed) treatments are shown in Table 6.20. The erosion loss from the second season maize crop following cowpeas was most significantly correlated with slope. The correlation coefficient between soil loss and slope for the first season close-canopy cowpea crop was low. No-tillage treatments (1973 data) showed no relation between soil loss and slope regardless of the crop, i.e. maize or cowpeas.

Table 6.20. Slope soil loss relations for each season for maize-maize (no tillage) and cowpea-maize (plowed) treatments.

Treatment	*Year*	*Season*	*Rainfall*	*R*	*Equation*
Cowpea-maize (plowed)	1972	I	High	0.20	$Y= 0.07\ S^{0.43}$
		I	Low	0.19	$Y= 0.20\ S^{0.32}$
		II	High	0.25	$Y= 0.26\ S^{0.71}$
		II	Low	0.22	$Y= 0.15\ S^{0.40}$
	1973	I	High	0.12	$Y= 0.11\ S^{0.26}$
		I	Low	0.17	$Y= 0.22\ S^{0.37}$
		II	High	0.74	$Y= 0.40\ S^{0.59}$
		II	Low	0.31	$Y= 2.11\ S^{0.41}$
Maize-maize (no-t illage)	1972	I	High	0.62	$Y= 0.23\ S^{1.29}$
		I	Low	0.40	$Y= 0.23\ S^{0.76}$
		II	High	0.41	$Y= 0.02\ S^{0.81}$
		II	Low	0.16	$Y= 0.08\ S^{0.41}$
	1973	I	High	0.10	$Y= 0.05\ S^{0.11}$
		I	Low	0.12	$Y= 0.12\ S^{0.11}$
		II	High	0.25	$Y= 0.04\ S^{0.20}$
		II	Low	0.11	$Y= 0.10\ S^{0.07}$

Table 6.21. Effect of soil and crop management on soil loss

	First season					*Second season*				
Slope %	*Bare-fallow*	*Maize-maize (mulch)*	*Maize-maize*	*Maize*-Cowpeas (no-til.)*	*Cowpeas-maize*	*Bare-fallow*	*Maize-maize (mulch)*	*Maize-maize*	*Maize*-Cowpeas (no-til.)*	*Cowpeas maize*
1	1.00	0.00	0.20	0.00	0.06	1.00	0.00	0.11	0.00	0.19
5	1.00	0.00	0.10	0.00	0.06	1.00	0.00	0.04	0.00	0.08
10	1.00	0.00	0.08	0.00	0.04	1.00	0.00	0.04	0.00	0.06
15	1.00	0.00	0.14	0.00	0.04	1.00	0.01	0.16	0.03	0.39

Table 6.22. Effect of different stages of growth of maize on soil erosion.

Treatment	Growth Stages			
	I	II	III	IV
1	1.00	1.00	1.00	1.00
2	0.0004	0.0000	0.0001	0.0143
3	0.2213	0.1277	0.0867	0.0214
4	0.0027	0.0003	0.002	0.0003
5	0.2638	0.0103	0.0003	0.0016

Cumulative soil-loss factors (C) for different crop rotations and soil management practices are shown in Table 6.21. As expected, mulch and no-tillage practices has the smallest coefficients and therefore were most effective in preventing soil loss. The effect of different growth stages of maize on soil loss coefficients is indicated in Table 6.22.

CONCLUSIONS

The following general conclusions can be drawn from the data presented in Chapter 6:

(i) The exponential slope-runoff relation for bare-fallow treatments does not hold. The runoff losses are governed more by soil hydrological characteristics than by slope. The correlation coefficients between slope and runoff for no-tillage and mulched treatments are high, although the magnitude of the runoff losses under these treatments is small, regardless of slope.

(ii) The slope-soil loss relationships for bare-fallow treatments indicate an exponential function (correlation coefficient between 0.7 and 0.9). The exponential relationship however, did not apply to mulching and no-tillage practices.

(iii) Mulching and no-tillage treatments were most effective in preventing runoff and soil loss on the slopes investigated.

REFERENCES

Borst, H. L. and R. Woodburn, 1942. The effect of mulching and methods of cultivation and runoff and erosion from Muskingum silt loam. Agric. Eng. 23:19–22.

Charreau, C., 1969. Effect of cultural techniques on runoff and erosion in Casamance (Senegal). Agro. Trop. 27:905–929.

Fournier, F., 1967. Research on soil erosion in Africa. Afr. Soils 12.53–96.

Harrold, L. L., 1972. Soil erosion by water as affected by reduced tillage

system. Proc. no-tillage systems symposium, Feb. 21–22, 1972. The Ohio State Univ.

Hudson, N. W., 1957 Erosion control research. The Rhod. Agric. J. 54: 297–323.

Hudson, N. W., 1964. Field measurements of accelerated soil erosion in localised areas. Rhod. Agric. J. 61:46–47.

Hudson, N. W. and D. C. Jackson, 1959. Results obtained in the measurement of erosion and runoff in Southern Rhodesia. Third Inter-African Soils Conference, Dalaba. Proceedings 2, 575–584.

Kowal, J., 1972. The hydrology of a small catchment basin at Samaru, Nigeria. IV Assessment of soil erosion under varied land management and vegetation cover. Nigerian Agric. J. 7:134–147.

Mannering, J. V. and L. D. Meyer, 1961. The effects of different methods of corn stalk residue management on runoff and erosion as evaluated by simulated rainfall. Soil Sci. Soc. Amer. Proc. 25:506–510.

Mannering, J. V. and L. D. Meyer, 1963. The effect of various rates of surface mulch on infiltration and erosion. Soil Sci. Soc. Amer. Proc. 27:84–86.

Mannering, J. V. and R. E. Burwell, 1968. Tillage methods to reduce runoff and erosion in the corn belt. Agric. Inf. Bull. U.S. Dept. Agr. Res. Service 33:14.

Moldenhauer, W. C., W. H. Wischmeier and D. T, Parker, 1967. The influence of crop management on runoff, erosion and soil properties of Marshall silty clay loam. Soil Sci. Soc. Amer. Proc. 31:541–546.

Roose, E. J., 1967. Ten years of erosion and runoff records in Senegal. Agron. Trop. 22:123–152.

Wiltshire, G. R. 1947. Runoff plots and standard runoff- and soil-loss measuring equipment used by the New South Wales Soil Conservation Service. Soil Conservation. J. 4:40–44.

Wischmeier, W. H. 1966. Relation of field runoff to management and physical factors. Soil Sci. Soc. Amer. Proc. 30:272–277.

Wischmeier, W. H., D. D. Smith and R. E. Uhland, 1958. Evaluation of factors in the soil loss equation. Agr. Eng. 39:458–462.

Zingg, A. W., 1940. Degree and length of land slope as it affects soil loss and runoff. Agric. Eng. 21:59.

7

Mulching effects on runoff and soil loss

Soil erosion is a work function involving detachment of soil particles from aggregates and transportation of the detached particles to another place. The energy to perform this work is provided by raindrop impact and the stress exerted by concentrated runoff. The stress increases with slope steepness and runoff velocity. Effective control of erosion, therefore, lies in reducing the direct impact of raindrops, maintaining maximum soil infiltrability and decreasing the quantity, the velocity and the transport capacity of runoff water. These control measures can be achieved through residue mulches on the soil surface.

The effects of mulching on soil and water conservation has been reviewed by Jacks et al (1955) and McCalla et al (1962). Briggs and Boltz (1910) advocated using mulch and residue on the soil surface to reduce runoff and control wind erosion on fallowed land in arid climates. Extensive experiments on use of mulches in soil and water conservation were initiated subsequently by various agencies. Duley and Kelly (1939) found that covering the soil surface with straw increased infiltration and prevented the formation of a thin, compacted, slowly permeable layer caused by raindrop impact on bare soil. Borst and Woodburn (1942 a and b) attributed the effect of mulching in reducing runoff and soil loss to increased surface detention and decreased rate of runoff. Taylor and Hays (1960) found that a heavy mulch of corn stalks and manure provided excellent erosion control on corn following corn on Fayette silt loam on a 16% slope. Similarly, Whitaker et al (1961) reported that a large amount of plant residue greatly reduced serious soil and water losses from sloping claypan soils. Meyer and Mannering (1961) found that soil loss from plots covered with shredded corn stalks was slightly less than one-half that from plots upon which unshredded corn stalks were left behind by mechanical corn pickers.

Mannering and Meyer (1961) applied 6.25 inches of simulated rainfall at a rate of 2.5 in/hr to mulched and unmulched plots on a 5% slope. The soil loss on the unmulched plots was 12 tons/acre. No runoff and soil losses were recorded from the plots that received mulch at the rate of two tons/acre. With one ton/acre of mulch the soil loss was only 0.2 ton/acre; with 0.5 ton/acre of mulch the soil loss was 1 ton/acre. Swanson et al (1965) reported that mulches effectively controlled erosion on a 6%

slope. Adams (1966) found that straw and gravel mulch decreased runoff and erosion. Barnett et al (1967) reported that mulching effectively protected newly seeded 40% backslopes from erosion. In their studies Barnett et al found that the average runoff and soil loss for all mulch treatments were 17% of rainfall and 3.4 tons/acre, respectively, compared to 38% of rainfall and 20.2 tons/acre for the unmulched plots.

The effectiveness of stone mulch in controlling runoff and soil loss has also been reported by various workers. Pebble mulches have been used to conserve soil water in China (Chapman, 1937; Tsiang, 1948) and in South Africa (Whitemore et al, 1953). Hide (1954) reported that evaporation, runoff and erosion were reduced on a Bath Flaggy silt loam with a 65% surface cover of stones. Jung (1960) found that on eight-meter-long bare plots with 10.5% slope, a stone cover replaced after every rain decreased runoff by reducing raindrop impact and sealing of upper pore spaces during heavy rainfall.Soil loss was prevented by the roughness of surface under the stone cover.

In summary, the effect of mulches in reducing erosion can be attributed to.

(i) reducing raindrop impact;

(ii) increasing soil infiltration rate by decreasing surface sealing;

(iii) increasing surface storage;

(iv) decreasing runoff velocity;

(v) improving soil structure and porosity; and

(vi) improving the biological activity related to soil cover and its influence on porosity.

One practical way to obtain mulch is by crop-residue management using no-tillage or mulch-tillage techniques. Extensive work on no-tillage systems has been reported by various workers (Burwell et al, 1968; Moldenhauer and Amemiya, 1968; Greb et al, 1970; Unger et al, 1971; and Harrold et al, 1970).

The results of mulching experiments reported herein were conducted at IITA during 1974. Runoff and soil losses from plowed plots mulched with 0, 2, 4 and 6 tons/ha of rice straw were compared with those from no-tillage plots on slopes ranging from 1 to 15%. No cover crops were grown. All plots received 120 kg/ha of N as urea and 30 kg/ha each of P and K. In addition to measuring soil and water losses, the nutrient contents of runoff water and eroded soil were also analyzed. The soil and water losses recorded are described below.

Mulch Rate and Runoff Loss: The effects of mulch rate on runoff losses during the first and second seasons of 1974 are shown in Tables 7.1 and 7.2, respectively. There were no definite relationships between runoff and slope, except that the 1% slope plots had the lowest runoff-losses. Mean

Table 7.1. Effect of mulch rate on runoff loss (mm), first season 1974.

Slope	*Mulch Rate (tons/ha)*					
%	*0*	*2*	*4*	*6*	*No-tillage*	*Mean*
1	283.2	6.0	4.2	0.0	6.4	60.0
5	345.9	61.2	10.1	6.7	8.9	86.6
10	218.5	45.5	20.9	12.3	15.2	62.5
15	294.3	46.9	20.0	12.1	14.1	71.6
Mean	285.5	39.9	13.8	7.8	11.2	

Table 7.2. Effect of mulch rate on runoff loss (mm), second season 1974.

Slope	*Mulch Rate (tons/ha)*					
%	*0*	*2*	*4*	*6*	*No-tillage*	*Mean*
1	128.5	30.2	2.5	0.0	5.1	33.2
5	137.1	64.9	18.2	4.0	5.9	46.0
10	84.4	28.3	13.8	8.8	8.8	28.8
15	80.4	39.9	30.6	7.8	8.5	33.4
Mean	107.6	40.8	16.3	5.1	7.1	

runoff losses during the first season were 60, 87, 63 and 72 mm for the 1, 5, 10 and 15% slopes, respectively. During the second season, the corresponding losses were 33, 46, 29 and 33 mm. Mulch rate had a significant effect on runoff. Mean runoff losses during the first season were 286, 40, 14 and 8 mm for plots with 0, 2, 4 and 6 tons/ha of straw mulch, respectively. Runoff losses from the no-tillage plots were between those from plots mulched with 4 and 6 tons/ha of straw. Similar results were obtained during the second season. Mean runoff losses of 108, 41, 16 and 5 mm were recorded from the plots with 0, 2, 4 and 6 tons/ha of mulch, respectively. The mean runoff loss from the no-tillage plots was 7 mm, compared to that from the plots with 6 tons/ha of mulch.

Multiple regression analyses of runoff with slope for different rates of mulching are shown in Table 7.3. At the 0 mulch rate runoff loss was not correlated with slope, but the correlation coefficients improved with increasing rates of surface mulch. The correlation coefficients were lower for the high rainfall conditions than for the low rainfall conditions. The analyses of the runoff data based on exponential functions are shown in

Tables 7.4 and 7.5. As expected from the previous analyses, the correlation coefficients relating runoff with slope improved with increasing mulch rates.

Tabl e 7.3. Mulch rate and runoff, multiple regression analysis
(a) High Rainfall

Mulch Rate (tons/ha)	R^2	*Equation*	*Average Y % of Rainfall*
0	0.27	$Y= 38.56 + 25.90\ S - 4.75\ S^2 + 0.21\ S^3$	60.8
2	ns	ns	15.4
4	0.16	$Y= 1.11 + 0.48\ S$	4.8
6	0.78	$Y= 1.12 + 0.65\ S - 0.03\ S^2$	1.7
No-tillage	0.51	$Y= 1.52 - 0.24\ S + 0.08\ S^2 - 0.004\ S^3$	2.2

(a) Low Rainfall

Mulch Rate (tons/ha)	R^2	*Equation*	*Average % of Rainfall*
0	0.08	$Y= 53.5 - 1.65\ S$	41.0
2	0.32	$Y= 4.12 + 4.97\ S - 0.62\ S^2 + 0.02\ S^3$	4.7
4	0.34	$Y= 0.79 + 0.31\ S$	3.2
6	0.41	$Y= 1.38 + 0.08\ S - 0.04\ S^2$	1.9
No-tillage	0.09	$Y= 1.64 + 0.24\ S$	3.4

Table 7.4. Slope runoff relations for different mulch rates
(a) High Rainfall

Mulch rate (tons/ha)	*r*	*Equation*	*Average Y % of Rainfall*
0	-0.1	$Y= 59.2\ S^{-0.04}$	55.7
2	0.44	$Y= 2.1\ S^{0.66}$	6.7
4	0.76	$Y= 0.8\ S^{1.05}$	2.7
6	0.89	$Y= 0.001\ S^{3.3}$	0.58
No-tillage	0.57	$Y= 1.2\ S^{0.29}$	1.93

Mulch Rate and Soil Loss: The effect of mulch rates on Soil losses for different slopes are shown in Figures 7.1 and 7.2 for the first and second seasons of 1974, respectively. Maximum soil losses during the first seasons were 110, 3.5 0.5 and 0.3 tons/ha from plots mulched with 0, 2, 4 and 6 tons/ha of rice straw, respectively. The maximum soil loss from the no-tillage plots was 0.6 tons/ha. Similar results were obtained during the second season (Fig. 7.2).

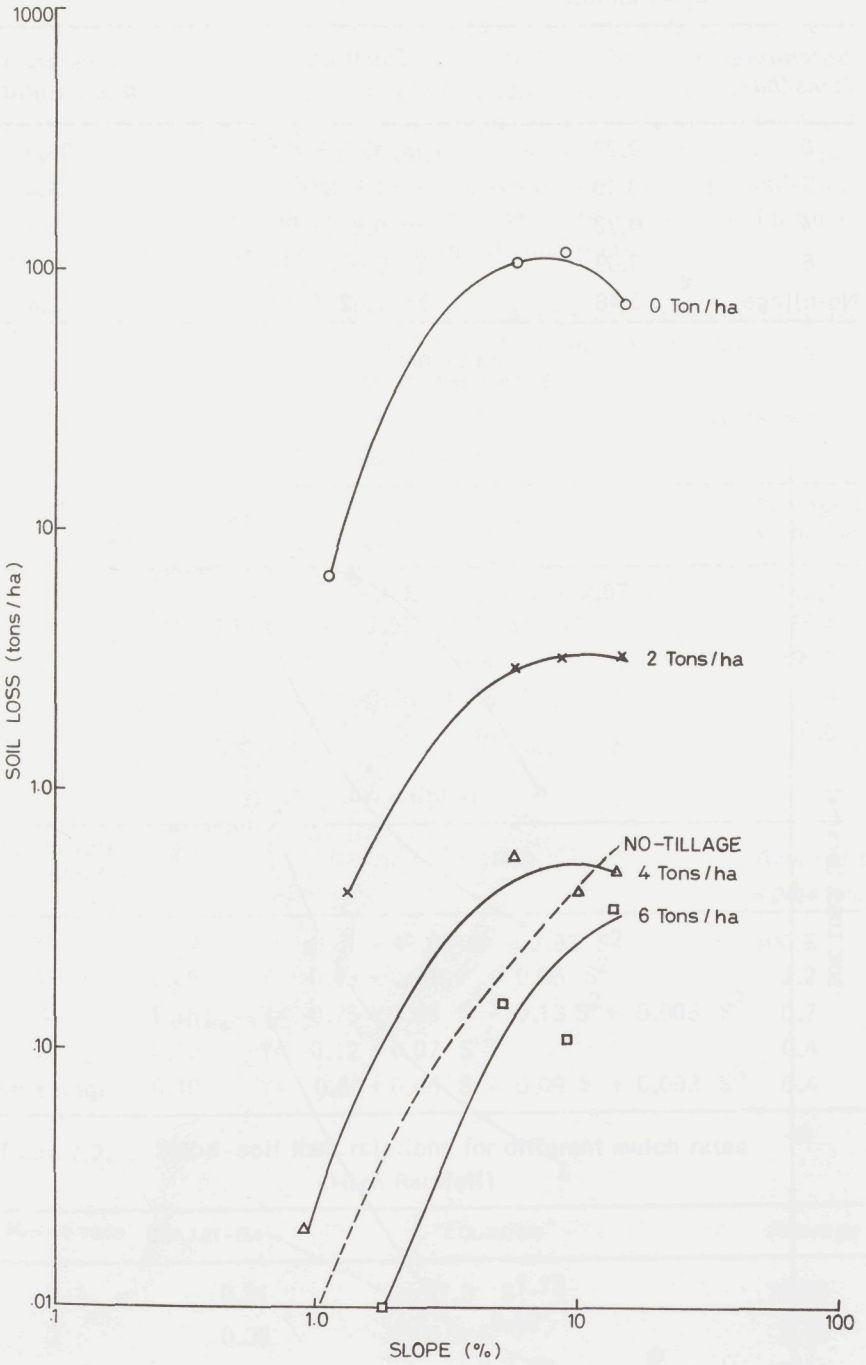


Fig. 7. Effects of mulch rate, no-tillage system and slope on soil erosion in the first season, 1974.

Table 7.5. Slope-runoff relation for different mulch rates (Low Rainfall)

Mulch rate (tons/ha)	*r*	*Equation*	*Average Y % of Rainfall*
0	0.27	$Y= 47.5\ S^{-0.22}$	33.0
2	0.49	$Y= 1.5\ S^{0.47}$	3.4
4	0.73	$Y= 0.8\ S^{0.66}$	2.3
6	0.09	$Y= 0.002\ S^{3.07}$	0.39
No-tillage	0.48	$Y= 1.62\ S^{0.30}$	2.6

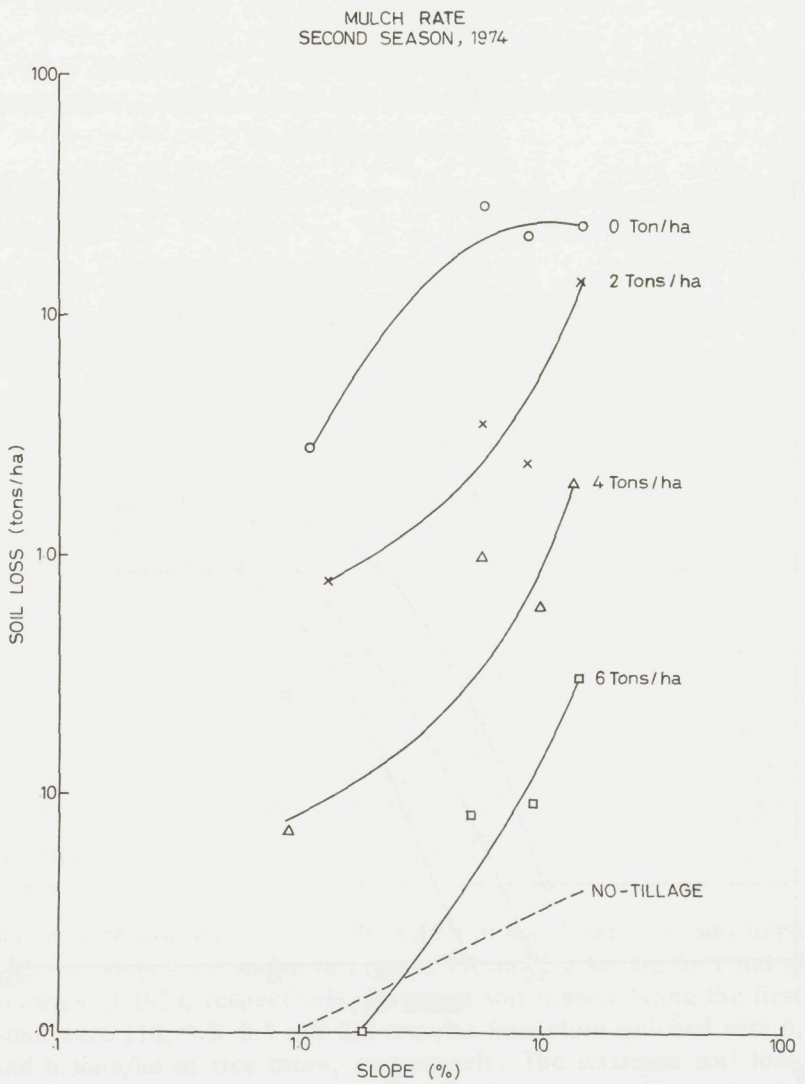


Fig. 7.2 Effects of mulch rate, no-tillage system and slope on soil erosion in the first season, 1975.

Multiple regression analyses of soil loss with slope, for both high and low rainfall, are given in Table 7.6. As expected, a slope-soil loss relationship exists only for the unmulched plots and the correlation coefficients were generally higher for high-rainfall conditions than for low-rainfall conditions. Under high-rainfall conditions, the mean soil losses from plots mulched with 0, 2, 4 and 6 tons/ha of mulch were 143, 16, 2 and 0.4 kg/ha/mm of rainfall, respectively. Similar data for low-rainfall conditions were 100, 2, 0.7 and 0.4 kg/ha/mm of rainfall. Soil losses from the no-tillage plots were similar to those from plots that received 6 tons/ha of mulch under both high and low rainfall conditions.

The analyses based on exponential relations between soil loss and slope are given in Tables 7.7 and 7.8 for high and low rainfall, respec-

Table 7.6. Mulch rate and soil loss, multiple regression analysis

(a) High Rainfall

Mulch rate (tons/ha)	R^2	*Equation*	*Average Y kg/ha/mm*
0	0.44	$Y = -38.8 + 51.97\ S - 2.57\ S^2$	143.1
2	0.12	$Y = -2.65 + 2.44\ S$	16.4
4	ns	ns	2.0
6	0.11	$Y = -0.06 + 0.05\ S$	0.4
No-tillage	ns	ns	0.6

(b) Low Rainfall

Mulch rate (tons/ha)	R^2	*Equation*	*Average Y kg/ha/mm*
0	0.34	$Y = -33.1 + 49.06\ S - 2.93\ S^2$	100.5
2	0.08	$Y = -0.49 + 0.91\ S - 0.05\ S^2$	2.2
4	0.15	$Y = -0.75 + 0.98\ S - 0.13\ S^2 + 0.005\ S^3$	0.7
6	0.12	$Y = -0.12 + 0.07\ S$	0.4
No-tillage	0.10	$Y = -0.50 + 0.65\ S - 0.09\ S + 0.003\ S^3$	0.4

Table 7.7. Slope-soil loss relations for different mulch rates (High Rainfall)

Mulch rate	*r*	*Equation*	*Average*
0	0.81	$Y = 11.8\ S^{1.13}$	76.60
2	0.35	$Y = 0.5\ S^{0.87}$	2.40
4	0.57	$Y = 0.07\ S^{1.05}$	0.37
6	0.46	$Y = 0.01\ S^{1.0}$	0.09
No-tillage	0.35	$Y = 0.01\ S^{0.5}$	0.09

tively. Once again, the best fit (r = 0.8) was obtained for the data from the unmulched plots. The correlation coefficients were also higher for the high-rainfall conditions than for the low.

Wischmeier (1973) proposed using a mulch factor – the ratio of soil loss with mulch to corresponding loss with no mulch – to predict in the universal soil-loss equation. Mulch factors for runoff and soil loss, averaged for all slopes, ranging from 1 to 15% are shown in Figure 7.3. The mulch factors decreased logarithmically with increasing mulch rates. The effects of slope are shown in Figure 7.4. The mulch factors increased with increase in slope only for the mulch rates of 4 and 6 tons/ha and for the no-tillage treatments.

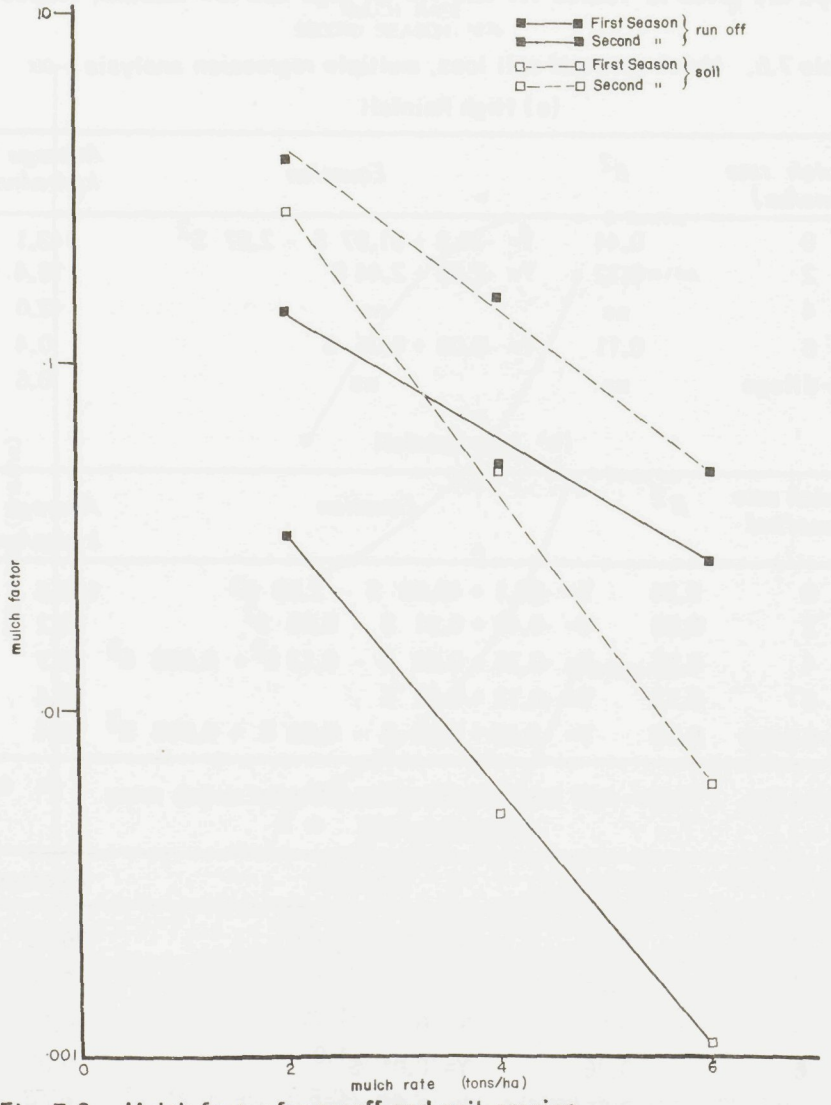


Fig. 7.3 Mulch factor for runoff and soil erosion.

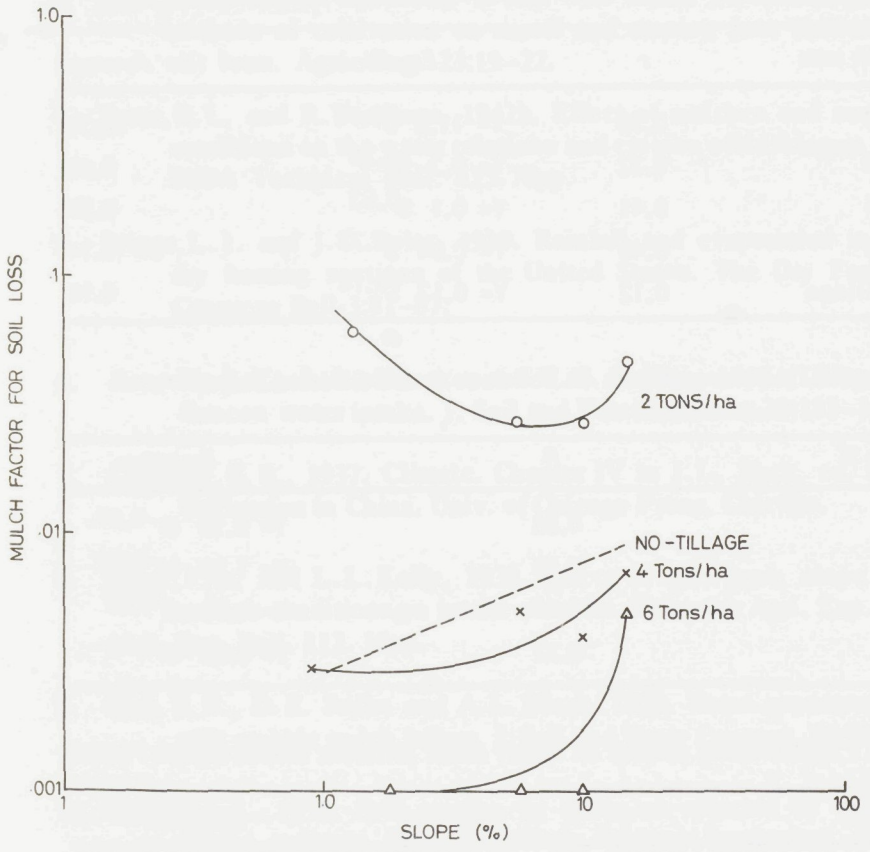


Fig. 7.4 Influence of degree of slope on mulch factor for soil erosion under different mulch rates and no-tillage system.

The mulch rate – soil loss and mulch rate – runoff relationships for different slopes are shown in Tables 7.9 and 7.10 respectively. The high correlation coefficients indicate that exponential relationships between soil loss and mulch rate and between runoff and mulch rate exist for the mulched treatments.

CONCLUSIONS

- Mulching with straw at a rate of 4 to 6 tons/ha effectively prevents runoff and soil loss from slopes ranging from 1 to 15%.
- The effectiveness of no-tillage treatments in preventing runoff and erosion is comparable to applying 4 to 6 tons/ha of straw mulch.
- The slope-soil relationships show an exponential function for un-mulched plots only. Slope-runoff relationships exist only for high-mulch and no-tillage treatments.

Table 7.8. Slope - soil loss relations for different mulch rates

Mulch rate	*r*	*Equation*	*Average*
0	0.38	$Y = 11.2\ S^{0.74}$	38.30
2	0.32	$Y = 0.3\ S^{0.35}$	0.68
4	0.41	$Y = 0.1\ S^{0.53}$	0.27
6	0.49	$Y = 0.04\ S^{0.72}$	0.14
No-tillage	0.12	$Y = 0.13\ S^{0.14}$	0.16

Table 7.9. Mulching effects on soil loss under different slopes (Mulch Factor)

Slope %	*R*	*Equation*
1	0.85	$Y = 0.19\ M^{-0.54}$
5	0.85	$Y = 1.25\ M^{-0.71}$
10	0.96	$Y = 1.09\ M^{-0.67}$
15	0.72	$Y = 0.98\ M^{0.24}$

Table 7.10. Mulching effects on runoff under different slopes (Mulch Factor)

Slope %	*R*	*Equation*
1	0.78	$Y = 0.39\ M^{-9.73}$
5	0.80	$Y = 1.16\ M^{-0.36}$
10	0.86	$Y = 5.53\ M^{-0.27}$
15	0.75	$Y = 5.26\ M^{-0.55}$

- Mulch-soil loss and mulch-runoff loss relationships also show an exponential function with a negative exponent of mulch rate ranging between 0.2 and 0.7.

REFERENCES

1. Adams, J. B., 1966. Influence of mulches on runoff erosion and soil moisture depletion. Soil Sci. Soc. Amer. Proc. 30: 110–114.

2. Barnett, A. P., E. G. Diseker and E. C. Richardson, 1967. Evaluation of mulching methods for erosion control on newly prepared and seeded highway back slope. Agron. J. 59:83–85.

3. Borst, H. L. and R. Woodburn, 1942a. The effect of mulching and methods of cultivation on runoff and erosion from Muskingum silt loam. Agri. Eng. 23:19–22.

4. Borst, H. L. and R. Woodburn, 1942b. Effect of mulches and surface conditions on the water relations and erosion ofMuskingum soil. USDA Technical Bull. 825.76pp.

5. Briggs, L. J. and J. O. Boltz, 1910. Rainfall and evaporation in the dry farming sections of the United States. The Dry Farming Congress Bull. 3:81–87.

6. Burwell, R. E., L. L. Sloneker and W. W. Nelson, 1968. Tillage influnces water intake. J. Soil and Water Conserv. 23:185–187.

7. Chapman, B. B., 1937. Climate. Chapter IV in J. L. Buck, ed. Land Utilization in China, Univ. of Chicago Press, Chicago.

8. Duley, F. L. and L. L. Kelly, 1939. Effect of soil type, slope and surface conditions on intake of water. Nebraska Agri. Exp. Sta. Res. Bull. 112. 16pp.

9. Greb, B. W., D. R. Smika and A. L. Black, 1970. Water conservation with stubble mulch fallow. J. Soil and Water Conserv. 25:58–62.

10. Harrold, L. L., 1972. Soil erosion by water as affected by reduced tillage systems. Proc. No-tillage Systems Symposium, Center for Tomorrow, Columbus, Ohio, Feb. 21–22, 1972.

11. Harrold, L. L., G. B. Triplett and R. E. Youker, 1967. Watershed tests of no-tillage corn. J. Soil and Water Conserv. 22: 98–100.

12. Harrold, L. L., G. B. Triplett and W. M. Edwards, 1970. No-tillage corn, characteristics of the system. Trans. Amer. Soc. Agric. Eng. 51(3) 128–131.

13. Hays, O. E., 1961. New tillage methods reduce erosion and runoff. J. Soil and Water Conserv. 16: 172–175.

14. Hide, J. C., 1954. Observations on factors influencing the evaporation of soil moisture. Soil Sci. Soc. Amer. Proc. 18: 234–239.

15. Jacks, G. V., V. D. Baird and R. Smith, 1955. Mulching, Commonwealth Bureau of Soil Sci. Tech. Comm. No. 49.

16. Jung, L., 1960. The influence of the stone cover on runoff and erosion on slate soil. Int. Ass. Sci. Hydrol. Pub. 53. Gen. Assembly, Helsinki 143–153.

17. McCalla, T.M. and T.J. Army, 1961. Stubble mulch farming. Adv. in Agron. 13: 125–196.

18. McCalla, T.M., T.J. Army and C.J. Witfield, 1962. Stubble-Mulch Farming. J. Soil and Water Conserv. 17: 204–208.

19. Mannering, J.V. and L.D. Meyer, 1961. The effects of different methods of Corn-stalk residue management on runoff and erosion as evaluated by simulated rainfall. Soil Sci. Soc. Amer. Proc. 25: 506–510.

20. Meyer, L.D. and J.V. Mannering, 1961. Minimum tillage for corn: its effect on infiltration and erosion. Agri Eng. 42: 72–75.

21. Meyer, L.D. and J.V. Mannering, 1967. Tillage and land modification for erosion control. Conf. Proc. Tillage for Greater Crop Production. A.S.A., St. Joseph, Michigan, 58–62.

22. Moldenhauer, W.C. and M. Amemiya, 1968. Tillage practices for controlling crop land erosion. J. Soil and Water Conserv. 24: 19–21.

23. Swanson, N.P., A.R. Derick, H.E. Weekly and H.R. Haise, 1965. Comparing mulches – Scientists check effects of four mulching materials on 6% slope. Agr. Res. 13(8).

24. Taylor, R.E., and O.E. Hays, 1960. Agron. Abstr., Amer. Soc. Agron. P. 41. Reported in D.D. Smith and W.H. Wischmeier (1962). Rainfall Erosion. Adv. Agron. 1962: 109–146.

25. Tsiang, T.C., 1948. Soil conservation, an international study. F.A.O. U.N., pp. 83–84.

26. Whitaker, F.D., V.C. Tamisan and J.F. Thornton, 1961. Runoff and Erosion Losses from Mexico. Silt loam in relation to fertilization and other management practices. Soil Sci. Soc. Amer. Proc. 25: 401–403.

27. Whitemore, J.S., J.N. Marais and W.H. Turpin, 1953. Weeds: Major menace to crop production. Farming in South Africa. 293–297.

28. Wischmeier, W.H., 1973. Conservation tillage to control water erosion. Proc. National Conference on conservation Tillage. Soil Conser. Soc. of Amer. Ames, Iowa, 1973, 133–140.

29. Unger, P.W., R.R. Allen and A.F. Wiese, 1971. Tillage and herbicide for surface residue maintenance, weed control and water conservation. J. Soil and Water Conserv. 26: 147–150.

8

Rainfall erosivity and soil erosion

The role of the kinetic energy of the raindrop in soil detachment has long been recognized (Ellison, 1947; Ekern and Muckenir, 1947; Woodburn, 1948). Ellison (1947) reported that the soil detachment hazard (D) is directly proportional to the product of the soil detachability (D_2) and the detaching capacity of the rain (D_3) and inversely proportional to the resistance factor (R) of surface covers and mulches in reducing runoff velocity (Equation 8.1).

$$D_1 = (D_2 x D_3)/R \text{ ---------- } 8.1$$

Soil transport is also a work function (8.1) influenced by the rainstorm characteristics. For example, Ekern and Muckenhim (1947) reported that for a constant drop size and time, the amount of sand transported was directly proportional to the intensity of the preciptation and showed a logarithmic relationship to drop diameter as shown in Equation 8.2.

$$\text{Sand Transport} = K_1 \log d - K_2 \quad (8.2)$$

Experiments conducted by Mookerjee (1950) in India showed a high correlation between rainfall intensity and the amount of eroded soil. Mihara (1953) attributed soil erosion less to running water and more to raindrop impact. Ekern's (1954) findings related storm erosivity exponentially to rainfall intensity. Similar results have been reported by Adams (1957) and Tamhane et al (1959). Free (1960) reported that only lasting rain of high intensity combined with some packing and sealing before the rainfall caused runoff and soil losses. Free also reported that the relationship of ratio of infiltration to runoff with rainfall energy was exponential and of the hyperbolic type. Rose (1960) concluded that the rate of soil detachment per unit area was influenced more by the momentum than the kinetic energy of the storm per unit area and time.

Wischmeier (1955) reported that the combination of rainfall energy and quantity of rainfall was the most important variable affecting soil erosion. Further analysis by Wischmeier et al (1958) showed that the correlations between both soil loss and total rainfall of individual storms and rainfall in 5-, 15-, or 30-minute intervals were poor. The product of the kinetic energy of the storm and the 30-minute intensity (EI_{30}) was most significantly correlated with the soil loss.

Although the EI_{30} index is the best known method of calculating the erosivity of rainfall, the index has not been entirely satisfactory, particularly for tropical rainstorms. The intensity used in the EI_{30} index is generally <50mm/hr, but storms of much higher intensities are frequent in the tropics. Rogers et al (1967) indicated that calculating the kinetic energy of rainfall from rainfall intensity was satisfactory. However, this may not be satisfactory in the tropics where rainstorms are often preceded by high winds. Lyles et al (1969) found that wind-driven rain considerably increased soil loss. Ahmad and Breckner (1974) found in Trinidad that correlations of soil loss with the EI_{30} index were generally low. In the developing countries of the tropics, characterizing the erosivity of the climate with the EI_{30} index presents problems, not only because of the technical reasons mentioned above but also because long-term rain-gauge records are not available. Other rainfall indices have been proposed for use in the tropics.

Fournier (1956) and Fournier and Henin (1959) analyzed the sediment load values of more than 140 rivers in Europe, Asia and the United States and found a significant correlation between total annual erosion, (ton/km^2) and the rainfall coefficient (Equation 8.3).

$$C = p^2/P \qquad (8.3)$$

ρ is the monthly rainfall during the wettest month of the year and P is the annual rainfall.

The soil loss or "specific degradation", was expressed as Equation 8.4.

$$D = aC - b \qquad (8.4)$$

D is the specific degradation or soil loss and a,b are coefficients whose magnitudes depend upon the orographic coefficient (0) of Equation 8.5.

$$(0) = H^2/S \qquad (8.5)$$

H is the height of the terrain above its base level and S is its projected area.

Fournier's index was more significantly correlated with erosion in the tropics than in the temperate climate and with steeper than with gentler slopes. This climatic index is useful for large watersheds. However, for small areas the erosivity of the climate, particularly in relation to soil management, cannot be easily predicted with this index.

Hudson (1971) reported from his work in Rhodesia that the cumulative kinetic energy of storms with intensities greater than 1 inch/hr (KE71) was more significantly correlated with soil loss than the EI_{30} index. Roose (1973) found from data collected in the Ivory Coast that climatic erosivity was significantly related to quantity of rainfall. His analysis indicated an exponential relationship between the EI_{30} index and rainfall

amount in the humid-forest region of the Ivory Coast and a linear relationship in the savanna region.

Calculations of the Rainfall Erosivity in Relation to Runoff and Soil Loss

The work reported here was conducted at IITA during 1972 – 1974. Rainfall intensity records were obtained for each storm using an automatic daily recording rain gauge (Belfort Inst. Model 5–780). The kinetic energy of the rainstorm was calculated by the relations described by Wischmeier et al (1958), using Equation 8.6.

$$\text{Kinetic energy (foot-tons/acre)} = 916 + 331 \log_{10} I \text{ (inches/hour)}$$

The kinetic energy thus calculated was multiplied by the greatest average intensity recorded during 7.5-, 15-, 22.5-, 30-, 37.5- and 45-minute intervals. The products were termed $EI_{17.5}$, EI_{15}, $EI_{22.5}$, EI_{30}, $EI_{37.5}$, and EI_{45}. Each was multiplied by the total amount of rain received (A). The new indices were designated AEI, with appropriate suffixes to denote time intervals. The erosivity of each storm was also calculated with Hudson's KE>1 index. Simple correlations were then computed between soil and water losses from bare-fallow plots and rainfall amount (A), rainfall intensities ($I_{7.5}$ to I_{45}), EI indices ($EI_{7.5}$ to EI_{45}) and AI and AEI indices.

Relationships Between Rainfall Amount and Runoff and Soil Loss from Different Slopes:

Tables 8.1, 8.2 and 8.3 show correlation coefficients and linear regression equations relating runoff and soil loss to rainfall amount, runoff to soil loss for each slope, runoff from a 5% slope to runoff and soil loss from other slopes, and soil loss from a 5% slope to soil loss from other slopes.

Fairly good estimates of water runoff can be obtained from rainfall data for bare-fallow plots. That the runoff-rainfall relationship exists and can be used to extrapolate results is further strengthened by the high values of the correlation coefficients. Similarly, it seems possible to obtain information on water runoff for different slopes from the runoff records on one of the slopes. Furthermore, the correlation coefficients between water runoff from 5% slopes and that from other slopes are high. The relationships between runoff and soil loss, although good, may not always make it possible to estimate soil loss from runoff data alone. The correlation coefficients between runoff and soil loss within each slope are not high. However, estimates of soil loss from water runoff from a representative slope (a 5% slope, for example) may be obtained from the regression equations given in the tables.

Table 8.1 gives correlation coefficients and linear regression equations relating runoff and soil loss from bare-fallow plots to amount of rainfall and relating runoff and soil loss from one slope to that from other slopes (1972).

Table 8.1 Correlation coefficient and linear regression equations for runoff and soil loss from bare fallow with amount of rainfall and relating runoff and soil loss from one slope to that of others (1972).

Ind. Variable	Dept. Variable		Equation
Amount of rainfall per storm (A)	Runoff 1% (W)	0,66	$W = 6.6A + 9.2$
Amount of rainfall per storm (A)	Runoff 5% (W)	0.54	$W = 6.8A + 17.0$
Amount of rainfall per storm (A)	Runoff 10% (W)	0.62	$W = 7.0A + 14.4$
Amount of rainfall per storm (A)	Runoff 15% (W)	0.65	$W = 6.9A + 8.0$
Amount of rainfall per storm (A)	Soil loss 1% (E)	0.94	$E = 0.09A - 0.05$
Amount of rainfall per storm (A)	Soil loss 5% (E)	0.72	$E = 0.48A + 0.27$
Amount of rainfall per storm (A)	Soil loss 10% (E)	0.52	$E = 0.52A + 0.65$
Amount of rainfall per storm (A)	Soil loss 15% (E)	0.86	$E = 2.53A - 1.59$
Runoff 5% (W_5)	Runoff 1% (W)	0.82	$W = 0.64W_5 + 0.03$
Runoff 5% (W_5)	Runoff 10% (W)	0.81	$W = 0.72W_5 + 0.06$
Runoff 5% (W_5)	Runoff 15% (W)	0.74	$W = 0.62W_5 + 0.03$
Soil loss 5% (E_5)	Soil loss 1% (E)	0.80	$E = 0.11E_5 - 0.008$
Soil loss 5% (E_5)	Soil loss 10% (E)	0.85	$E = 1.29E_5 + 0.12$
Soil loss 5% (E_5)	Soil loss 15% (E)	0.81	$E = 3.63E_5 - 0.96$
Runoff 1% (W_1)	Soil loss 1% (E)	0.81	$E = 0.77W_1{}^* - 0.04$
Runoff 5% (W_5)	Soil loss 5% (E)	0.81	$E = 4.20W_5{}^* - 0.07$
Runoff 10% (W_{10})	Soil loss 10% (E)	0.60	$E = 5.23W_{10}{}^* + 0.20$
Runoff 15% (W_{15})	Soil loss 15% (E)	0.70	$E = 19.30W_{15}{}^* - 0.73$
Runoff 5% (W_5)	Soil loss 1% (E)	0.69	$E = 0.51W_5{}^* - 0.02$
Runoff 5% (W_5)	Soil loss 10% (E)	0.65	$E = 5.03W_5{}^* + 0.15$
Runoff 5% (W_5)	Soil loss 15% (E)	0.57	$E = 13.07W_5{}^* - 0.53$

Rainfall = *cm per storm*
**Runoff* = *fraction of the rainfall*
Soil loss = *t/ha/storm*
Runoff = *percent of rainfall*

Computation of Erosivity Indices from Rainfall Amount:

Roose (1973) attempted to compute the EI_{30} index from rainfall data. He found a linear correlation between rainfall amount and the EI_{30} index for the savanna region of the Ivory Coast and a logarithmic relation between rainfall amount at the EI_{30} index for the humid-forest zone. The correlation coefficient and regression equations for computing kinetic energy (E) and the EI_{30} and KE>1 indices from rainfall amount are shown in Table 8.4. High correlation coefficients between rainfall amount and the various indices for all the three years indicate that a linear relationship exists and that it is possible to predict erosivity from rainfall amount.

Table 8.2 Correlation coefficient and linear regression equations for runoff and soil loss from bare fallow plots with amount of rainfall and relating runoff and soil loss from one slope to that of others (1973).

Ind. Variable	Dep. Variable	r	Equation
Amount of rain per storm (A)	Runoff 1% (W)	0.26	$W = 1.98A + 33.0$
Amount of rain per storm (A)	Runoff 5% (W)	0.21	$W = 1.88A + 37.0$
Amount of rain per storm (A)	Runoff 10% (W)	0.23	$W = 1.96A + 34.0$
Amount of rain per storm (A)	Runoff 15% (W)	0.27	$W = 2.73A + 28.9$
Amount of rain per storm (A)	Soil loss 1% (E)	0.94	$E = 0.13A \quad 0.07$
Amount of rain per storm (A)	Soil loss 5% (E)	0.20	$E = 0.21A + 0.30$
Amount of rain per storm (A)	Soil loss 10% (E)	0.91	$E = 2.13A - 0.34$
Amount of rain per storm (A)	Soil loss 15% (E)	0.79	$E = 2.11A - 0.47$
Runoff 5% (W_5)	Runoff 1% (W)	0.77	$W = 0.67 W_5 + 0.09$
Runoff 5% (W_5)	Runoff 10% (W)	0.77	$W = 0.74 W_5 + 0.08$
Runoff 5% (W_5)	Runoff 15% (W)	0.79	$W = 0.91 W_5 - 0.02$
Soil loss 5% (E_5)	Soil loss 1% (E)	0.20	$E = 0.03E_5 + 0.16$
Soil loss 5% (E_5)	Soil loss 10% (E)	0.31	$E = 0.70E_5 + 2.62$
Soil loss 5% (E_5)	Soil loss 15% (E)	0.29	$E = 0.77E_5 + 2.21$
Runoff 1% (W_1)	Soil loss 1% (E)	0.30	$E = 0.53W_1{}^* \ 0.06$
Runoff 5% (W_5)	Soil loss 5% (E)	0.60	$E = 6.96W_5{}^* + 0.64$
Runoff 10% (W_{10})	Soil loss 10% (E)	0.42	$E = 11.43W_{10}{}^* + 0.70$
Runoff 15% (W_{15})	Soil loss 15% (E)	0.55	$E = 14.20W_{15}{}^* + 0.17$
Runoff 5% (W_5)	Soil loss 1% (E)	0.24	$E = 0.36W_5{}^* + 0.10$
Runoff 5% (W_5)	Soil loss 10% (E)	0.33	$E = 8.73W_5{}^* + 1.46$
Runoff 5% (W_5)	Soil loss 15% (E)	0.39	$E = 11.63W_5{}^* + 0.07$

Rainfall = cm per storm
** Runoff — fraction of rainfall*
Soil loss = ton/ha/storm
rainfall = percent of rainfall

The Relationship Between Runoff and Erosivity Indices:

Simple correlation coefficients relating water runoff from bare-fallow plots to the various indices are shown in Tables 8.5, 8.6 and 8.7 for 1972, 1973 and 1974 respectively. In general, runoff was significantly correlated with total rainfall of a given storm. The kinetic energy of the rainstorm. although significantly correlated, was not as highly correlated with runoff as the total amount of rainfall during a given storm. The various EI indices correlate fairly well with water runoff. Among the AI indices, the highest correlation was obtained with $AI_{7.5}$. AEI indices were not as highly cor-related as the AI indices.

Table 8.3 Correlation coefficient and linear regression equations for runoff and soil loss from bare fallow plots with amount of rainfall and relating runoff and soil loss from one slope to that of from others (1974).

Ind. Variable	Dep. Variable	r	Equation
Amount of rain per storm (A)	Runoff 1% (W)	0.15	$W = 1.90A + 4.28$
Amount of rain per storm (A)	Runoff 5% (W)	0.21	$W = 3.21A + 4.72$
Amount of rain per storm (A)	Runoff 10% (W)	0.07	$W = 0.76A + 34.8$
Amount of rain per storm (A)	Runoff 15% (W)	0.56	$W = 8.50A + 12.83$
Amount of rain per storm (A)	Soil loss 1% (E)	0.59	$E = 0.12A + 0.02$
Amount of rain per storm (A)	Soil loss 5% (E)	0.72	$E = 1.76A - 0.02$
Amount of rain per storm (A)	Soil loss 10% (E)	0.68	$E = 2.30A - 1.32$
Amount of rain per storm (A)	Soil loss 15% (E)	0.71	$E = 1.78A - 1.42$
Runoff 5% (W_5)	Runoff 1% (W)	0.82	$W = 0.66W_5 + 0.11$
Runoff 5% (W_5)	Runoff 10% (W)	0.64	$W = 0.44W_5 + 0.12$
Runoff 5% (W_5)	Runoff 15% (W)	0.62	$W = 0.62W_5 + 0.01$
Soil loss 5% (E_5)	Soil loss 1% (E)	0.59	$E = 0.05E_5 + 0.11$
Soil loss 5% (E_5)	Soil loss 10% (E)	0.91	$E = 1.26E_5 - 1.09$
Soil loss 5% (E_5)	Soil loss 15% (E)	0.70	$E = 0.72E_5 - 0.05$
Runoff 1% (W_1)	Soil loss 1% (E)	0.56	$E = 0.89W_1^* - 0.10$
Runoff 5% (W_5)	Soil loss 5% (E)	0.46	$E = 7.27W_5^* + 0.58$
Runoff 10% (W_{10})	Soil loss 10% (E)	0.37	$E = 12.00W_{10}^* + 0.36$
Runoff 15% (W_{15})	Soil loss 15% (E)	0.73	$E = 12.00W_{15}^* - 0.93$
Runoff 5% (W_5)	Soil loss 1% (E)	0.56	$E = 0.72W_5^* - 0.07$
Runoff 5% (W_5)	Soil loss 10% (E)	0.47	$E = 10.27W_5^* - 0.96$
Runoff 5% (W_5)	Soil loss 15% (E)	0.39	$E = 6.31W_5^* - 0.22$

Rainfall = *cm per storm*
* *Runoff* = *fraction of rainfall*
Soil loss = *ton/ha/storm*
Runoff = *percent of rainfall*

The Relationship Between Soil Loss and Erosivity Indices:

Correlation coefficients relating soil loss from bare-fallow plots during individual storms to various erosivity indices are shown in Tables 8.8, 8.9 and 8.10 for 1972, 1973 and 1974 respectively. The correlation coefficients between soil loss and the various indices are generally lower than those between water runoff and the indices. Again, the total amount of rainfall during a given storm correlated fairly well with soil loss from all slopes investigated. Mean intensity during a 45-minute period (I_{45}) was more highly correlated with soil loss than with either total kinetic energy of the storm or the EI_{30} index. The best estimate of soil loss during an individual storm was obtained with $AI_{7.5}$. The weighted-mean average correlation coefficients between runoff and soil loss and the various indices for all the slopes are shown in Table 8.11. Soil loss is generally poorly correlated with any of the variables listed.

Table 8.4 Correlation coefficients and regression equations relating rainfall amount A with various erosivity indices.

Year	Ind. Variable	Dep. Variable	r	Equation
1972	Rainfall amount per storm	E	0.97	E = 396.2 A - 112.0
	"	EI_{30}	0.87	EI_{30} = 1640.5 A - 1968.5
	"	KE > 1	0.88	KE > 1 = 362.5 A - 160.0
	"	AI_m	0.97	AI_m = 13.77 A - 11.3
1973	"	E	0.99	E = 367.0 A - 7.7
	"	EI_{30}	0.93	EI_{30} = 254.9 A - 22.3
	"	KE > I	0.88	KE > 1 = 853.0 A - 555.6
	"	AI_m	0.92	AI_m = 9.22 A - 4.2
1974	"	E	0.84	E = 390.6 A - 77.4
	"	EI_{30}	0.78	EI_{30} = 215.5 A + 39.2
	"	KE > 1	0.79	KE > 1 = 839.5 A - 813.7
	"	AI_m	0.88	AI_m = 9.74 A - 7.3
1972 - 1974	"	E	0.95	E = 379.6 A - 54.0
	"	EI_{30}	0.87	EI_{30} = 273.8 A - 56.5
	"	KE > 1	0.82	KE > 1 = 1047.9 - 1058.4
	"	AI_m	0.92	AI = 10.42 A - 6.9

E = foot - ton per acre *KE > 1 = foot-ton per acre*
EI_{30} = foot - ton per acre *AI_m = Cm^2/hr* *A = cm*

Table 8.5. Correlation coefficient (r) of run-off at different slopes (%) with various indices (1972)

Variable	*1%*	*5%*	*10%*	*15%*
$I_{7.5}$	0.44	0.43	0.39	0.38
I_{15}	0.68	0.69	0.67	0.70
$I_{22.5}$	0.75	0.75	0.75	0.78
I_{30}	0.81	0.81	0.80	0.83
$I_{37.5}$	0.86	0.85	0.85	0.87
I_{45}	0.87	0.87	0.87	0.89
$EI_{7.5}$	0.85	0.79	0.82	0.86
EI_{15}	0.85	0.78	0.80	0.85
$EI_{22.5}$	0.85	0.78	0.80	0.85
$EI_{37.5}$	0.85	0.78	0.80	0.83
EI_{45}	0.85	0.78	0.80	0.84

Table 8.6. Correlation coefficient (r) of run-off at different slopes with erosivity indices (1973).

Variable	*1%*	*5%*	*10%*	*15%*
I_{15}	0.75	0.75	0.82	0.74
$I_{22.5}$	0.84	0.85	0.90	0.81
I_{30}	0.89	0.89	0.92	0.85
$I_{37.5}$	0.87	0.89	0.90	0.81
I_{45}	0.91	0.91	0.93	0.88
$EI_{7.5}$	0.90	0.90	0.95	0.88
EI_{15}	0.92	0.91	0.95	0.89
$EI_{22.5}$	0.92	0.91	0.94	0.89
$EI_{37.5}$	0.93	0.93	0.95	0.88
EI_{45}	0.93	0.91	0.80	0.80

Table 8.7. Correlation coefficient (r) of run-off at different slopes (1%) with various erosivity indices (1974).

Variable	*1%*	*5%*	*10%*	*15%*
I_{15}	0.75	0.78	0.65	0.75
$I_{22.5}$	0.77	0.79	0.68	0.75
I_{30}	0.81	0.84	0.74	0.80
$I_{37.5}$	0.79	0.81	0.71	0.75
I_{45}	0.86	0.89	0.78	0.86
$EI_{7.5}$	0.78	0.85	0.71	0.79
EI_{15}	0.75	0.81	0.67	0.77
$EI_{22.5}$	0.73	0.79	0.67	0.74
$EI_{37.5}$	0.76	0.81	0.70	0.78
EI_{45}	0.79	0.84	0.74	0.81

A New Erosivity Index (AI_M).

The applicability of the EI_{30} index under tropical conditions needs further analysis. The parameters used for computing the EI_{30} index are kinetic energy (E) and maximum 30-minute intensity (I_{30}). The empirical bases for calculating kinetic energy of a storm seriously limits the applicability of EI_{30} for determining erosivity of tropical storms. Raindrop-size distribution and wind velocity associated with tropical rainstorms can cause error in computing kinetic energy. The kinetic energy values that Wischmeier calculated with this formula are therefore under-estimated. It

Table 8.8. Correlation coefficient (r) of soil loss at different slopes (1%) with various erosivity indices (1972).

Variable	*1%*	*5%*	*10%*	*15%*
I_{15}	0.79	0.64	0.55	0.67
$I_{22.5}$	0.82	0.66	0.57	0.76
I_{30}	0.85	0.69	0.59	0.83
$I_{37.5}$	0.87	0.72	0.60	0.86
I_{45}	0.88	0.72	0.61	0.89
$EI_{7.5}$	0.77	0.55	0.46	0.91
EI_{15}	0.76	0.53	0.44	0.90
$EI_{22.5}$	0.76	0.53	0.43	0.90
$EI_{37.5}$	0.76	0.53	0.43	0.89
EI_{45}	0.76	0.53	0.43	0.89

Table 8.9. Correlation coefficient (r) of soil loss at different slop (%) with various erosivity indices (1973).

Variable	*1%*	*5%*	*10%*	*15%*
I_{15}	0.60	0.20	0.79	0.66
$I_{22.5}$	0.70	0.22	0.81	0.69
I_{30}	0.75	0.26	0.81	0.73
$I_{37.5}$	0.70	0.31	0.77	0.65
I_{45}	0.77	0.28	0.82	0.75
$EI_{7.5}$	0.73	0.19	0.85	0.76
EI_{15}	0.75	0.18	0.83	0.78
$EI_{22.5}$	0.76	0.16	0.80	0.77
$EI_{37.5}$	0.74	0.20	0.78	0.73
EI_{45}	0.78	0.17	0.80	0.80

has been shown that an 8 mph wind can increase the kinetic energy of a rainstorm by 30%. The low correlation coefficients between soil loss and erosivity indices that include E may be attributed to these limitations. There is an urgent need to monitor the kinetic energy of tropical rainstorms and to develop empirical relationships involving parameters of intensity, drop-size distribution and wind velocity.

Table 8.10. Correlation coefficient (r) of soil loss at different slopes (1%) with various erosivity indices (1974).

Variable	*1%*	*5%*	*10%*	*15%*
I_{15}	0.72	0.79	0.62	0.65
$I_{22.5}$	0.63	0.69	0.54	0.63
I_{30}	0.68	0.69	0.51	0.57
$I_{37.5}$	0.56	0.48	0.51	0.55
I_{45}	0.67	0.64	0.53	0.66
$EI_{7.5}$	0.75	0.76	0.59	0.66
EI_{15}	0.64	0.73	0.48	0.66
$EI_{22.5}$	0.56	0.64	0.42	0.63
$EI_{37.5}$	0.57	0.61	0.40	0.59
EI_{45}	0.59	0.59	0.41	0.58

Table 8.11 Correlation coefficients of various erosivity indices with runoff and soil loss.

Year	Erosivity Index	Runoff 1%	5%	10%	15%	Soil loss 1%	5%	10%	15%
1972	A	0.66	0.54	0.62	0.64	0.94	0.72	0.52	0.86
	E	0.57	0.50	0.53	0.60	0.91	0.71	0.50	0.92
	EI_{30}	0.37	0.27	0.33	0.41	0.75	0.53	0.34	0.87
	AI_m	0.61	0.43	0.55	0.56	0.90	0.61	0.81	0.84
	KE>1	0.38	0.33	0.36	0.47	0.77	0.57	0.37	0.85
	I_m	0.68	0.51	0.60	0.66	0.82	0.59	0.46	0.67
1973	A	0.26	0.21	0.23	0.27	0.94	0.20	0.91	0.79
	E	0.30	0.24	0.29	0.31	0.93	0.21	0.93	0.81
	EI_{30}	0.37	0.30	0.38	0.36	0.82	0.14	0.86	0.81
	AI_m	0.30	0.19	0.31	0.31	0.86	0.11	0.88	0.77
	KE>1	0.38	0.30	0.40	0.39	0.87	0.20	0.91	0.83
	I_m	0.39	0.23	0.49	0.42	0.37	0.13	0.51	0.44
1974	A	0.15	0.21	0.07	0.56	0.59	0.72	0.68	0.71
	E	0.23	0.33	0.16	0.63	0.65	0.87	0.88	0.75
	EI_{30}	0.27	0.36	0.20	0.67	0.64	0.89	0.91	0.82
	AI_m	0.26	0.34	0.11	0.62	0.70	0.86	0.85	0.81
	KE>1	0.37	0.42	0.11	0.12	0.52	0.79	0.74	0.93
	I_m	0.34	0.42	0.16	0.54	0.60	0.68	0.68	0.65

The intensity parameter of the EI_{30} index also needs critical appraisal. The intensity of a temperate rainstorm rarely exceeds 50 mm/hr. Rainstorms of much higher intensities are frequent in the tropics, however, and intensities exceeding 100 mm/hr are not uncommon. A third factor that can influence the effectiveness of the EI_{30} index is the direction of the storm in relation to the direction of the slope. This parameter is particularly important on steeper slopes. Soil creep, the detachment and subsequent movement of soil downslope, can be significantly affected by the resolution of the impact momentum vector of the raindrop into its components. A fourth factor is socio-economic. The calculations involved in the EI_{30} index are cumbersome and skilled technicians and computer facilities are needed for correct and speedy calculations. Lack of such facilities and talent is a problem in many developing countries of the tropics.

The AI_m index, the product of the maximum intensity (I_m) in cm/hr and total rainfall (A) in cm has advantages over the EI indices. First, the AI_m index includes maximum intensity, an important factor in tropical rainstorms. It also includes total rainfall which takes into account the fact that a very intense storm that lasts only a short period and that results in low total rainfall is usually non-erosive. As pointed out in Chapter 5, slope-soil loss relationships are significant only for storms with more than 25 mm of rainfall.

Combining these two important parameters, maximum intensity and total rainfall, in one index provides a more accurate indication of rainstorm erosivity than using either of the parameters alone. Another advantage of the AI_m index is that it is simple to compute.

The AI_m index is definitely not the ultimate index, but should prove useful until something better comes along. The AI_m index, for example, can be improved further by incorporating a wind velocity factor that will reflect the kinetic energy of a windy storm.

The weighted-mean average correlation coefficients for all slopes and all years between runoff and soil loss and the KE>1, EI_{30} and AI_m erosivity indices are shown in Table 8.12. The AI_m index is more highly correlated with water runoff and soil loss than the other indices.

Preparation of Erosivity Maps from the Index:

The AI_m erosivity index is defined as:

$$AI_m = \sum_{1}^{l} [\sum_{1}^{k} ai_m] /100$$

In this index, a is the amount of rain in individual storm, i_m is the maximum intensity of the individual storm, k is 31 and l is 12. It is the summation of the product ai over all the rainy days in a year. If a is in cm and i in cm/hr, the unit of AI_m is cm^2/hr. AI_m is usually between 1 and

Table 8.12 Weighted Mean Average Correlation Coefficient (r) of Various Erosivity Indices with Runoff and Soil Loss from 10% Slope Plot with Barefallow Treatment.

Erosivity Index	Runoff	Soil Loss
KE>1	0.32	0.60
EI30	0.34	0.65
AI_m	0.37	0.69

10 for areas with annual rainfall up to 1000 mm, between 1 and 20 for areas that receive 1000 to 2000 mm of annual rainfall, and between 1 and 30 for areas that receive 2000 to 3000 mm of annual rainfall. Monthly AI_m indices for Ibadan during 1972, 1973 and 1974 are shown in Figure 8.1. The slope of the curve reflects erosivity during a given month or during any period in the year.

AI_M indices for a region connecting different ecological zones can be similarly plotted (Fig. 8.2). Such erosivity maps can help in designing

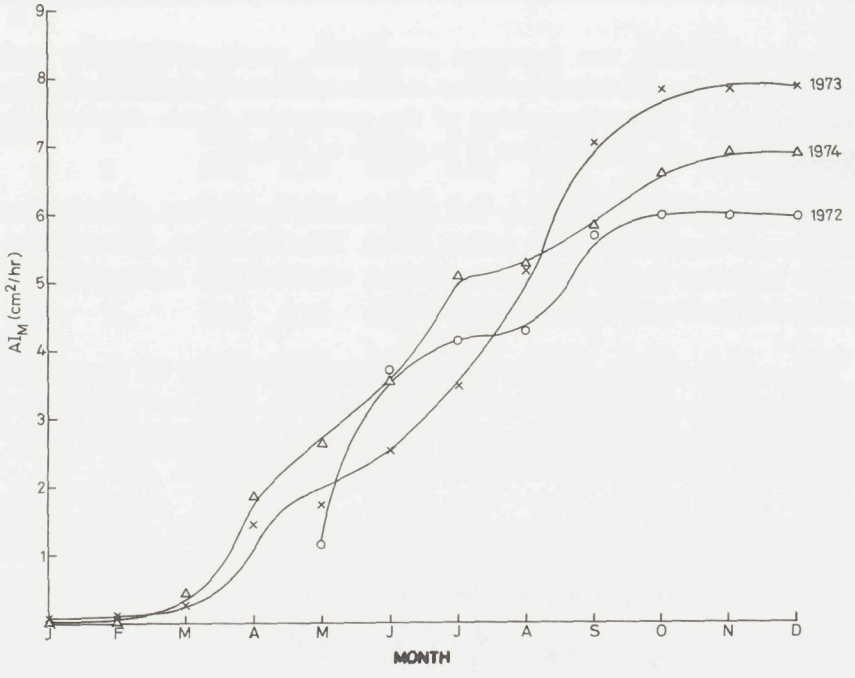


Fig. 8.1 Cumulative distribution of erosivity index AI_m from Ibadan. If one does not divide the R.H.S. of AI_m equation, the numerical value of AI_m (cm^2/hr) and EI_{30} (foot-tons per acre-inch) are identical. Hence it does not matter how K factor is computed by either by AI_m or EI_{30}.

erosion-control practices as well as in planning agricultural operations and developing soil and crop-management techniques suited to a given location.

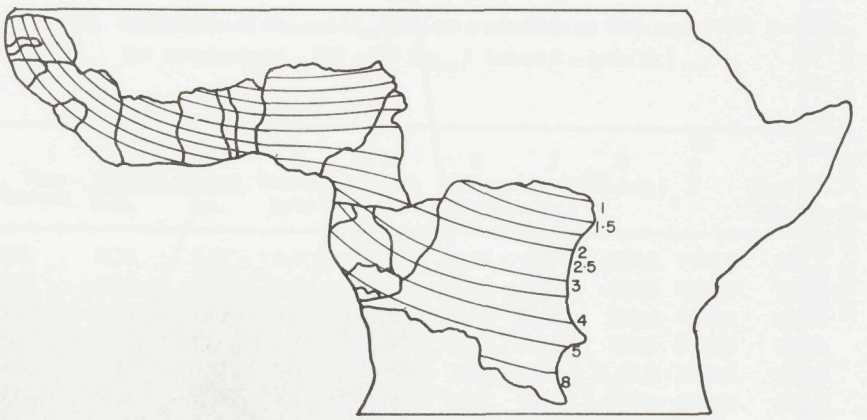


Fig. 8.2 A hypothetical iso-erodent map for West Africa.

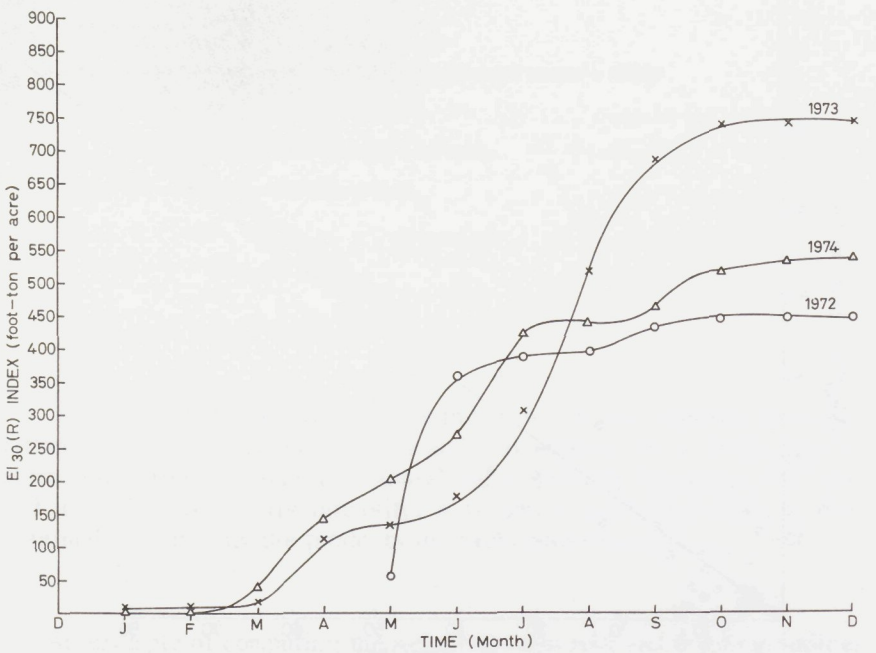


Fig. 8.3 Cumulative distribution of EI_{30} index for Ibadan.

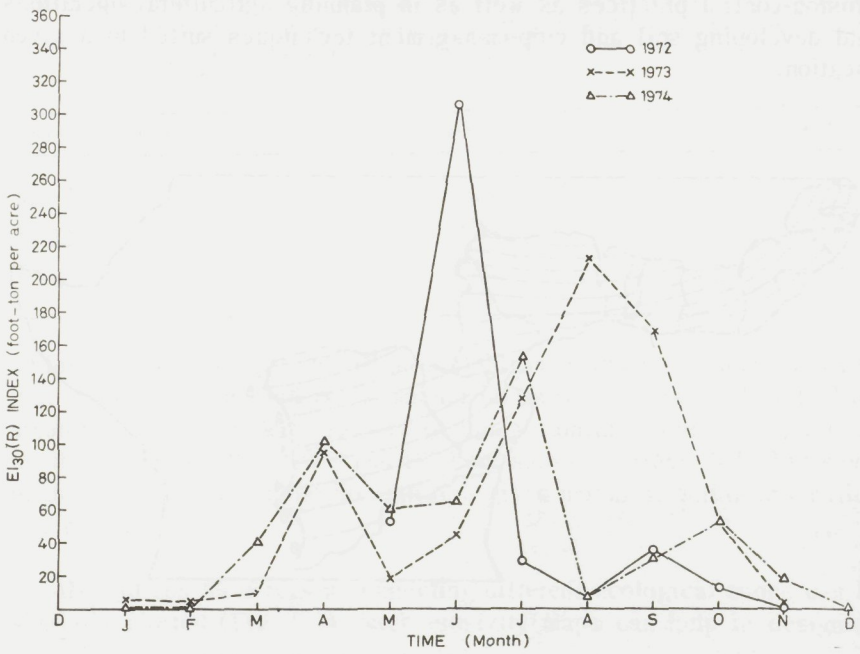


Fig. 8.4 Monthly distribution of EI_{30} index for Ibadan.

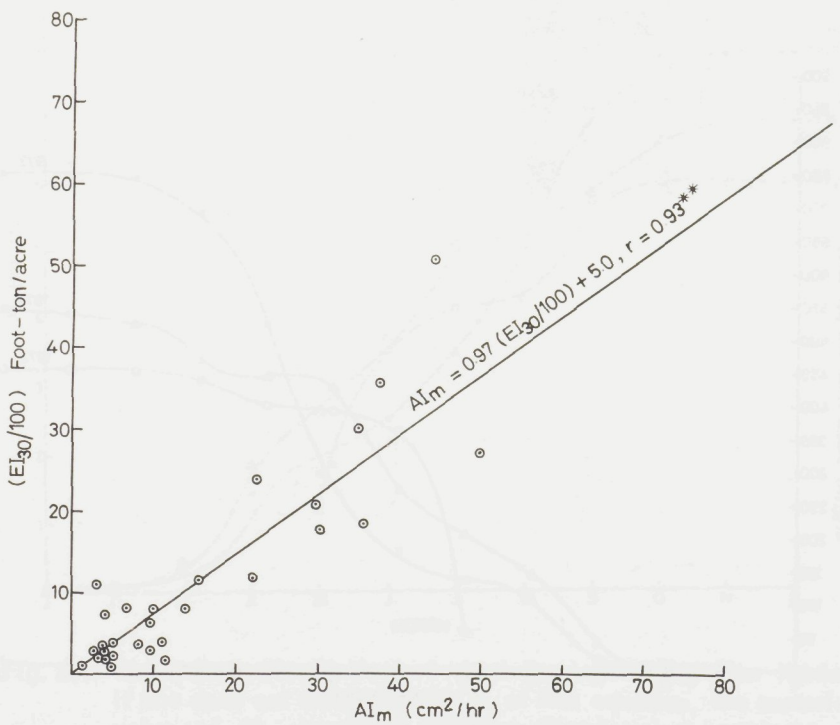


Fig. 8.5 Relationship between $(EI_{30}/100)$ in foot-ton/acre and AI_m (cm^2/hr) for individual storm.

Table 8.13. Computation of AI_m and EI_{30} index for a rainstorm on 16th June, 1972. E = (foot-ton per acre inch) = 916 + 331 $\log_{10}$ I (where I = inch/hr.)

1 Time Interval	2 Rainfall Amount inch.	3 Rainfall Amount cm.	4 Rainfall Intensity in/hr	5 Intensity cm/hr	6 aim (cm/hr)	7 Log I (in/hr)	8 331 Log I	9 E	Total E (9 x 2)
7.5	0.75	1.91	6.0	15.24	29.11	0.778	257.5	1173.5	880.1
7.5	0.65	1.65	5.2	13.21	21.26	0.716	236.9	1152.9	749.9
7.5	0.55	1.40	4.4	11.18	15.65	0.643	212.8	1128.8	620.8
7.5	0.45	1.14	3.6	9.14	10.42	0.556	184.0	1100.0	495.0
7.5	0.25	0.64	2.0	5.08	3.25	0.301	99.6	1015.6	253.9
7.5	0.55	1.40	4.4	11.18	15.65	0.643	212.8	1128.8	620.8
7.5	0.15	0.38	1.2	3.05	1.16	0.079	26.1	942.1	141.3
7.5	0.30	0.76	2.4	6.10	4.64	0.380	125.8	1041.8	312.5
7.5	0.20	0.51	1.6	4.06	2.07	0.204	67.5	983.5	196.1
7.5	0.25	0.64	2.0	5.08	3.25	0.301	99.6	1015.6	253.9
7.5	0.05	0.13	0.4	1.02	0.13	0.398	-197.7	784.3	39.2

$AI_m = \Sigma\ ai_m = 106.59$

AI_m *as obtained from peak intensity and total rainfall amount* = 160.93

Total E = 4563.17

I_{30} *(Maximum intensity in 30 minutes)* = 4.8 *in/hr.*

$EI_{30}/100 = (4563.17 \times 4.8)/100 = 219.03$

Another way to compute the AI_m index, which may improve the correlation coefficient between the AI_m and soil erosion, is to divide a rainstorm into different intensity classes and to multiply the amount of rainfall in each class by its intensity. A weighted mean AI_m index is then obtained by summing the products for each intensity class.

An example of computing the weighted-mean AI_m and the EI_{30} indices is shown in Table 8.13. As expected, the numerical value of the AI_m obtained by this method is lower than that computed from a single peak intensity value.

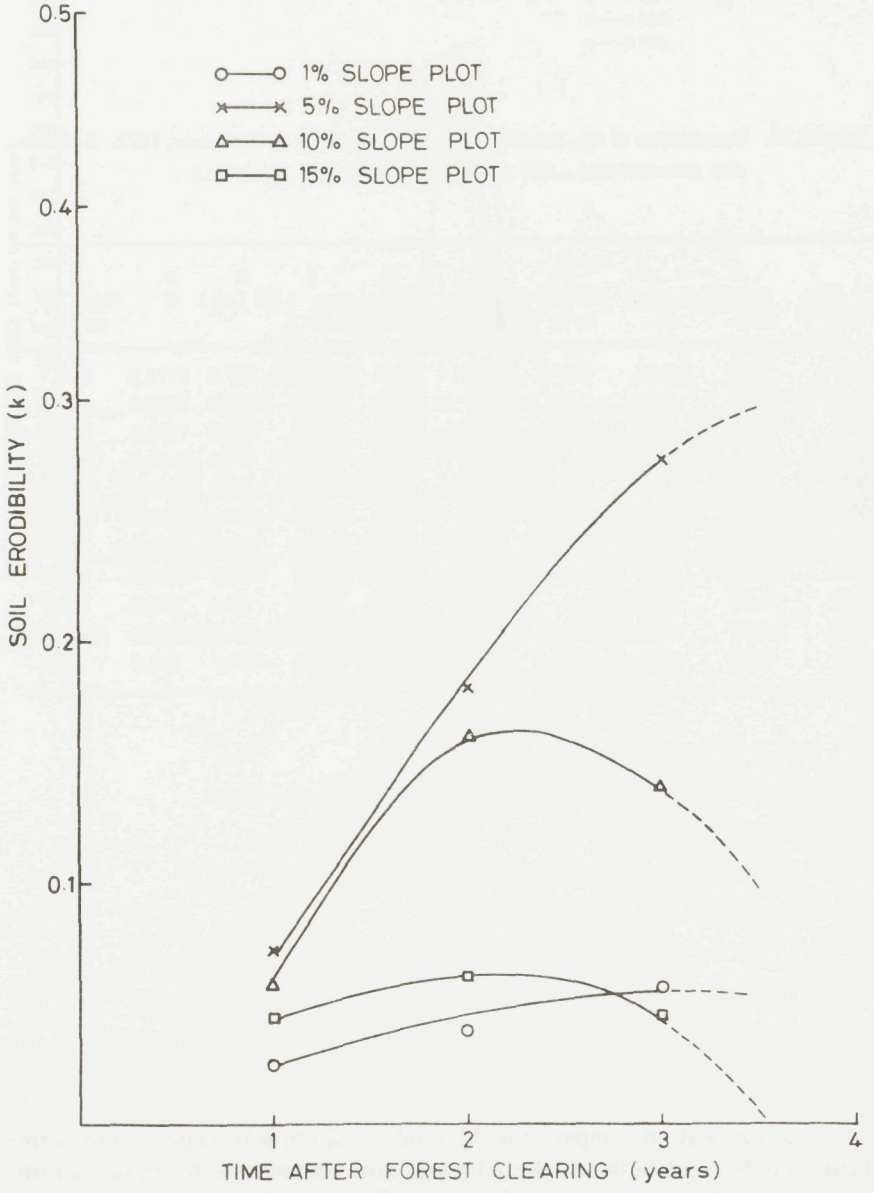


Fig. 8.6 Changes in soil erodibility factor (k) with time after forest clearing.

The distribution of the EI_{30} index and its relation to AI_m is shown in Figs. 8.3 – 8.5. When AI_m is not divided by 100, it is numerically identical to EI_{30}. Therefore, K factor does not alter significantly by using either of the two indices (Fig. 8.6).

REFERENCES

1. Adams, J. E., 1957. A rainfall simulator and erodibility of some Iowa soils. Iowa St. Coll. J. Sci. 31: 347-348.

2. Ahmad, N., and E. Breckner, 1974. Soil erosion on three Tobago soils. Trop. Agric. 51: 313-324.

3. Bruce-Okine, E., and R. Lal, 1975. Soil erodibility as determined by raindrop technique. Soil Sci. 119 (2) : 149-157.

4. Ekern, P. C., 1954. Rainfall intensity as a measure of storm erosivity. Proc. Soil Sci. Soc. Amer. 18: 212-216.

5. Ekern, P. C. and R. J. Muckenhirn, 1947. Water drop impact as a force in transporting sand. Proc. Soil Sci. Soc. Amer. 12: 441-444.

6. Ellison W. D., 1947. Soil erosion studies: Part 1. Agric. Eng. 28: 145-146.

7. Fournier, F., 1956. The effect of climatic factors on soil erosion. Estimates of solids transported in suspension in runoff. Ass. Int. Hydrol. Pub. 38: 6.

8. Fournier, F. and S. Henin., 1959. A new climatic formula for evaluating the specific degradation of soils. C. R. Acad. Sci., Paris. 248: 1694-1696.

9. Free, G. R., 1960. Erosion characteristics of rainfall. Agric. Eng. Mich. 41: 447-449, 455.

10. Hudson, N. W., 1971. Soil conservation. Batsford, London, 1971.

11. Lyles, L., L. A. Disrud and N. P. Woodruff, 1969. Effect of soil physical properties, rainfall characteristics and wind velocity on clod disintegration by simulated rainfall. Proc. Soil Sci. Soc. Amer. 33: 302-306.

12. Mihara, Y., 1953. Effects of raindrop and grass on soil erosion. Proc. Sixth Int. Grassl. Congr. 1953: 987-990.

13. Mookerjee, D., 1950. Anti-soil erosion equipment at Arabari, West Bengal. Cent. Bd. Irrig. J. 7: 191-193.

14. Rogers, J.S., L.C. Johnson, D.M.A. Jones and B.A. Jones, 1967 Sources of error in calculating the kinetic energy of rainfall. J. Soil and Water Conserv. 22 (4): 140-143.

15. Roose, E.J., 1973. Dix-sept années de mesures experimentales de l'erosion et du ruissellement sur un sol ferrallitique sableux de basse Cote d'Ivoire. Contribution a l'ètude de l'èrosion hydrique en milieu intertropical. ORSTOM, Adiopodoumé 125 p. These, Abidjan, N. 20.

16. Rose, E.E., 1960. Soil detachment caused by rainfall. Soil Sci. 89: 28-35.

17. Tamhane, R.V., T.D. Biswas and B. Das, 1959. Effect of intensity of rainfall on soil loss and runoff. J.Indian Soc. Soil Sci. 7:231-238.

18. Wischmeier, W.H., 1955. Punch cards record runoff and soil-loss data. Agric. Eng. 36: 664-666.

19. Wischmeier, W.H. and D.D. Smith, 1958. Rainfall energy and its relationship to soil loss. Trans. Amer. Geophysl. Union 39:285-291.

9

Effect of slope length on runoff and soil loss

The effect of slope length on runoff loss is not well understood and is a debatable issue. Slope length, as defined in the universal soil-loss equation, is the distance from the point of origin of overland flow to either the point where the slope decreases to the extent that deposition begins or the point where runoff enters a well defined channel that may be part of a drainage network or a constructed channel such as a terrace or diversion (Smith and Wischmeier, 1957). Therefore, the slope length factor (L) is the ratio of runoff/soil loss from a particular slope length to that from a 72.6 foot length when all other conditions are the same.

Wischmeier (1966) reported from his investigations on 21 locations that the effect of slope length on runoff per unit area was of questionable significance. He found that for 18 locations the total growing season runoff per unit area was greatest on short slopes. Total dormant season runoff was found to be greater on longer slopes for 11 locations, but it was equal to or greater than the runoff on the short slopes for the other 10. Borst and Woodburn (1942) also found no significant effect of slope length on water runoff.

Numerous studies, however, have shown that the soil loss per unit area is related to slope length. The effect of slope length on soil loss may be a result of increased erosive potential due to greater accumulation of runoff on longer slopes. Runoff velocity increases with an increase in runoff accumulation. Zingg (1949) reported that average soil loss per unit area increased in proportion to the 0.6 power of slope length. Musgrave (1947) found that exponent m, $(\lambda/72.6)^m$, was 0.35. Wischmeier (1972) has shown that the value of the m exponent varies from 0.3 to 0.7 with a median value of 0.45.

Another complicating factor in defining the exact relationship between slope length and runoff and soil loss from field plot experiments is the nature of the slope. Runoff and soil loss are significantly influenced by whether the slope is convex, concave, complex or regular. Gard and Van Doren (1950) reported that on a 5% slope, 210-foot plots had less runoff and soil loss per unit area than plots 140 feet long. They reported that erosion on concave slopes was worse than the soil-loss measurement implied. Lixandru (1968) reported from Rumania that soil and water losses

on 12% regular-slope plots increased with increase in length up to 35 meters. Young and Mutchler (1969) concluded that soil loss from irregular slopes depended on the steepness of a short section of the slope immediately above the point of measurement. They visualized that soil was primarily transported by raindrop splash to a rill system and downward by runoff in the rills. A breakdown of the rill system at the bottom of concave slopes (due to decreasing local steepness) resulted in sheet flow and sediment deposition thereby decreasing the soil loss from concave slopes.

Nature of Slope on IITA's Slope-Length Plots

The slope-length plots at IITA are not of regular slope. There are two general slopes of 10% and 15%. On each of the slopes, plots of 12.5m and 37.5m were set up. The general nature of the slopes of these plots is shown in Fig. 9.1. The longer plot on the 10% slope has an exact slope

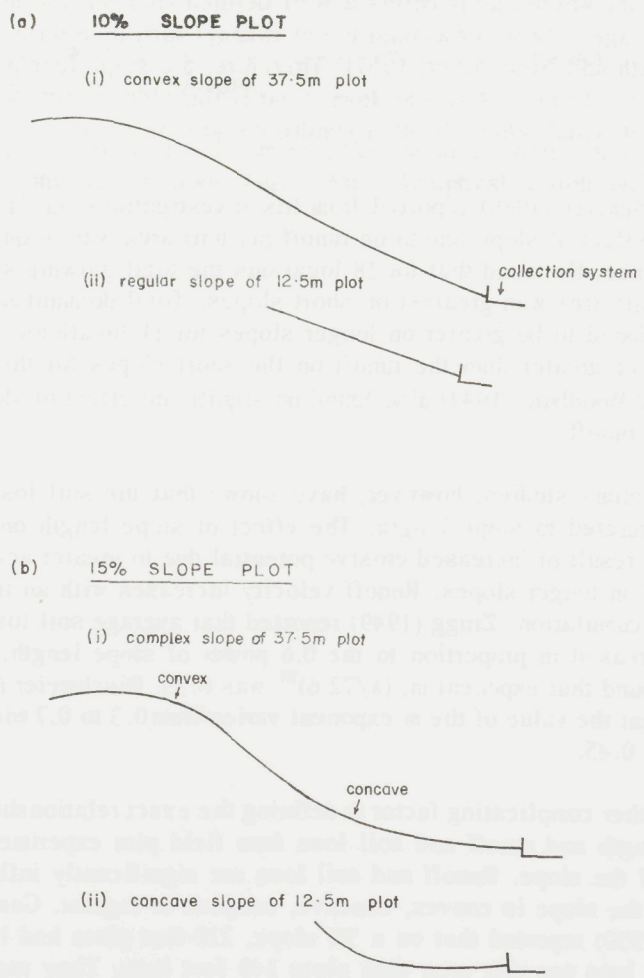


Fig. 9.1 Slope characteristics and slope length of runoff plots at 10 and 15 percent slopes.

of 9.3% and the slope is convex with curvature about 27m from the collection system. The 12.5-m plot on the 10% slope has a regular 10% slope. The 37.5m plot on the 15% slope has a mean slope of 13.4%,but the slope is a complex with a convex curvature about 27 m and a concave curvature about 10 m from the collection system. The 12.5 m plot on the 15% slope has a mean slope of 19.4% with a concave curvature about 10 m from the collection system. While such complexity could be considered an undesirable complication it is by no means typical of the forest areas of West Africa.

The interpretation of the results from these plots, therefore, must include consideration not only of degree and length of the slopes but also of the nature of the slopes.

Effect of Slope Length on Runoff and Soil loss Under Maize-Cowpea Rotation for Irregular Slopes:

The runoff and soil loss data for 1972 and 1973 are shown in Tables 9.1 and 9.2 respectively. Regardless of the slope, runoff loss per unit area was always less on the longer slopes than on the shorter slopes. The mean water runoff for 1972 was in the ratio of 1:1.76 for long and short slopes. Similar water runoff data for 1973 was in the ratio of 1:2.42. The average soil loss during 1972 was similar to that of water runoff with a ratio of 1:1.77 for long and short slopes. In 1973, the soil loss data were in the ratio of 1:1.50.

Table 9.1. Effect of contour length on runoff and soil loss under maize-cowpea rotation (a) First season 1972. Rainfall–

Runoff/ Soil loss	*12.5 m long*		*37.5 m long*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	230.2	214.3	133.6	125.8
Soil loss (tons/ha)	21.2	7.9	11.4	5.9
Slope	Regular	Concave	Convex	Complex

(b) Second season 1972. Rainfall –

Runoff/ Soil loss	*12.5 m long*		*37.5 m long*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	18.8	21.7	9.1	7.7
Soil loss (tons/ha)	2.7	3.2	1.4	1.1

The effect of the nature of the slope on water runoff and soil loss is obvious from the data presented in Tables 9.1 and 9.2. Total soil loss during 1972 from the 12.5-m plot of regular 10% slope was 23.9 ton/ha compared to 12.8 ton/ha of soil loss from the 37.5 m plot of irregular 10% slope. During 1972, 2.15 times as much soil was lost from the 12.5 m plot of 10% regular slope as from the 12.5 m plot of 19.2% concave slope. During 1973, 54% more soil was lost from the regular slope than from the steeper concave slope.

Table 9.2. Effect of contour length on runoff and soil loss under maize-cowpea rotation (a) First season 1973 Rainfall –

Runoff/ Soil loss	*12-5 m long*			*37.5 m long*
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	193.1	203.0	88.5	80.5
Soil loss (tons/ha)	31.3	22.8	21.5	15.8

(b) Second season 1973. Rainfall –

Runoff/ Soil loss	*12.5 m long*			*37.5 m long*
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	88.1	55.1	25.7	28.0
Soil loss (tons/ha)	5.2	0.9	1.5	1.4

Table 9.3. Effect of contour length on runoff and soil loss under bare fallow treatment. (a) First season 1974.

Runoff Soil loss	*12.5 m long*		*37.5 m long*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	302.7	260.4	175.6	157.3
Soil loss (tons/ha)	77.3	34.6	114.3	68.6
Slope	Regular	Concave	Convex	Complex

(b) Second season 1974.

Runoff Soil loss	*12.5 m long*		*37.5 m long*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
Runoff (mm)	162.4	140.7	52.3	52.7
Soil loss (tons/ha)	32.3	14.0	40.2	26.8

Also during 1972, 83% more soil was lost from the 37.5 m plot of 9.3% convex slope than from the 37.5 plots of 13.4% complex slope. Similar data for 1973 indicate that 34% more soil was lost from the convex slope than from the complex slope.

It is justified to conclude, therefore, that the nature of slope was more important than the degree of slope within the slope ranges of the present investigations. Under maize-cowpea rotation, convex and regular slopes had higher runoff and soil losses than concave slopes.

Effect of Slope Length on Runoff and Soil Loss Under Bare fallow Treatments for Irregular Slopes:

Data presented in Table 9.3 indicate the interaction between the nature of slope, the degree of slope and slope length on runoff and soil loss. Once again, water runoff is greater on the shorter slopes than on the longer ones. The water runoff per unit area on the 12.5 m plots was twice that from the 37.5 m plots. The soil loss on from the 37.5 m plots was 58% greater than that from 12.5 m plots.

The effect of the nature of the slope on runoff can be seen by comparing water runoff per unit area from the 12.5 m plot of 10.0% regular slope with that of the 12.5 m plot of 19.2% concave slope. The water runoff from the 10% regular slope was 16% more than that from the 19.2% concave slope. The soil loss however, was 2.25 times greater from the regular slope than from the concave slope of the same length and double the gradient.

A similar comparison for 37.5 m plots indicates the effect of convex versus complex slope on water runoff and soil loss. The 37.5 m plot of 9.3% convex slope had 8.5% more water runoff and 62% more soil loss per unit area than the same length plot of 13.4% complex slope.

CONCLUSIONS

- Water runoff per unit area was always greater from shorter than from longer slopes.
- Under maize-cowpea rotation, more soil and water loss per unit area was lost from convex and regular slopes than from complex or concave slopes. The soil and water loss per unit area was also greater from shorter than from longer slopes.
- Under bare fallow, although water runoff per unit area was higher from shorter than from longer slopes, soil loss generally increased with increasing slope length.

REFERENCES

1. Borst, H. L. and R. Woodburn, 1942. The effect of mulching and methods of cultivation on runoff and erosion from Muskingum silt loam. Agr. Eng. 23: 19–22.

2. Gard, L. E. and C. A. Van Doren, 1950. Soil losses as affected by cover, rainfall and slope. Soil Sci. Soc. Amer. Proc. 14: 374–378.

3. Jamison, V. C. and D. B. Peters, 1967. Slope length of claypan soil affects runoff. Water Resources Res. 3: 471–480.

4. Lixandru, G., 1968. Determination of critical slope length in relation to erosion. Stiinta Sol. 6: 12–18

5. Musgrave, G. W., 1947. Quantitative evaluation of factors in water erosion – a first approximation. J. Soil and Water Conserv. 2: 133–138.

6. Smith, D. D. and W. H. Wischmeier, 1957. Factors affecting sheet and rill erosion. Amer. Geophys. Union Trans. 38: 889–896.

7. Wischmeier, W. H. 1966. Relation of field-plot runoff to management and physical factors. Soil Sci. Soc. Amer. Proc. 30: 272–277.

8. Wischmeier, W. H., 1972. Upslope erosion analysis. Chapter 15 in H. W. Shen, ed. Environmental Impact on Rivers, Colorado State University, Fort Collins.

9. Wischmeier, W. H., D. D. Smith and R. E. Ukland, 1958. Evaluation of factors in the soil-loss equation. Agr. Eng. 39: 458–462.

10. Young, R. A. and C. K. Mutchler, 1969. Soil movement on irregular slopes. Water Resources Res. 5: 1084–1089.

11. Zingg, A. W. 1940. Degree and length of land slope as it affects soil loss in runoff. Agr. Eng. 21: 59.

10

Nutrient loss in water runoff

Lack of response or relatively little response to applied fertilizer in tropical soils may be attributed to leaching losses and partially to losses in water runoff and eroded sediments. The eutrophication of waters in rivers and streams is also the direct result of these losses. Quantitative information of the magnitude of such losses from West African soils is rather scanty, but there is little doubt that the removal of solutes and the loss of applied fertilizer are important factors depleting soil fertility. Various workers have attempted to estimate the quantity of solutes lost from soils in temperate regions.Drum et al (1960) for example, reported a loss of 82 $t/mi^2/yr$ of solutes from soils in the U.S. and 44.5 $t/mi^2/yr$ from soils in the U.S.S.R.

Losses of P in runoff water and eroded sediments in temperate regions have received the attention of various workers (Ryden et al, 1973). Duley (1926) reported that the major loss of P in runoff water was through eroded sediments. These results were reported from Georgia where P losses of only 0.03 to 0.04 kg/ha/yr were found in the runoff water. Engelbrecht and Morgan (1961) found P losses ranging from 0 to 16 kg/ha/yr in surface drainage water in Illinois. Munn et al (1973) reported that simulated runoff tests conducted on micro-plots of some Ohio soils showed a significant correlation between total phosphorus in runoff and the amount of soil removed by erosion. From watershed investigations, Schuman et al (1973) reported a loss of 0.5 to 2.1 kg/ha of P in water runoff.

Although the literature indicates that most of the P losses occur through eroded sediments, the concentration of P in runoff water has been reported high enough to be a primary cause of eutrophication of water supplies.

There have been many reports conceming the loss of nitrogen and other nutrient elements in runoff water. Rogers (1944) reported that eroded sediments from corn land were richer in N and P than the original soil. Bryant and Slater (1948) found from their studies in Iowa that although only small amounts of soluble material were lost in runoff water, the removal of solutes and the loss of applied fertilizers were important factors in soil fertility depletion. Mattyasovszky and Duck (1954) reported that runoff water from a heavy storm carried 9.8 ppm of NO_3-N and 3.2 g/1

of sediment. Moe et al (1967) found less than 2 kg/ha of urea-N in runoff water. Total loss of N in this study ranged from 2.4 to 12.7% of applied N. In other investigations,these authors reported that the maximum loss of N in runoff water from a 12.5-cm storm amounted to 15% of the applied fertilizer. Frere (1971) found considerable variation in the nutrient contents of runoff from different watersheds. When a major storm was composed of more than one peak, the average nutrient concentration varied by as much as 200 percent between waterflow peaks. Barnett et al (1972) reported from their studies on some Puerto Rican soils that the average concentration of N in runoff water ranged from 0.01 to 0.02 ppm and the average concentration of K varied from 0.01 to 2.29 ppm. Nutrient lósses in runoff water in northern Nigeria have been reported by Kowal(1972). The average annual loss of Ca, Mg, and Na in runoff water and eroded soil varied from 14 to 30 kg/ha. The average annual N loss ranged from 7 to 19 kg/ha.

Methods of Sample Collection and Water Analyses:

In the studies reported here runoff water samples from each of 24 plots were collected after every storm during 1972 and 1973 and were either analyzed immediately or stored at 4°C pending anlysis.The water samples were analyzed for pH, conductivity, NO_3-N, PO_4-P, K, Ca and Mg. The concentration of Ca and K were determined by flame photometry and the concentration of Mg by atomic absorption spectrophotometry. Phosphorus was measured colorimetrically using the molybdic acid-blue method; NO -N was measured colorimetrically using brucine(Greweling and Peach, 1965).

NUTRIENT CONTENTS

(A) *Effect of Cropping Sequence and Soil Management: 1972–73 Results:*

The pH of the runoff water was significantly affected by soil and crop management treatments. For instance during April 1973, the pH of runoff water from bare-fallow plots was 6.6 and the pH of runoff water from mulched and no-tillage plots was 7.1. By October 1973, the pH of runoff water from bare-fallow plots was 5.9; from cowpea-maize (conventional plowing) plots, 6.4; from maize-maize (conventional plowing) plots, 6.5; from maize-cowpea (no-tillage) plots, 6.6; and from maize-maize (mulched) plots, 6.7.

Total Nutrient Loss:

Total nutrient losses in the runoff water were proportional to the surface runoff and were, therefore, affected both by slope and soil-management treatments (Figures 10.1 and 10.2) The nutrient losses from the no-tillage plots during 1972 must be viewed separately because the soil surface had been disturbed and there was no surface mulch. For the sake of comparison among treatments, therefore, the results of the 1973 studies are discussed here.

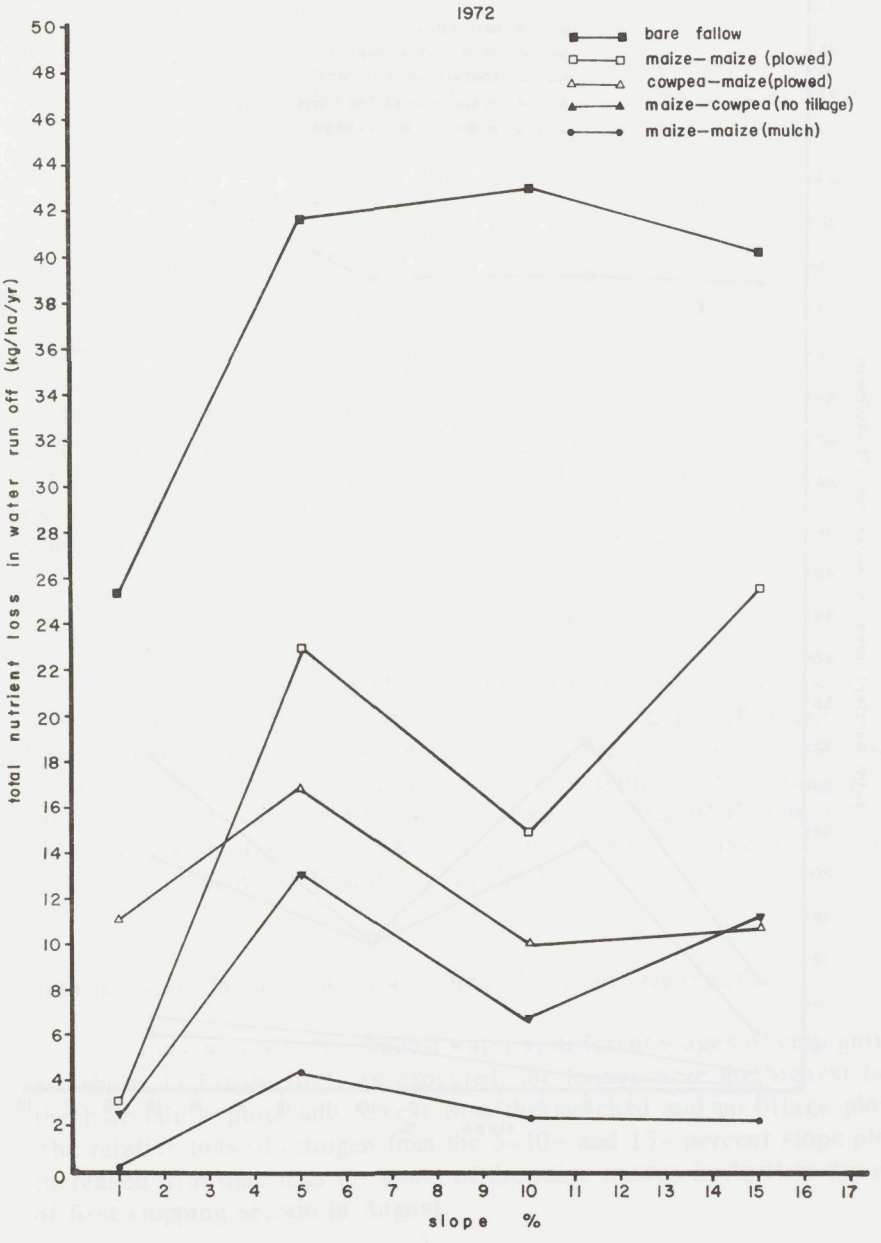


Fig. 10.1 Effects of slopes, crop rotations and residue management on loss of total nutrient elements in runoff water in 1972.

Total nutrient losses in runoff water followed the order of bare-fallow> maize-maize (conventional plowing)> cowpea-maize (conventional plowing) maize-cowpea (no-tillage)> maize-maize (mulched). Total annual nutrient losses from the bare-fallow plots ranged from 74 to 84 kg/ha.

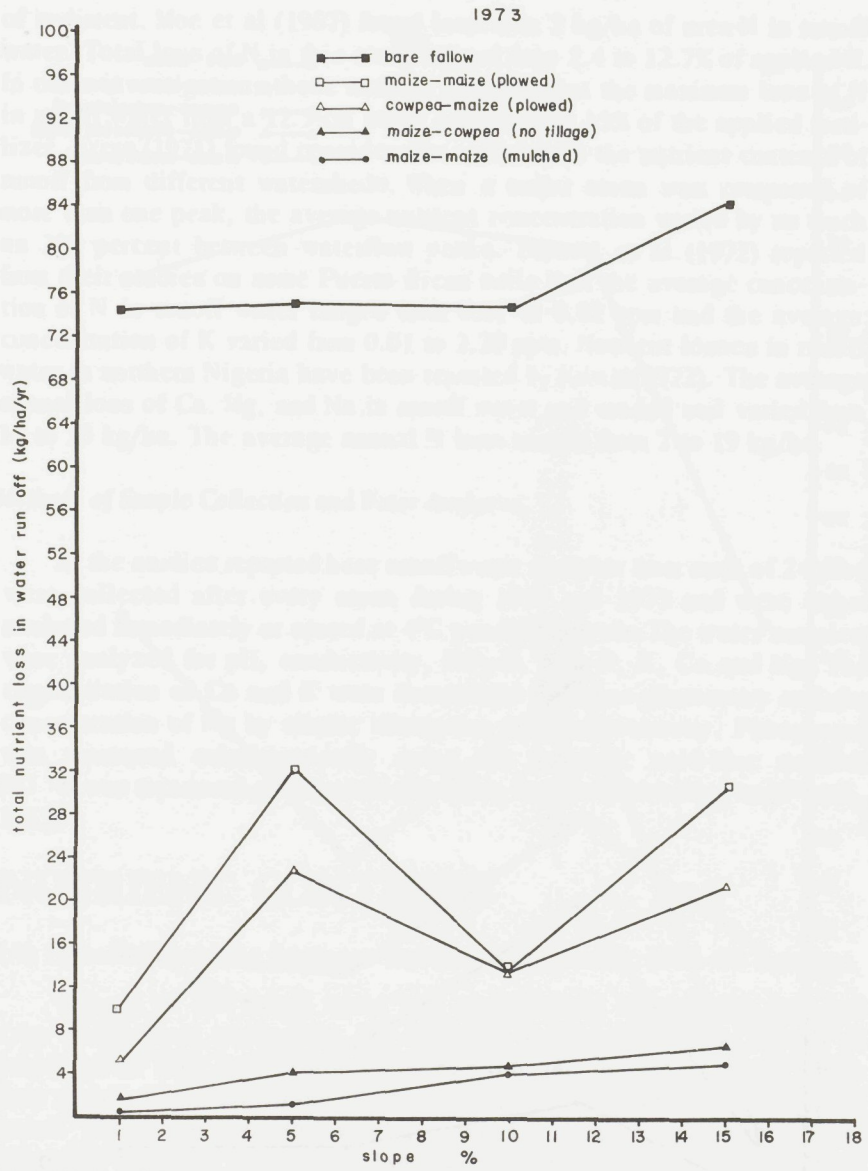


Fig. 10.2 Effects of slopes, crop rotations and residue management on loss of total nutrient elements in runoff water in 1973.

Total annual nutrient losses from the maize-maize (conventional plowing) plots varied from 10 to 32 kg/ha and those from the cowpea-maize (conventional plowing) from 5 to 23kg/ha. The total annual nutrient losses from the mulched and no-tillage plots were the lowest and ranged from 0 to 5 kg/ha from the mulched plots and 2 to 7 kg/ha from the no-tillage plots.

Loss of Different Plant Nutrients:

The effects of soil and crop management treatments on losses of various plant nutrients in runoff water for both growing seasons of 1972 and 1973 are shown in Tables 10.1, 10.2, 10.3 and 10.4. Only the results of the 1973 studies are discussed here.

There were no definite trends in nutrient losses with regard to slope steepness. The highest nutrient loss occurred from the bare-fallow plots and the lowest from the mulched and no-tillage plots. The losses of NO_3-N in the runoff water from the 5% slope plots during the first season 1973 were 3.3 kg/ha from the bare-fallow plot, 1.5 kg/ha from the maize-maize (conventional plowing) plot, 0.1 kg/ha from the no-tillage plot and 0.04 kg/ha from the mulched plot. The losses of P were less, ranging from 0 to 1.5 kg/ha from 5% slope plots. The losses of K ranged from 0.1 to 9 kg/ha, those of Ca from 0.1 to 19 kg/ha and those of Mg from 0 to 3.3 kg/ha. Similar losses were recorded during the second season.

Effect of Length of Slope on Nutrient Loss in Water Runoff:

The effect of length of slope on nutrient loss during the first and second seasons of 1972 and 1973 are shown in Tables 10.5 and 10.6. Nutrient losses in water were proportional to the quantity of runoff and, therefore, the analysis presented in Chapter 9 applies here. During 1972 losses of NO -N varied from 0.09 to 6.0 kg/ha, those of P from 0.06 to 1.9 kg/ha, those of K from 0.5 to 13.4 kg/ha, those of Ca from 0.3 to 14.1 kg/ha, and those of Mg from 0.3 to 4.2 kg/ha.

Nutrient Losses in Runoff Water at Different Stages of Crop Growth:

The losses of NO -N in runoff water at different stages of crop growth are shown in Figure 10.3. As expected, the losses were the highest from the bare-fallow plots and lowest from the mulched and no-tillage plots. The relative loss of nitrogen from the 5–10– and 15– percent slope plots increased with time from the onset of the rainy season in April to the end of first cropping season in August.

The change in the hydro-thermal regime of the soil from hot and dry at the beginning of the season to cool and moist toward the end may be one of the reasons for higher nitrate losses in runoff water during August. Similar data on P, K, Ca and Mg losses from the 5 percent slope plots are shown in Figure 10.4. While the losses of NO_3-N increased during the growing season, P, K, Ca and Mg losses were highest during mid-season and decreased markedly toward the end.

Table 10.1. Nutrient loss in runoff water (kg/ha) for different slopes and soil management treatments. (First season 1972)

Rotation	1%					5%					10%					15%				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
Bare	3.85	0.41	4.540	8.07	1.80	6.25	0.63	7.50	14.60	2.69	7.34	1.81	8.30	15.67	4.78	5.25	0.54	6.17	14.87	4.77
Maize (mulch)	0.002	0.001	0.006	0.04	0.006	1.11	0,03	0.51	2.19	0.09	0.24	0.14	0.23	0.58	0.12	0.29	0.02	0.34	0.78	0.13
Maize	2.42	0.14	1.48	4.66	0.60	1.99	0.39	3.81	5.84	2.05	1.92	0.14	1.86	3.23	0.59	2.09	0.17	2.29	2.05	1.71
Maize (no-tillage)	0.42	0.34	0.39	0.87	0.45	1.83	0.41	5.58	11.26	2.96	2.73	0.35	3.58	4.41	2.30	3.06	0.34	4.40	12.86	3.65
Cowpea (plowed)	0.15	0.014	0.24	0.28	0.58	0.80	0.17	3.04	3.65	0.76	0.63	0.09	1.65	2.91	0.24	0.74	0.96	2.10	1.79	0.46

Table 10.2. Nutrient loss in runoff water (kg/ha) as affected by different slopes and soil management treatments. (Second season 1972)

Rotation	1%					5%					10%					15%				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
Bare	0.48	0.26	0.62	4,95	0.41	0.68	0.21	1.18	7.59	0.40	0.28	0.16	0.61	4.28	0.37	0.80	0.53	0.83	5.89	0.49
Maize (mulch)	0.00	0.00	0.00	0.00	0.00	0.02	0.004	0.03	0.25	0.02	0.06	0.02	0.13	0.72	0.07	0.05	0.02	0.10	0.57	0.04
Maize	0.04	0.02	0.08	1.69	0.01	0.19	0.03	0.25	2.14	0.18	0.10	0.07	0.20	1.68	0.13	0.18	0.10	0.29	1.63	0.14
Cowpea (no-tillage)	0.03	0.03	0.04	0.29	0.02	0.08	0.02	0.12	0.74	0.06	0.10	0.04	0.29	1.03	0.09	0.07	0.04	0.21	0.98	0.08
Maize	0.02	0.05	0.13	0.90	0.09	0.53	0.09	0.46	3.39	0.32	0.13	0.03	0.22	0.73	0.10	0.44	0.29	0.63	3.31	0.28

Table 10.3. Nutrient loss in run-off water (kg/ha) as affected by different slopes and soil management treatments (First Season 1973)

Rotation	1%					5%					10%					15%				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
Bare	3.86	1.73	7.35	11.88	3.12	3.29	1.49	9.12	19.07	3.29	3.74	1.54	8.28	21.88	4.24	4.25	1.97	10.36	21.53	6.54
Maize (Mulch)	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.12	0.14	0.03	0.14	0.07	0.62	0.30	0.11	0.16	0.80	0.44	0.22	0.10
Maize	0.54	0.48	2.01	3.31	0.74	1.52	1.18	8.00	11.21	2.54	0.43	0.36	2.21	3.91	0.91	0.80	0.86	4.86	9.01	1.76
Maize (No-tillage)	0.12	0.04	0.21	0.17	0.06	0.13	0.10	0.56	0.53	0.24	0.11	0.07	0.45	0.30	0.12	0.12	0.89	0.69	0.25	0.31
Cowpea (Plowed)	0.15	0.27	0.74	1.35	0.29	0.76	0.34	5.23	6.42	1.21	0.35	0.40	1.93	2.55	0.65	0.32	0.44	2.32	1.70	0.76

Table 10.4. Nutrient loss in run-off water (kg/ha) as affected by slope and soil management treatment (Second Season 1973)

Rotation	1%					5%					10%					15%				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
Bare	11.37	1.88	9.62	18.21	5.20	7.54	1.92	8.31	17.54	3.48	7.75	2.18	9.92	12.06	2.75	8.94	2.71	9.03	15.80	2.77
Maize Maize (Mulch)	0.00	0.00	0.00	0.00	0.00	0.22	0.02	0.20	0.22	0.05	0.44	0.93	0.74	0.47	0.15	0.51	0.13	1.60	0.77	0.23
Maize	0.50	0.10	0.80	0.92	0.15	1.60	0.31	3.52	2.01	0.39	1.12	0.26	2.09	1.88	0.38	2.09	0.84	5.37	3.89	0.96
Cowpea (No-tillage)	0.30	0.03	0.25	0.41	0.19	0.32	0.07	1.31	0.47	0.14	0.48	0.13	2.03	0.80	0.18	0.51	0.12	2.82	0.75	0.30
Maize (Plowed)	0.48	0.17	0.72	0.68	0.24	1.79	0.41	3.76	2.54	0.75	0.94	0.35	3.39	2.47	0.65	2.32	1.23	5.10	6.06	1.21

Table 10.5. Contour length and nutrient loss (kg/ha) in run-off (a) First season 1972

Slope	12.5 m long					37.5 m long				
%	NO_3-N	PO_4-P	K	G	Mg	NO_3-N	PO_4-P	K	G	Mg
10.0	6.00	0.60	6.46	8.48	2.70					
19.2	3.51	0.70	5.77	18.89	2.65					
9.3						1.65	0.44	3.42	13.77	1.18
13.4						2.01	0.29	5.84	11.75	5.06
				(b) Second season 1972						
10.0	0.08	0.08	0.52	3.93	0.32					
19.2	0.52	0.13	0 47	4.63	0.45					
9.3						0.09	0.06	0.26	1.91	0.17
13.4						0.15	0.07	0.27	1.89	0.21

Table 10.6. Contour length and nutrient loss in water kg/ha. (a) First season 1973

Slope	12.5 m long					37.5 m long				
%	NO_3-N	PO_4-P	K	G	Mg	NO_3-N	PO_4-P	K	G	Mg
10.0	2.69	1.87	11.06	14.11	3.05					
19.2	2.19	1.75	10.60	13.72	4.24					
9.3						0.87	0.87	4.37	6.54	1.64
13.4						0.57	0.60	3.78	6 18	1.55
				(b) Second season 1973						
10.0	2.51	0.91	13.40	6.98	1.42					
19.2	1.23	0.41	6.72	2.97	0.76					
9.3						0.68	0.25	3.27	1.79	0.28
13.4						0.80	0.22	2.98	1.28	0.33

Relative Nutrient Concentration in Runoff Water:

Relative nutrient concentrations in runoff water on October 22, 1973 are shown in Figure 10.5. The concentration of NO_3-N in runoff water was only slightly affected by soil, slope and crop-management treatments. Nitrate concentration ranged from 4 to 6 ppm. Concentrations of PO_4-P, K, Ca and Mg, however, were significantly influenced by different treatments. The phosphate concentration was the highest in the runoff water from the cowpea plots in the maize-cowpea rotation with both no-tillage and conventional plowing treatments. The Ca concentration was significantly higher in the runoff water from the bare-fallow plots than in the

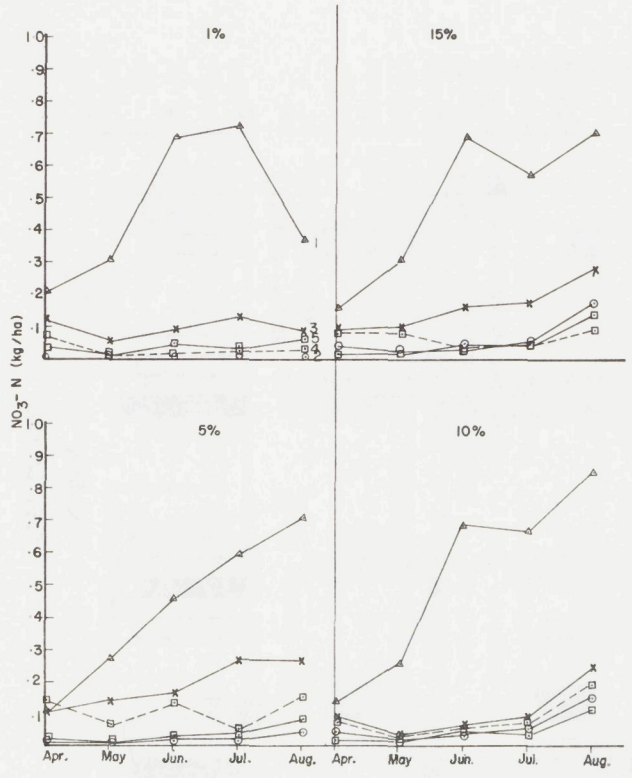


Fig. 10.3 Loss of NO_3-N in runoff water at different stages of crop growth as influenced by soil management and crop rotation treatments.

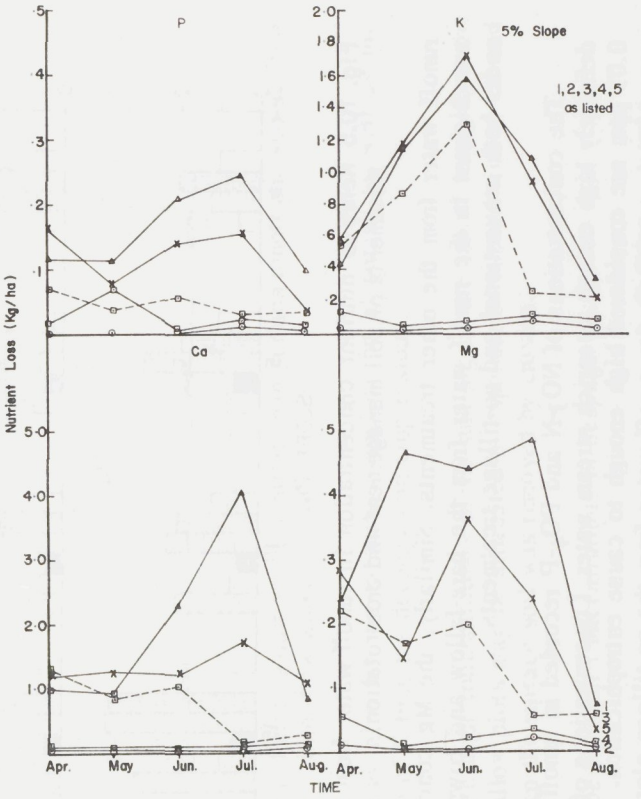


Fig. 10.4 Loss of nutrient elements such as P, K, Ca and Mg in water runoff at different stages of crop growth.

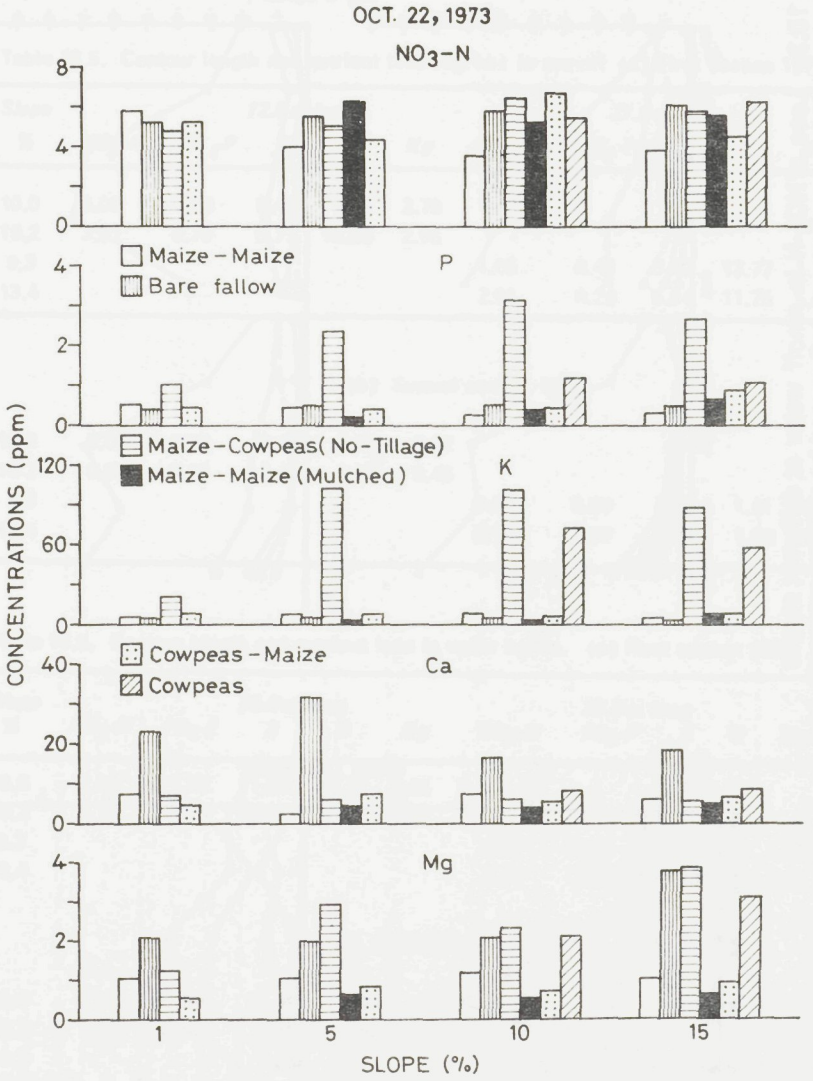


Fig. 10.5 Relative nutrient concentration in runoff water from different treatments of soil management and crop rotation.

runoff water from the other treatments. Similarly, the Mg concentration was highest in the runoff water from the bare-fallow and cowpea plots under both conventional and no-tillage treatments.

The concentrations of NO_3-N and PO_4-P recorded in runoff water is definitely high enough to enrich stream water. Concentrations of P above 0.05 ppm are considered high enough to cause eutrophication. The high concentrations of P in the runoff water from the no-tillage plots may be due to surface application of the fertilizer and the high solubility of superphosphate in the partially decomposed mulched layer (Fink and Wesley, 1974). The high concentrations of K in the runoff water from the no-tillage

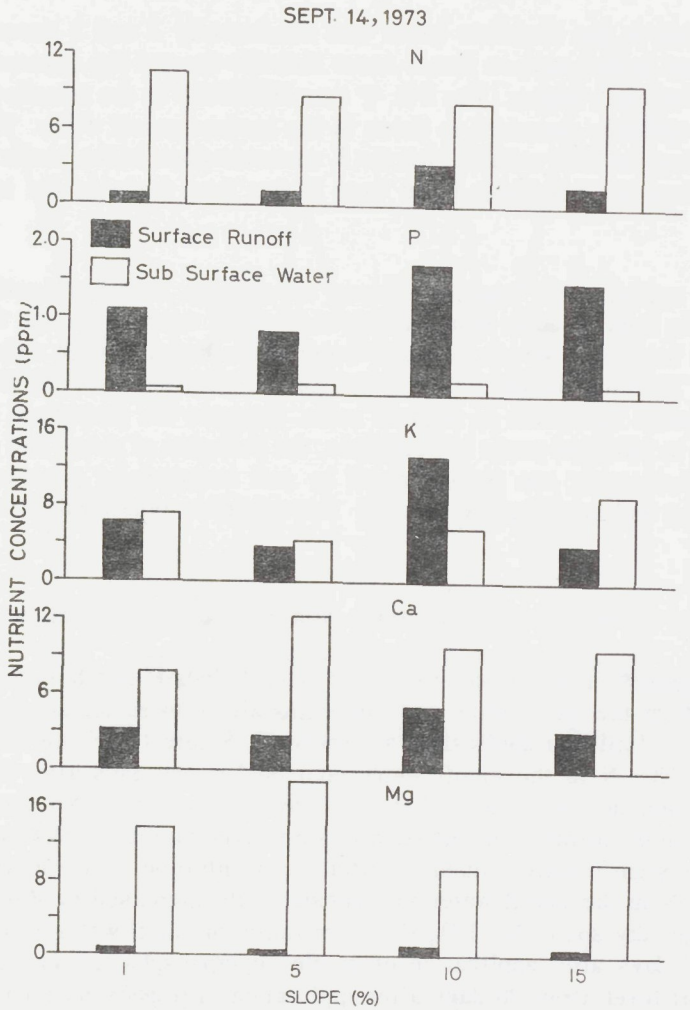


Fig. 10.6 Relative nutrient concentration in surface runoff and sub-surface inter-flow water.

plots may also be due to surface application of potash as well as the release of K from the decomposing crop residue.

The high concentrations of Ca and Mg in the runoff water from the bare-fallow plots may be attributed to exposure of subsoil rich in Ca and Mg when the surface soil was removed by erosion.

Relative Nutrient Concentrations in Seepage Water:

During heavy storms in July and September of 1972 and 1973, interflow water was also collected from some plots on the 15-percent slope. The relative nutrient concentrations of the interflow and surface runoff water from one of these plots are shown in Figure 10.6. The NO_3-N con-

centration in the interflow water was consistently 2 and 3 times higher than that in the surface runoff water and the Ca and Mg concentrations were also much higher. The PO -P concentrations in the interflow water were negligible compared to those in the surface runoff water. The concentrations of K is variable, but the K concentrations in the surface runoff water from the no-tillage plots were higher than those in the interflow water.

It appears that leaching losses of nitrogen may be significantly higher in tropical soils than the losses in runoff water. Although the total annual losses of NO_3-N in runoff water under crops may be only 2 to 3 kg/ha, leaching losses may account for the relatively low efficiency of nitrogenous fertilizers in tropical soils. Because the phosphate concentration in interflow water is negligible, the pollution of rivers and streams in tropical soils can be minimized by soil management practices, e.g. mulching and no-tillage techniques that minimize runoff and favor interflow.

Changes in Nutrient Concentrations with Time after Application:

Changes in the concentrations of NO_3-N, PO_4-P and K in the runoff water from the bare-fallow and conventionally plowed maize plots with time after fertilizer application are shown in Figure 10.7. The concentration of NO_3-N in the runoff water increased a few days after fertilizer application and decreased sharply 20 to 25 days after. No consistent pattern in the nitrate concentration was observed thereafter. The frequency of rains significantly influenced nitrate concentration. The concentration of NO_3-N in the runoff water was substantially increased by rain after a prolonged dry spell. The PO_4-P concentration in runoff water was highest 7 to 10 days after application of single superphosphate, and reached a constant level about 20 days after application. The phosphate concentration reached a steady value of 0.1 ppm 90 days after. The K concentration, however, was highest immediately after application and decreased steadily with time after application. The K concentration decreased from about 10 ppm immediately after application to 3 ppm 50 days after and leveled off at 2 ppm between 65 to 90 days.

Relation between Volume of Runoff and Nutrient Concentration:

From the data of five consecutive rainstorms between May 28 and June 2, 1972, the runoff losses from bare-fallow plots ranged from 0.22 to 30.19 mm, while those from conventionally plowed maize plots varied from 0.09 to 11.23 mm. The concentrations of N, P and K in the runoff water were relatively independent of runoff volume. During one storm the concentration of NO_3-N was 3 ppm in 0.18 mm of runoff and 3.7 ppm in 1.8 mm of runoff. The P concentration during this period was steady at 0.35 ppm and that of K at 5 to 6 ppm.

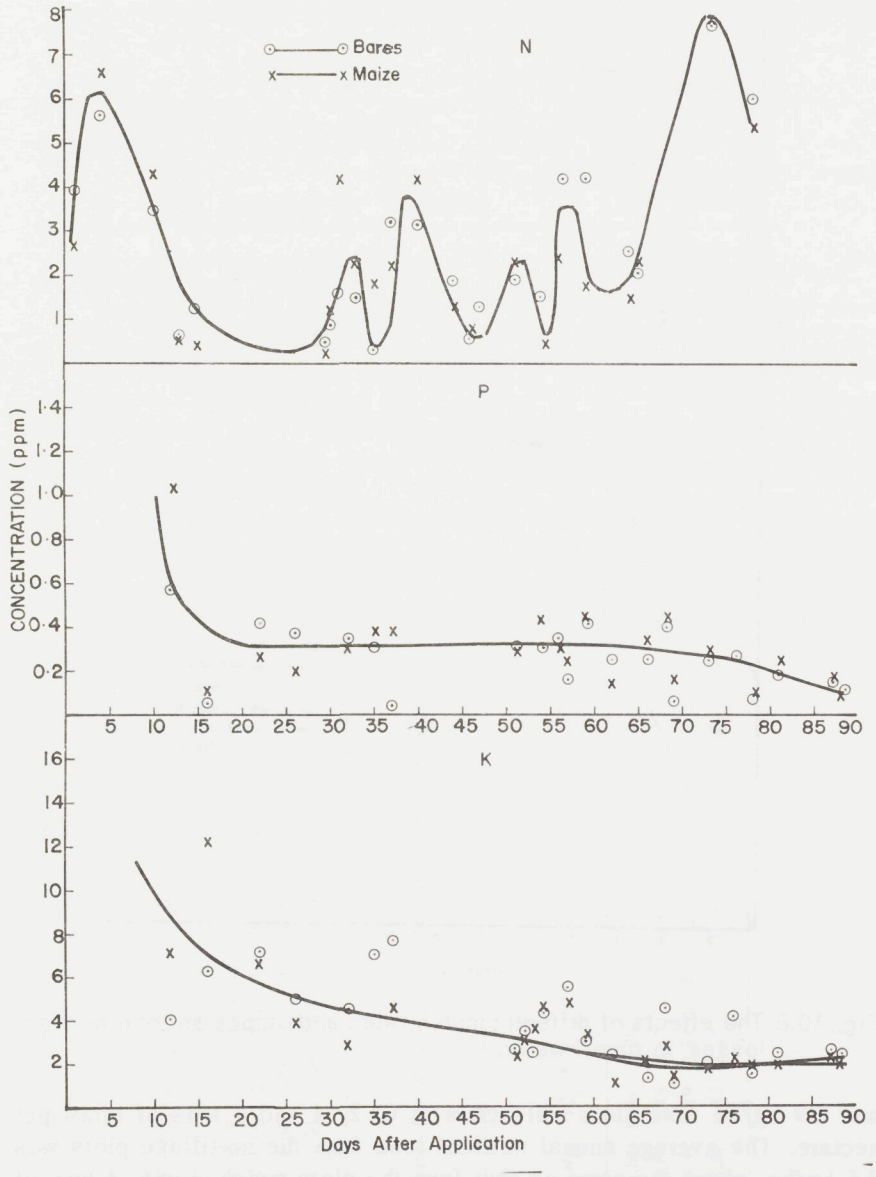


Fig. 10.7 Changes in the concentration of NO_3-N, P and K at different times after fertilizer application.

(B) *Nutrient Losses in Runoff Water as Affected by Different Mulch Rates:*

Total Nutrient Loss:

The effects of different mulch rates and slopes on total nutrient losses in water runoff from uncropped plots are shown in Figure 10.8. Total nutrient losses decreased logarithmically with increases in mulch rate. For example, the mean annual nutrient losses were 54.6, 9.5, 4.2

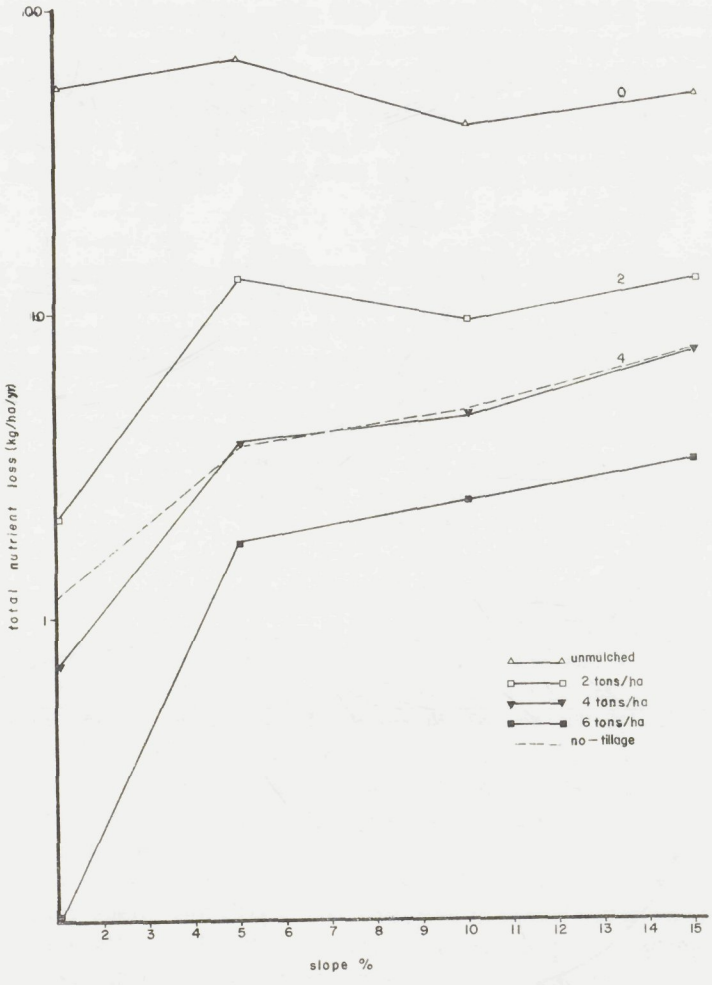


Fig. 10.8 The effects of different mulch rates and slopes on total nutrient losses in runoff water.

and 1.9 kg/ha from plots mulched with 0, 2, 4 and 6 tons of straw per hectare. The average annual nutrient loss from the no-tillage plots was 3.6 kg/ha, about the same as that from the plots mulched with 4 tons of straw per hectare.

Losses of Different Plant Nutrients:

The losses of different plant nutrients as affected by mulch rate and slope steepness during the first and second seasons of 1974 are shown in Tables 10.7 and 10.8. There were no significant effects of slope steepness on nutrient losses. The highest losses during one season were 13.4 kg/ha of NO -N, 2.5 kg/ha of PO -P, 20 kg/ha of K, 14 kg/ha of Ca and 2.7 kg/ha of Mg. Negligible nutrient losses were recorded from the plots mulched with 4 to 6 tons of straw per hectare.

Table 10.7. Nutrient loss in run-off water (kg/ha) at different mulch rates (tons/ha). (First Season,1974)

Slope %	0					2					4					6					No tillage				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
1	9.47	2.16	12.40	11.59	1.78	0.14	0.03	0.16	0.17	0.04	0.09	0.03	0.17	0.13	0.10	0.00	0.00	0.00	0.00	0.00	0.15	0.04	0.16	0.17	0.06
5	10.16	2.50	19.90	14.08	2.66	1.59	0.35	1.90	1.52	0.71	0.24	0.14	0.51	0.33	0.10	0.19	0.03	0.19	0.17	0.07	0.29	0.07	0.32	0.28	0.10
10	7.35	1.45	11.22	8.71	2.09	1.04	0.29	2.03	1.17	0.36	0.45	0.15	0.13	0.70	0.29	0.23	0.07	0.61	0.37	0.11	0.36	0.15	0.88	1.49	0.18
15	13.43	2.43	15.04	9.21	2.60	1.00	0.39	2.06	0.72	0.36	0.51	0.12	0.13	0.69	0.18	0.33	0.10	0.68	0.42	0.18	0.34	0.11	1.78	0.55	0.26

Table 10.8. Nutrient loss in run-off water (kg/ha) at different mulch rates (tons of straw/ha) (Second Season 1974)

Slope %	0					2					4					6					No tillage				
	NO_3-N	PO_4-P	K	Ca	Mg	NO_3 N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg	NO_3-N	PO_4-P	K	Ca	Mg
1	3.48	1.17	3.75	9.09	0.58	0.58	0.26	0.53	0.14	0.13	9.96	0.02	0.04	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.16	0.03	0.15	0.22	0.04
5	1.48	1.17	3.75	19.87	0.64	1.49	0.67	0.58	3.96	0.57	0.43	0.20	0.71	1.04	0.13	0.10	0.03	0.12	0.13	0.03	0.16	0.03	0.22	0.29	0.05
10	1.11	0.71	2.64	5.61	0.31	0.49	0.33	1.28	2.25	0.22	0.40	0.12	0.72	1.40	0.31	0.24	0.06	0.33	0.35	0.06	0.24	0.06	0.45	0.58	0.09
15	1.71	0.72	2.68	4.98	0.52	0.83	0.37	0.14	4.71	0.57	0.63	0.30	1.52	2.33	0.30	0.29	0.07	0.45	0.67	0.11	0.31	0.10	0.69	0.65	0.14

Table 10.9. Effect of slope length on nutrient loss in water run-off under bare fallow. (First Season, 1974)

Nutrient kg/ha	*12.5 m long*		*37.5 m long*	
	Run -off		*Run- off*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
NO_3-N	7.6	10.5	3.4	4.5
P	2.6	1.9	1.6	1.5
K	17.3	14.5	7.7	7.6
Ca	5.8	11.2	4.2	4.3
Mg	2.3	4.2	2.2	1.6

Table 10.10. Effect of slope length on nutrient loss in water run-off under bare fallow. (Second Season, 1974)

Nutrient kg/ha	*12.5 m long*		*37.5 m long*	
	Run-off		*Run-off*	
	10.0%	*19.2%*	*9.3%*	*13.4%*
NO_3-N	4.2	3.1	3.9	3.8
P	1.7	2.0	2.1	2.1
K	1.3	1.2	1.4	1.2
Ca	2.6	3.7	2.4	2.6
Mg	0.6	0.6	0.5	0.6

The effects of slope length on nutrient losses in runoff water are shown in Tables 10.9 and 10.10. Nutrient losses in runoff water from plots mulched at the rate of 4 to 6 tons of straw/ha or from the no-tillage plots were relatively negligible.

CONCLUSIONS

Although the total losses of NO -N, Po -P and K in runoff water are rather small, the relative concentration of these elements is high enough to enrich water and cause pollution of streams and lakes. The leaching losses of nitrogen, as indicated by higher concentrations of No -N in inter-flow water further strengthens the case for using minimum tillage and mulch farming techniques to conserve soil and water and minimize pollution hazards in the tropics.

Nutrient losses in runoff water from plots mulched at the rate of 4 to 6 tons/ha of straw or from the no-tillage plots were negligible.

REFERENCES

1. Barnett, A.P., J.R. Carreker and F. Abruna, 1972. Soil and nutrient losses in run-off with selected cropping treatments in tropical soils. Agron. J. 64: 391–395.

2. Black, C.A., 1970. Behavior of soil and fertilizer phosphorus in relation to water pollution: Agricultural practices and water quality. Pages 72–93 in The Role of Agriculture In Clean Water. Ames, Iowa. Nov. 18–20, 1970.

3. Bryant, J.C. and C.S. Slater, 1948. Runoff water as an agent in the loss of soluble materials from certain soils. Iowa St. Coll. J. Sci. 22: 269–297.

4. Drum, W.H., S.G. Heidel and L.J. Tison, 1960. World wide run-off of dissolved solids. Int. Ass. Sci. Hydrol. Publ. 51. Gen. Assembly Helsinki: 618–628.

5. Duley, F.L., 1926. The loss of soluble salts in runoff water. Soil Sci. 21: 401–409.

6. Englebrecht, D.S. and J.J. Morgan, 1961. Land drainage as a source of phosphorus in Illinois surface waters. P. 74–79. Sec. Tr. W61–3. U.S. Public Health Service, Washington, D.C.

7. Fink, R.J., and D. Wesley, 1974. Corn yield as affected by fertilization and tillage systems. Agron. J. 69: 70–71.

8. Frere, M.H., 1971. Requisite sampling frequency for measuring nutrient and pesticide movement with runoff water. J. Agric. and Food Chem. 19 (5): 837–839.

9. Greweling, T. and M. Peech, 1965. Chemical soil tests. Cornell Univ. Agric. Expt. Station Bul. 960.

10. Johnston, W.R., F. Ittihadish, R.M. Daum and A.F. Pillsbury, 1965. Nitrogen and Phosphorus in tile drain effluent. Soil Sci. Soc. Amer. Proc. 29: 287–287.

11. Kowal, J., 1972. The hydrology of a small catchment Basin of Samaru, Nigeria IV. Assessment of soil erosion under varied land management and vegetation cover. Niger Agric. J. 7: 134–147.

12. Mattyasovszky, J. and T. Duck, 1954. The effect of erosion on the nutrient status of soils. Agrokem Talajt 3: 163–172.

13. Moe, P. G., J. V. Mannering and C. B. Johnson, 1967. Further studies of nitrogen losses in surface runoff water on fragipan soil. Res. Prog. Rep. Purdue Univ. Agric. Exp. Sta. No. 287.

14. Moe, P.G., J.V. Mannering and C.B. Johnson, 1967. Loss of fertilizer N in surface runoff water. Soil Sci. 104: 389–394.

15. Moe, P.G., J.V. Mannering and C. B. Johnson, 1968. A comparison of nitrogen losses from urea and ammoniun nitrate in surface runoff water. Soil Sci. 105: 428–433.

16. Munn, D. A., E. O. Mclean, A. Ramiroz and T. J. Logan, 1973. Effect of soil, cover, slope and rainfall factors on soil and phosphorus movement under simulated rainfall conditions. Soil Sci. Soc. Amer. Proc. 37: 428–431.

17. Rogers, H. T. 1944. Plant nutrient losses from a corn, wheat, clover rotation on Dunmore silt loams. Soil Sci. Soc. Amer. Proc.6:263–271.

18. Ryden, J. C., J. K. Syers and R. F. Harris, 1973. Phosphorus in runoff and stream. Adv. Agron. 1973: 1–45.

19. Schuman, G. E., R. G. Sponier and R. F. Piest, 1973. Phosphorus losses from four agricultural watersheds on Missouri Valley Losses. J. Soil Water Conserv. 22: 228–231.

20. Timmons, D. R., R. E. Burwell and R. F. Holt, 1968. Loss of crop nutrients through runoff. Minnesota Sci. 24: 16–18.

11

Nutrient loss in eroded sediments

Tolerable limits of soil erosion depend on the depth of the surface soil, the nutrient status and physical characteristics of the subsoil and the nature of the crops to be grown. Soil erosion results both in loss of nutrients and degradation of soil physical characteristics. In this chapter, the loss of nutrients with eroded sediments will be discussed.

Massey et al (1973) reported an average loss of 192 kg of organic matter, 10.6 kg of N and 1.8 kg of exchangeable K per hectare on a Wisconsin soil of 11 percent slope. Osborn and Mathews (1955) found that losses of N from the 0–15 cm layer of soil ranged from 45 percent under continuous small grains to 60 percent under continuous row cropping. Thomas et al (1968) reported that the highest concentrations of nutrients in the soil lost from various treatments were 633 ppm of Ca and 104 ppm of K. The total loss of Ca was 1622 kg/ha while that of K ranged from 0.14 to 0.22 kg/ha. One major nutrient lost in the eroded sediment is applied phosphorus (Ensminger, 1952; Gupta and Singh, 1967; Scarseth and Chandler, 1938; Volk, 1945). Extensive loss of nitrogen in eroded sediments has also been reported by various workers (Kowal, 1972; Massey et al, 1953; Osborn and Mathews, 1955; Rogers, 1944).

Methods of Nutrient Analysis:

For the studies reported here composite samples of eroded sediments from all storms were collected from all 25 plots at the end of each growing season. The samples were analyzed for organic carbon by wet combustion, total nitrogen by Kjeldahl, available phosphorus by the Bray No. 1 method and ammonium acetate extractable cations, e.g. Ca^{++}, Mg^{++} and K^{+}.

Nutrient losses in the eroded sediments will be discussed in two sections. The first deals with nutrient losses as affected by different cropping sequences and soil-management practices. The second deals with the effects of different mulch rates on nutrient losses.

Effect of Cropping Sequence and Soil Management on Nutrient Losses in Eroded Sediments.

Total Nutrients:

Total annual nutrient losses, the sum of the N, P, K, Ca and Mg losses, during 1973 are shown in Figure 11.1. Total nutrient losses in eroded soil from the mulch and no-tillage treatments were negligible. The total annual nutrient losses from the bare-fallow plots ranged from 65 kg/ha from the 1% slope to 600 kg/ha from the 10 and 15% slopes. Annual nutrient losses from the maize-maize (conventional plowing) plots were 9 kg/ha from the 1% slope and 140 kg/ha from the 15% slope. Similar losses from the cowpea-maize plots were 5.6 kg/ha from the 1% slope and 210 kg/ha from the 15% slope.

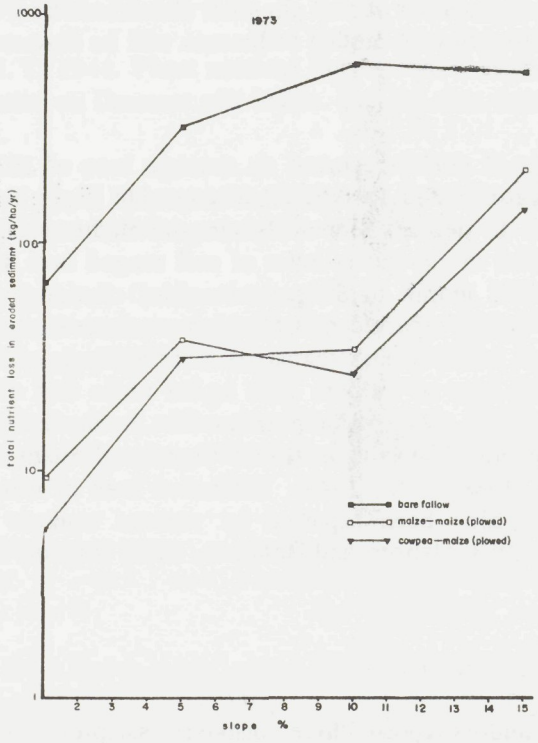


Fig. 11.1 Effects of slopes and crop rotations on total nutrient loss in eroded sediments during 1972.

Total annual losses of organic carbon during 1972 and 1973 are shown in Figures 11.2 and 11.3. Because erosion losses were high during 1973, so were the nutrient losses in eroded sediments. Organic C losses from the bare-fallow plots varied from 54 to 1030 kg/ha during 1972 and from 400 to 3080 kg/ha during 1973. There were no significant differences in the losses of organic C from the maize-maize or cowpea-maize plots. Mean annual losses ranged from 20 to 200 kg/ha during 1972 and 40 to 900 kg/ha during 1973.

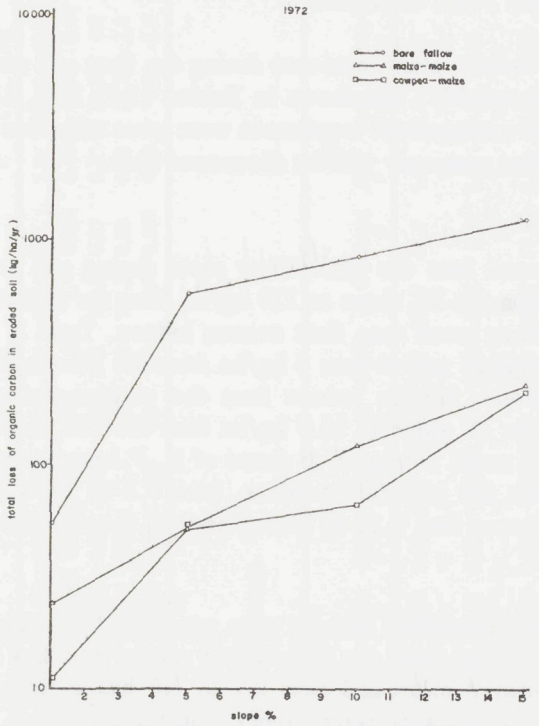


Fig. 11.2 Total loss of organic carbon in the eroded sediments in 1972.

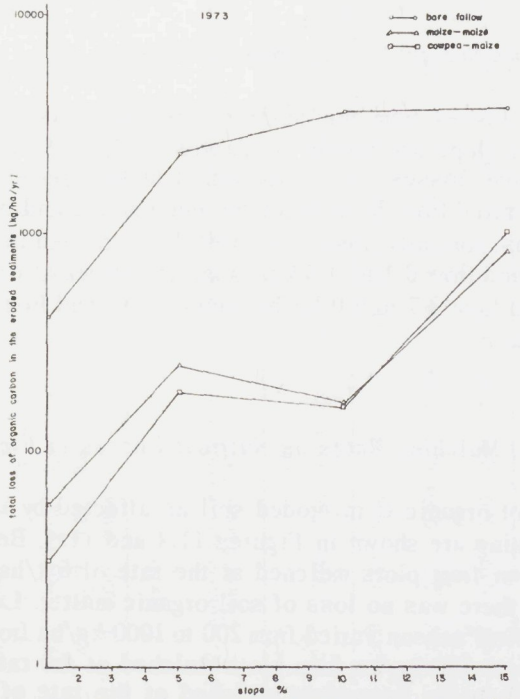


Fig. 11.3 Total loss of organic carbon in the eroded sediments in 1973.

Loss of Different Plant Nutrients:

Losses of various plant nutrients during the first and second growing seasons of 1972 and 1973 are shown in Tables 11.1, 11.2, 11.3, and 11.4. Because the soil-management treatments were more effective during 1973, the results for that year only will be discussed here.

Total N losses from the bare-fallow plots during one season ranged from 25 kg/ha from the 1% slope to 220 kg/ha from the 15% slope. Second season losses were lower than first season losses. Total N losses from the maize-maize plots varied from 4 kg/ha from the 1% slope to 38 kg/ha from the 15% slope. Similar losses from the cowpea-maize plots were 2.4 kg/ha from the 1% slope to 16.0 kg/ha from the 15% slope. Losses of available P were small compared to those of N. P losses ranged from 1.5 to 9.8 kg/ha from the bare-fallow plots, from 0.2 to 1.6 kg/ha from the maize-maize plots and from 0.15 to 1.0 kg/ha from the cowpea-maize plots.

Losses of exchangeable cations were generally high. K losses varied from 2.2 to 16.7 kg/ha from the bare-fallow plots, from 0.4 to 4.2 kg/ha from the maize-maize plots and from 0.2 to 2.0 kg/ha from the cowpea-maize plots. Ca losses were much higher than Mg losses.

Slope Length and Nutrient Loss in Eroded Sediments:

Nutrient losses from the maize-cowpea plots as affected by degree and length of slope are shown in Tables 11.5, 11.6, 11.7 and 11.8. In general, nutrient losses were proportional to soil losses. Total N losses during 1973 varied from 26 to 45 kg/ha under maize and from 2 to 11 kg/ha under cowpeas. Similarly, losses of available P ranged from 1 to 2.8 kg/ha under maize and from 0.1 to 0.5 kg/ha under cowpeas. Losses of exchangeable K ranged from 2.7 to 6.0 kg/ha under maize and from 0.2 to 1.0 kg/ha under cowpeas.

(B) *Effects of Mulching Rates on Nutrient Losses in Eroded Sediments:*

Losses of organic C in eroded soil as affected by slope and rate of surface mulching are shown in Figures 11.4 and 11.5. Because there was no soil erosion from plots mulched at the rate of 6 t/ha or from the no-tillage plots there was no loss of soil organic matter. Losses of organic C during the first season varied from 200 to 1000 kg/ha from the unmulched plots, from 16 to 100 kg/ha from plots mulched at the rate of 2 t/ha, and from 10 to 15 kg/ha from plots mulched at the rate of 4 t/ha. Similar losses were recorded during the second season (Fig. 11.5).

Table 11.1. Nutrient loss in eroded soil (kg/ha) as affected by different slope and soil management treatments. (First Season, 1972).

Treatment	1%						5%						10%						15%					
	O.C	NO_3-N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	NO_3-N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	NO_3-N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	NO_3-N	Bray P	Exch. Ca	Exch. Mg	Exch. K
1	25.4	0.06	0.12	10.2	1.3	0.9	322.6	0.15	0.6	41.7	5.9	4.8	350.0	0.21	0.71	50.1	10.4	7.3	892.8	0.6	1.5	101.0	21.7	15.8
2	T	T	T	T	T	T	1.6	0.001	0.01	0.2	0.03	0.04	2.1	0.0004	0.001	0.2	0.04	0.03	2.0	0.001	0.001	0.3	0.04	0.03
3	21.2	0.003	0.04	2.4	0.41	0.4	48.1	0.001	0.06	4.6	0.8	0.5	92.6	0.02	0.05	10.5	1.7	1.2	173.5	0.07	0.3	29.5	4.2	2.9
4	6.1	0.002	0.01	0.8	0.10	0.06	28.3	0.015	0.06	3.8	0.4	0.7	100.4	0.04	0.3	11.3	2.3	1.2	137.7	0.09	0.33	20.2	2.2	1.7
5	1.9	0.001	0.004	0.3	0.04	0.04	12.5	0.004	0.03	1.9	0.2	0.2	32.6	0.02	0.05	5.5	0.9	0.5	29.0	0.001	0.01	3.5	0.8	0.4

T= Traces

Table 11.2. Nutrient loss in eroded soil (kg/ha) as affected by different slopes and soil management treatments. (Second Season, 1972)

	1%						5%						10%						15%					
	O. C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K
1	28.0	1.69	0.02	1.26	0.12	0.21	254.2	29.3	0.52	13.92	1.28	2.62	490.0	50.73	0.60	24.5	1.63	2.67	403.7	44.8	1.07	25.1	1.81	3.48
2	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3	2.3	0.22	0.004	0.16	0.006	0.018	4.2	1:4	0.01	0.65	0.05	0.35	29.0	2.01	0.02	0.92	0.07	0.19	63.2	6.14	0.07	4.00	0.16	0.53
4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
5	8.8	0.97	0.02	0.39	0.03	0.05	40.2	4.1	0.04	2.04	0.13	0.40	34.5	3.53	0.03	1.82	0.12	0.27	198.0	17.20	0.38	13.61	0.53	1.46

T= Traces

Table 11.3. Nutrient loss in eroded soil as affected by slope and soil management. (First Season, 1973)

	1%						5%						10%						15%					
	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch K	O.C	Total N	Bray P	Exch. Ca	Ech. Mg	Exch. K
1	269.9	24.87	1.57	18.05	0.88	2.20	1005.6	72.36	4.30	52.2	2.97	6.43	2492.3	198,88	12.54	151.1	13.67	20.75	2842.0	217.42	9.82	144.1	13.47	16.72
2	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3	45.8	3.47	0.22	2.52	0.14	0.35	193.6	14.83	0.87	9.36	0.78	2.14	107 8	8.36	0.70	6.15	0.45	1.10	453.3	37.77	1.61	27.10	2.40	4.24
4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
5	24.6	2.38	0.15	1.42	0.08	0.24	107.7	8.37	0.40	6.29	0.53	1.67	100.3	6.95	0.17	12.30	0.40	1.16	203.7	16.02	0.99	17.37	0.92	1.92

T = Traces

Table 11.4. Nutrient loss in eroded soil as affected by slope and soil management. (Second Season, 1973)

Treat-ment	1%						5%						10%						15%					
	O.C	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C.	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C.	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K	O.C.	Total N	Bray P	Exch. Ca	Exch. Mg	Exch. K
1	119.6	11.78	0.40	5.37	0.31	0.62	1312.0	113.8	5.0	56.0	3.0	7.28	1139.42	111.55	7.71	71.57	5.24	7.64	939:04	96.12	3.26	59.03	4.66	12.69
2	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
3	11.6	1.13	0.04	0.56	0.04	0.08	56.40	5.92	0.16	2.87	0.24	0.55	60.39	5.13	0.17	3.71	3.73	0.28	404.32	37.53	0.68	25.03	1.88	2.93
4	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
5	6:7	0.69	0.04	0.43	0.03	0.06	79.60	8.36	0.22	4.81	0.39	0.90	74.50	7.15	0.19	4.70	0.32	0.69	868.03	85.03	2.52	80.62	4.00	5.94

T = Traces

Table 11.5. Contour length and nutrient loss in eroded soil (g/ha). First season 1972

Nutrient	*12.5 m*		*37.5 m*	
kg/ha	*10.0%*	*19.2%*	*9.3%*	*13.4%*
O.C.	342.30	184.10	108.20	143.40
NO_3-N	0.22	0.08	0.04	0.01
Bray-P	0.33	0.12	0.11	0.09
Exch. Ca	50.80	17.00	17.10	14.20
Exch. Mg	6.60	2.20	2.60	2.20
Exch. K	5.00	2.30	1.60	1.50

Table 11.6. Contour length and nutrient loss in eroded soil (kg/ha). Second season 1972

Nutrient	*12.5 m*		*37.5 m*	
kg/ha	*10.0%*	*19.2%*	*9.3%*	*13.4%*
O.C.	93.10	116.00	51.80	55.10
Total N	9.10	12.00	5.58	4.90
Bray-P	0.10	0.17	0.06	0.05
Exch. Ca	4.94	6.94	2.59	2.91
Exch. Mg	0.32	0.38	0.16	0.14
Exch. K	0.67	0.94	0.36	0.39

Table 11.7 Contour length and nutrient loss in eroded soil (kg/ha). First season 1973

Nutrient	*12.5 m*		*37.5 m*	
kg/ha	*10.0%*	*19.2%*	*9.3%*	*13.4%*
O.C.	563.4	554.0	516.00	328.10
Total N	40.69	41.04	45.15	25.36
Bray-P	2.83	1.93	1.95	0.92
Exch. Ca	35.30	29.39	28.11	17.88
Exch. Mg	2.72	2.58	1.37	1.65
Exch. K	5.25	5.96	4.46	2.66

Table 11.8. Contour length and nutrient loss in eroded soil (kg/ha). Second season 1973

Nutrient kg/ha	*12.5 m* 10.0%	19.2%	9.3%	*37.5 m* 13.4%
O.C.	128.44	19.27	31.00	45.50
Total N	10.92	1,88	2.83	4.76
Bray-P	0.49	0.05	0.10	0.07
Exch. Ca	6.33	1.35	17.88	3.63
Exch. Mg	0.44	0.10	0.11	0.17
Exch. K	0.98	0.18	0.20	0.41

Table 11.9. Effect of mulch rate (ton/ha) on nutrient loss (kg/ha) in eroded soil (First season 1974.)

	1%					5%					10%					15%				
Mulch rate	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*
0	27.1	0.45	1.01	12.4	0.95	40.1	2.70	10.7	56.8	4.6	44.3	3.50	11.40	64.40	7.40	126.1	2.00	11.6	83.5	11.2
2	2.0	0.02	0.10	0.78	0.06	12.3	0.18	0.46	4.92	0.20	5.7	0.17	0.44	3.15	0.31	11.6	0.09	0.60	6.60	0.51
4	0.06	0.002	0.004	0.03	0.002	2.0	0.36	0.11	0.93	0.06	2.1	0.02	0.10	0.89	0.07	1.7	0.02	0.10	1.08	0.08
6	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	1.5	0.01	0.10	0.03	0.10
No-tillage	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

Table 11.10. Effect of mulch rate (ton/ha) on nutrient loss (kg/ha in eroded soil (Second season 1974)

	1%					5%					10%					15%				
Mulch rate	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*	*N*	*P*	*K*	*Ca*	*Mg*
0	11.4	0.19	0.42	5.2	0.22	77.8	1.46	3.48	33.40	1.21	32.0	1.36	2.16	22.6	1.12	50.0	1.00	2.79	28.6	1.66
2	2.5	0.02	0.12	1.0	0.07	15.0	0.22	0.56	6.00	0.24	10.6	0.31	0.82	5.9	0.58	52.3	0.39	2.68	29.7	2.31
4	0.2	0.005	0.14	0.10	0.007	3.40	0.006	0.19	1.57	0.10	10.0	0.08	0.46	4.2	0.35	7.0	0.07	0.39	4.4	0.34
6	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	1.2	0.01	0.1	0.9	0.1
No-tillage	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T

Losses of various plant nutrients in eroded soil as affected by slope steepness and mulch rate are shown in Tables 11.9 and 11.10. During the first season, N losses ranged from 27 to 126 kg/ha from the unmulched plots, from 2 to 12 kg/ha from the plots mulched at the rate of 2 t/ha. The maximum loss of available P was only 3.5 kg/ha. During one season, the maximum loss of exchangeable K was 12 kg/ha; that of Ca, 8.4 kg/ha; and that of Mg 11, kg/ha. Nutrient losses during the second season were lower than those during the first, but the trends in relation to mulch rates and slope steepness were the same.

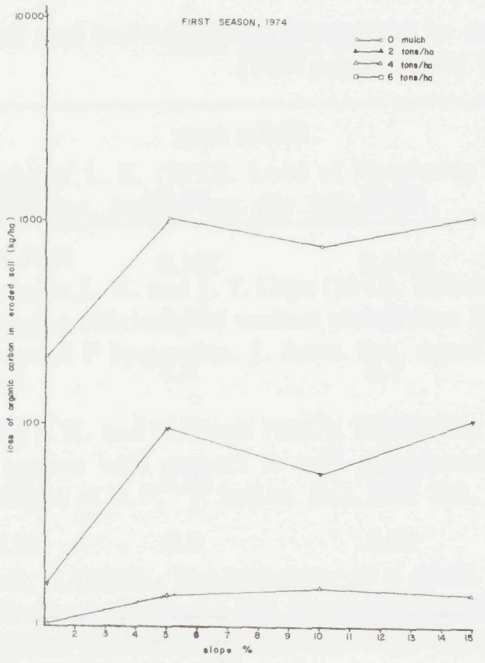


Fig. 11.4 Effect of mulch rates on total loss of organic carbon in the eroded sediments in the second season, 1974.

Fig. 11.5 Effect of mulch rates on total loss of organic carbon in the eroded sediments in the second season, 1974.

Table 11.11 Effect of contour length on nutrient loss (kg/ha) in eroded soil: (First season 1974)

Nutrient	*12.5 m long*		*37.5 m long*	
kg/ha	*10.0%*	*19.2%*	*9.3%*	*13.4%*
Organic C.	1314.6	761.0	1314.8	1352.8
N	145.4	84.1	129.2	135.3
P	1.2	0.8	2.2	1.2
K	24.7	9.7	15.2	13.2
Ca	95.7	55.9	98.1	93.2
Mg	12.1	9.6	11.5	14.7

Table 11.12. Effect of contour length on nutrient loss (kg/ha) in eroded soil: (Second season 1974)

Nutrient	*12.5 m long*		*37.5 m long*	
kg/ha	*10.0%*	*19.2%*	*9.3%*	*13.4%*
Organic C.	613.7	440.7	795.4	679.2
N	56.8	48.7	96.5	68.7
P	0.38	0.10	0.91	0.35
K	3.4	2.3	4.7	3.4
Ca	34.7	24.2	51.7	42.2
Mg	4.0	3.7	5.7	5.3

Contour Length and Nutrient Loss:

The effects of contour length and slope steepness on nutrient losses in eroded soil are shown in Tables 11.11 and 11.12. The trends in nutrient losses are similar to the trends in soil losses presented in Chapter 6. Maximum nutrient losses during one season were 145 kg/ha of N, 2.2 kg/ha of P, 25 kg/ha of K, about 100 kg/ha of Ca and 15 kg/ha of Mg.

REFERENCES

1. Ensminger, L. E. (1952). Loss of Phophates by erosion. Soil Sci. Soc. Amer. Proc. 16: 338–342.

2. Ensminger, L. E. and J. T. Cope (1947). Effect of soil reaction on the efficiency of various phosphates for cotton and on loss of P by erosion. J. Amer. Soc. Agron. 39: 1–11.

3. Gupta, R. N. and N. Singh (1967). Selectivity of erosion processes with respect to soil phosphorus in the alluvial tracts of U. P. J. Indian Soc. Soil Sci. 15: 261–268.

4. Kowal, J. (1972). The hydrology of a small catchment basin at Samaru, Nigeria. IV. Assessment of soil erosion under varied land management and vegetation cover. Nigeria Agric. J. 7: 134–147.

5. Massey, H. F., M. L. Jackson and O. E. Hays (1953). Fertility erosion on two Wisconsin Soils. Agron. J. 45: 543–547.

6. Osborn, W. M., and O. R. Mathews, 1955. Crop rotation, tillage and fertility experiments at Lawton field station 1917–49. U. S. D. A. Cor. 951 : 58.

7. Rogers, H. T. (1944). Plant nutrient losses from a corn, wheat, clover rotation on Dunmore Silt loam, Soil Sci. Soc. Amer. Proc. 6: 263–271.

8. Scarseth, G. D., and W. V. Chandler (1938) Losses of phosphate from a light textured soil in Alabama and its relation to some aspects of soil conservation. Agron. S. 30: 361–375.

9. Thomas, A. W., R. L. Carter and J. R. Carreker (1968). Soil, water and nutrient losses from Tifton Loamy Sand. Trans. ASAE 11: 677–679.

10. Volk, G. W. (1945). Response to residual phosphorus of cotton in continuous culture. Agron. S. 35: 330–340.

12

Properties of the eroded sediments in relation to the original soil

Rogers (1944) reported that the eroded material from corn land was richer in nitrogen and phosphorus than the original soil. The enrichment ratio, the ratio of plant nutrients in eroded soil to those left behind in the soil, has been discussed by various workers (Fippin, 1945; Massey and Jackson, 1952; Barrows and Kilmer, 1963). Barrow and Kilmer reported that soil P is primarily lost through eroded sediments. Information on the physical properties of eroded sediments in relation to the parent soil and the changes in soil physical properties as a result of erosion for tropical soils is rather scarce. (Jones and Wild, 1975).

A. *Soil Physical Properties*

(a) *Texture.* The textures of the surface samples of the soil at the beginning of these studies in February 1972 and in February 1974, and of soil samples eroded during the first season of 1973 are shown in Figure 12.1. Although the texture of the plots of treatments 2 and 4 did not change, there were significant changes in the particle size distribution among the treatments 1, 3 and 5 between 1972 and 1974. The most dramatic changes in soil texture were in the bare-fallow plots, where there was a marked increase in gravel content during the two years.

The gravel concentration in the eroded sediments was only slightly affected by degree of soil slope (Figure 12.2). Sand content, however, increased with increase in slope. The sand content of the eroded sample increased from 33% on the 1-percent slope to 66% on the 15-percent slope. The most erodible particles on the 5, 10 and 15-percent slopes were sand. The silt and clay contents of the eroded soil decreased with increase in slope. The silt content decreased from 25% to 9% and the clay content from 27% to 12% as the slope increased from 1 to 15 percent. The change in particle size distribution of the eroded soil with change in slope may be due to the increased velocity of runoff water at steeper slopes and thus its increased capacity to transport coarse particles. The erosion ratio indicates that silt-plus-clay content of the eroded soil was generally higher than that of the field soil. The erosion ratio was significantly lower for 10 and 15-percent slope plots than for the 1 and

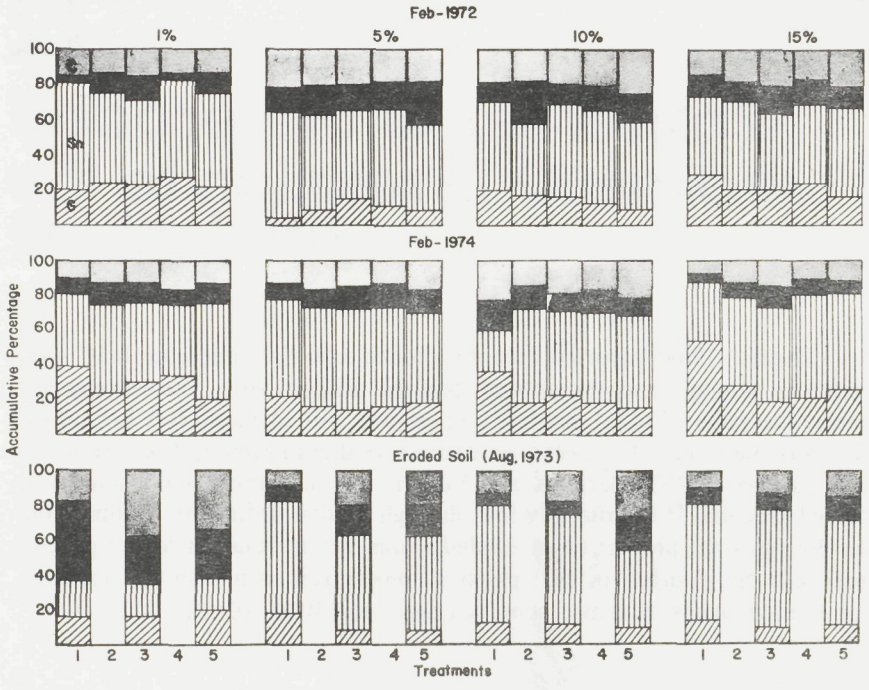


Fig. 12.1 Changes in the textural composition of surface soil from 1972–1974 as compared to that of the eroded sediments.

5-percent slope plots (Table 12.1). The crop rotation did not significantly affect the erosion ratio, although the values were low for bare-fallow plots.

(b) *Soil Moisture Characteristics.* Soil moisture retention characteristics of the eroded and field soil for different treatments are shown in Figure 12.3. The eroded soil had a higher moisture retention capacity at all suction ranges than the field soil and this can be attributed to the higher silt, clay and organic matter contents of the eroded soil. The moisture retention capacity of eroded soil from 1-, 5-, 10- and 15-percent slope maize-maize (conventionally plowed) plots respectively were 0.41, 0.50, 0.45 and 0.55 gg^{-1} at 0.1 bar suction compared to 0.25, 0.24, 0.25 and 0.25 gg^{-1} for the field soil. A similar trend in moisture content is obvious for other suctions as well. The eroded soil from the bare-fallow plots had a lower moisture retention capacity than the eroded soil from the maize-maize or cowpea-maize plots.

The data on soil moisture equivalent follow the same trend (Table 12.2). The mean soil moisture equivalent of the eroded soil was 31.1% compared to 16.2% for the field soil. The mean soil moisture equivalents of the eroded soil from the bare-fallow plots (18.3%) were lower than those of the eroded soil from the maize-maize (26.0%) or the cowpea-maize (24.9%) plots.

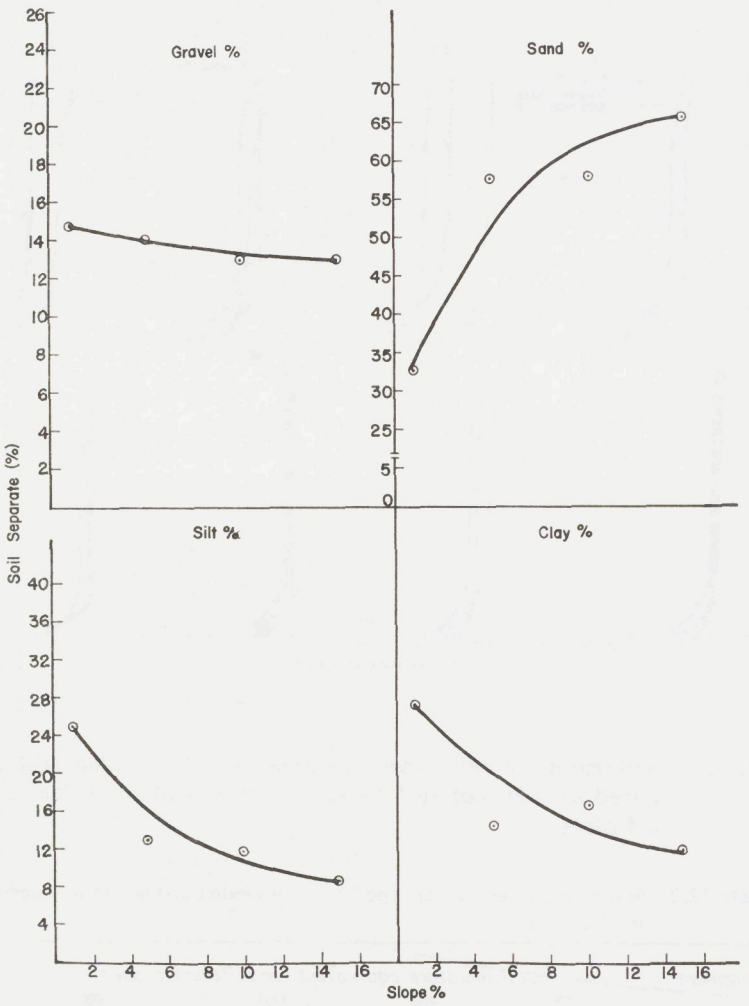


Fig. 12.2 Influence of soil slope on concentration of gravels, sand, silt and clay in the eroded sediments.

Table 12.1. The erosion ratio as affected by slope and soil management treatments.

Treatment	*Slope %*				*Mean*
1	4.62	1.34	1.03	1.23	2.06
3	3.44	2.38	1.02	2.74	2.40
5	3.14	2.73	1.69	1.61	2.29
Mean	3.73	2.15	1.25	1.86	

$$\text{Erosion Ratio} = \frac{\text{silt + clay}}{\text{gravel + sand}} \text{ of eroded sediments} / \frac{(\text{silt + clay}}{\text{gravel + sand}} \text{ of field soil)}$$

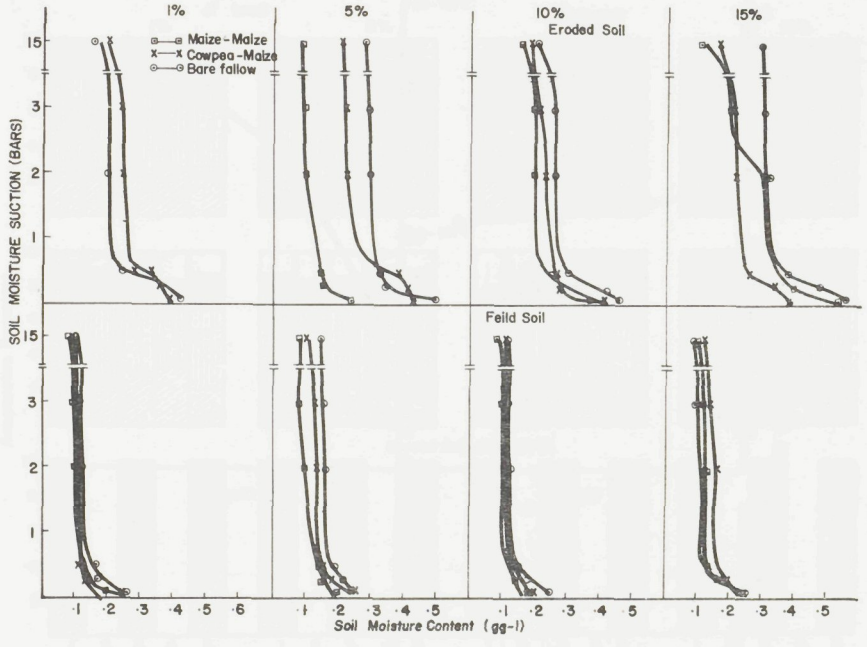


Fig. 12.3 Soil moisture retention characteristics of eroded soil as compared with that of surface soil samples obtained from the run-off plots.

Table 12.2. Soil moisture equivalent (gg^{-1}) of the eroded sediments as compared to the field soil.

Treatment	*Soil moisture equivalent for different slopes*								*Mean*
	1%		*5%*		*10%*		*15%*		
	ES	*FS*	*ES*	*FS*	*ES*	*FS*	*ES*	*FS*	
1	–	0.146	0.182	0.117	0.286	0.115	0.287	0.149	0.183
3	0.281	0.174	0.386	0.197	0.266	0.163	0.407	0.203	0.260
5	0.359	0.141	0.356	0.201	0.306	0.151	0.299	0.181	0.249
Mean	0.320	0.154	0.308	0.172	0.286	0.143	0.331	0.178	

ES = Eroded sediments

FS = Field soil

B. *Soil Chemical Properties*

(a) *Enrichment Ratio.* The enrichment ratio data for different treatments are shown in Table 12.3. The enrichment ratio is high for organic C and P. Except for P, the enrichment ratios for other nutrients are lowest from the bare-fallow plots. This may be due to the dilution effect resulting from greater erosion losses from the bare-fallow plots. The

Table 12.3. Average enrichment ratio for different nutrients.

Treatment	*O.C.*	*N*	*P*	*K*	*Ca*	*Mg*
1	2.21	1.54	5.96	1.36	1.52	1.12
3	2.75	1.73	5.55	2.02	1.45	1.16
5	2.22	1.65	5.83	1.62	1.62	1.23

Each value is average of 16 figures for 4 slopes and 4 growing seasons.

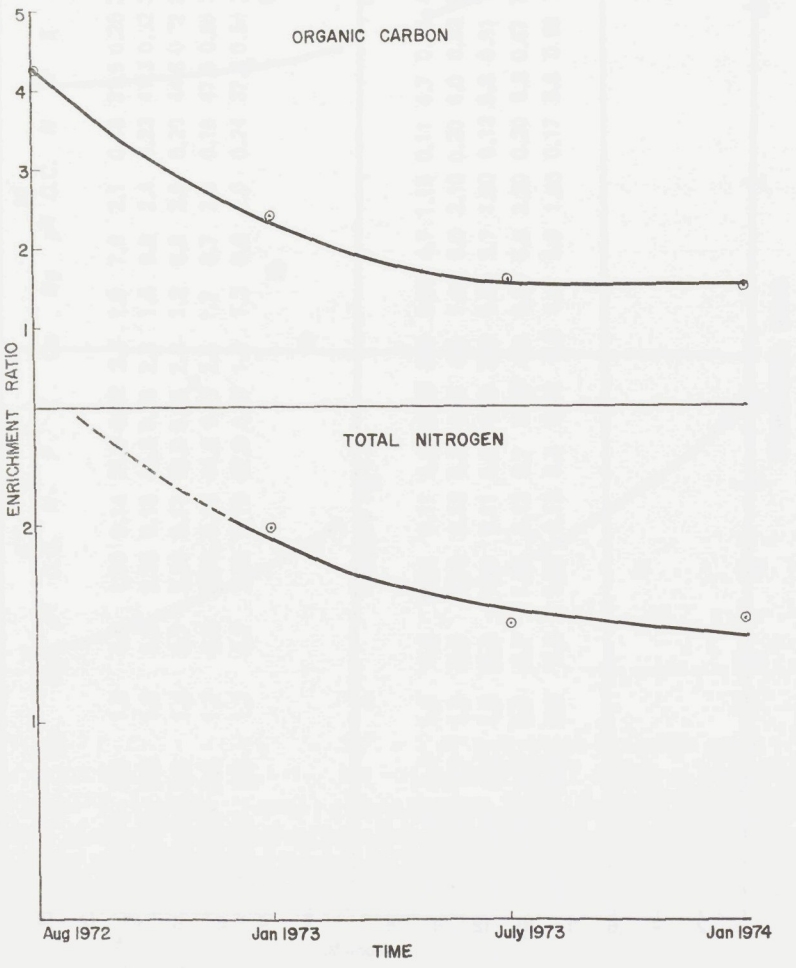


Fig. 12.4 Changes in the enrichment ratio of organic carbon and total nitrogen with time.

enrichment ratios of organic C and N decreased with time after forest clearing (Figure 12.4). The average enrichment ratio for organic C was 4.25 in August 1972 and 1.5 in January 1974.

Similarly, the average enrichment ratio for N decreased from 2.0 in January 1973 to 1.4 in January 1974. Gradual decline in organic C and total N contents of soil may account for the decrease of enrichment ratios with time. The enrichment ratios of other elements did not follow any trend with time after forest clearing.

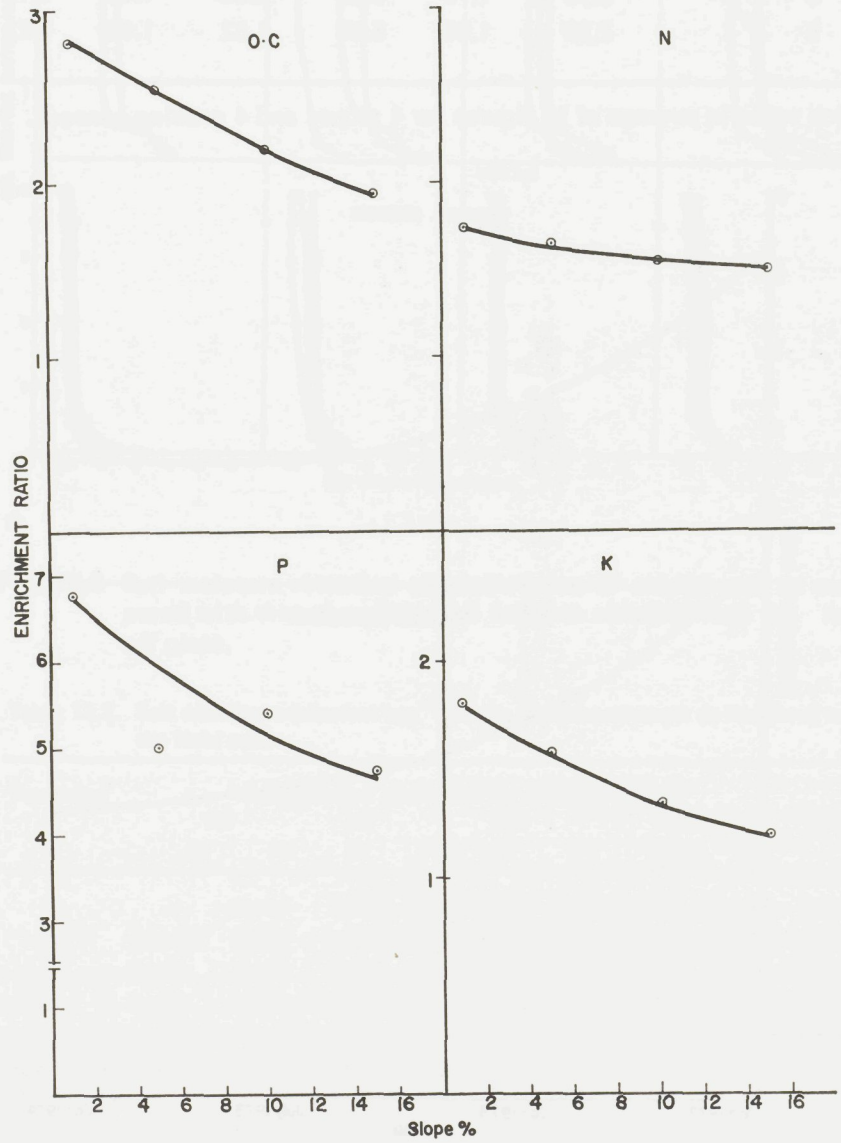


Fig. 12.5 Effects of soil slope on the enrichment ratio of some nutrient elements.

Soil slope had a significant effect on the enrichment ratios of certain elements (Figure 12.5). The average enrichment ratio of organic C, N, P and K decreased with increase in slope. The enrichment ratio of organic

Table 12.4. Soil chemical properties. February 1972

Treat-ment	1							5							10							15						
	pH	*O.C.*	*N*	*P*	*K*	*Ca*	*Mg*	*pH*	*O.C.*	*N*	*P*	*K*	*Ca*	*Mg*	*pH*	*O.C.*	*N*	*P*	*K*	*Ca*	*Mg*	*pH*	*O.C.*	*N*	*P*	*K*	*Ca*	*Mg*
1	6.5	2.7	0.25	78.4	0.77	3.5	1.5	6.4	1.90	0.14	31.9	0.32	2.5	1.0	7.0	2.1	0.18	31.9	0.25	3.5	1.6	7.3	2.5	0.24	53.9	0.67	3.10	2.3
2	6.7	2.9	0.27	85.8	0.56	3.5	1.5	6.9	2.30	0.18	44.5	0.56	2.3	1.4	6.9	2.4	0.23	41.3	0.32	3.0	2.3	7.3	2.1	0.21	44.5	0.56	4.3	2.2
3	6.3	2.5	0.23	96.9	0.56	3.5	1.4	6.7	2.20	0.17	35.0	0.56	2.3	1.2	6.8	2.5	0,20	44.5	0.32	2.5	1.6	7.1	2.2	0.19	54.9	0.23	3.0	1.9
4	6.4	2.3	0.21	81.9	0.56	3.0	1.7	6.9	2.70	0.19	44.5	0.77	2.5	1.7	6.7	2.0	0.16	47.6	0.56	3.5	1.9	7.1	2.3	0.21	47.6	0.56	4.0	2.1
5	5.5	2.7	0.21	100.8	0.67	3.3	1.7	6.7	2.30	0.19	31.9	0.67	1.8	1.3	6.8	2.0	0.24	37.8	0.56	2.8	1.8	7.5	2.7	0.25	53.9	0.56	3.5	2.2
February 1974																												
1	5.0	1.30	0.15	5.0	0.43	6.4	1.2	4.8	0.95	0.11	4.8	0.48	3.6	0.95	4.7	1.15	0.11	4.7	0.36	4.2	1.1	4.2	1:1	0.11	4.2	0.10	4.0	0.58
2	6.0	2.85	0.24	6.0	0.56	9.7	1.7	6.0	1.90	0.13	5.3	0.61	4.6	1.00	6.0	2.10	0.20	6.0	0.82	7.7	1.9	5.8	2.5	0.14	5.3	0.46	8.2	1.92
3	5.6	1.60	0.17	5.6	0.46	7.6	1.5	5.3	1.20	0.11	5.3	0.31	3.6	0.86	5.7	1.90	0.13	5.8	0.51	7.1	1.8	5.3	1.4	0.12	5.3	0.10	6.4	1.73
4	5.5	2.1	0.22	5.5	0.78	9.8	2.1	5.7	1.65	0.13	5.7	0.46	4.9	0.84	5.8	2.20	0.20	5.8	0.67	7.8	1.5	5.6	2.1	0.19	5.5	0.78	8.0	1.79
5	5.8	1.75	0.14	5.8	0.47	8.6	2.0	5.8	1.65	0.13	5.8	0.46	5.5	1.4	5.9	1.90	0.17	5.9	0.56	7.6	1.6	5.8	1.9	0.16	5.8	0.41	8.4	1.65

C decreased by 0.66 for each percent increase, that of N by 0.017, that of P by 0.14 and that of K by 0.04. This decrease in enrichment ratio with increase in slope may be due to the coarse nature of the eroded sediments from the steeper slopes compared to higher clay and silt contents of the eroded soil from the gentle slopes (Figure 12.1).

(b) *Soil Chemical Properties.* The chemical properties of the surface soil immediately after forest clearing in February 1972 and two years later, in February 1974, are shown in Table 12.4. In general, there was a decrease in soil pH, organic C, total N, available P and exchangeable K. The decreases in organic C, total N and K contents were negligible for mulched and no tillage treatments.

Table 12.5. Effect of soil management and cropping sequence on chemical characteristics of the soil (0-10 cm layer) July 1974

Treatment	*pH*	*Organic carbon %*	*Total nitrogen %*	*Bray-1 P (ppm)*	*CEC (meq/100)*	*Exchangeable cation (meq/100 g) Ca^{++}*	*Mg^{++}*	*K^{+}*
Bare fallow	5.10	1.32	0.079	41.87	7.22	5.04	0.63	0.46
Maize-maize (plowed)	5.35	1.30	0.096	42.52	8.07	6.10	0.94	0.58
Maize-cowpea (No-tillage)	5.50	1.90	0.143	62.65	9.07	6.62	1.13	0.76
Maize-maize (mulch)	5.60	2.10	0.148	54.86	10.42	7.74	1.36	0.88

Some chemical characteristics of the soil analyzed during July 1974 are shown in Table 12.5. The values are averaged over all slopes. Soil pH organic C content, CEC, exchangeable cations, available P and total N were in the following order: bare-fallow, maize-maize (plowed), maize-cowpeas (no-tillage), maize-maize (mulched). Mulching and minimum tillage treatments by preventing soil erosion, maintained chemical fertility of the soil.

REFERENCES

1. Barrows, H. L., and Kilmer, V. J., 1963. Plant nutrient losses from soils by water erosion. Adv. Agron. 15:303–316.

2. Hudson, N.W., and Jackson, D.C., 1959. Results achieved in measurement of erosion and runoff in Southern Rhodesia. Proc. 3rd Inter-African Soils Conf., Dalaba, 1959.

3. Fippin, E. O., 1945. Plant nutrient losses in silt and water in the Tennessee River System. Soil Sci. 60:223–239.

4. Jones M. J., and A. Wild, 1975. Soils of the West African savanna. Tech. Comm. 55, C. A. B. Farnham Royal.

5. Latterell, J. J., Holt, R. F., and Timmons, D. R., 1971. Phosphate availability in lake sediments. J. Soil and Water Conserv. 1: 21–25.

6. Massey, H. F., and Jackson, M.L., 1952. Selective erosion of soil fertility constituents. Soil Sci. Soc. Amer. Proc. 16 : 4.

7. Rogers, H. T., 1944. Plant nutrient losses from a corn, wheat, clover rotation on Dunmore Silt Loam. Soil Sci. Soc. Amer. Proc. 6: 263–271.

13

Changes in soil physical characteristics and crop yield as a result of erosion

The degree of soil erosion that can be tolerated depends upon the depth of surface soil, the nutrient status and physical properties of the subsoil, and the nature of crops to be grown. For shallow tropical soils derived from basement complex rocks, a loss of a few centimeters of surface soil may result in serious yield reductions. Little quantitative information on the effects of soil erosion on crop yields exists. This chapter describes the magnitude of the effects of soil erosion on soil physical properties and crop yields.

Two major effects of soil erosion are degradation of soil physical properties and loss of plant nutrients, both applied and inherent. One major nutrient lost in eroded soil is applied phosphorus (Ensminger , 1952; Gupta and Singh, 1967; Scarseth and Chandler, 1938; Volk, 1945). Losses of N and other nutrients in eroded soil have also been reported by various workers(Kowal,1972; Massey et al, 1935; Osborn and Mathews 1955; Rogers, 1944).

Reports conceming the effects of soil erosion on crop yields vary. Although the majority indicate yield depressions (Doshchanov and Muratova, 1953; Filipovic, 1968; Pasevet al.,1968; Tikhonov, 1960; Transhliev and Tikhonov, 1963), some report a temporary increase (Grosse, 1967). In the latter study, the loss of organic matter in eroded soil was at least temporarily compensated by better physical conditions of the exposed subsoil.

In the studies reported here changes in grain yield over time as affected by various treatments and the effect of artificially removing soil on the grain yields of maize and cowpeas were investigated. Varying depths of surface soil from an Egbeda series soil were removed and the growth and development of maize and cowpeas were observed.

Changes in soil nutrients and in soil fertility status have already been discussed in Chapter 11 and 12. Changes in the physical characteristics of the soil as a result of soil erosion and crop response will be discussed in this chapter.

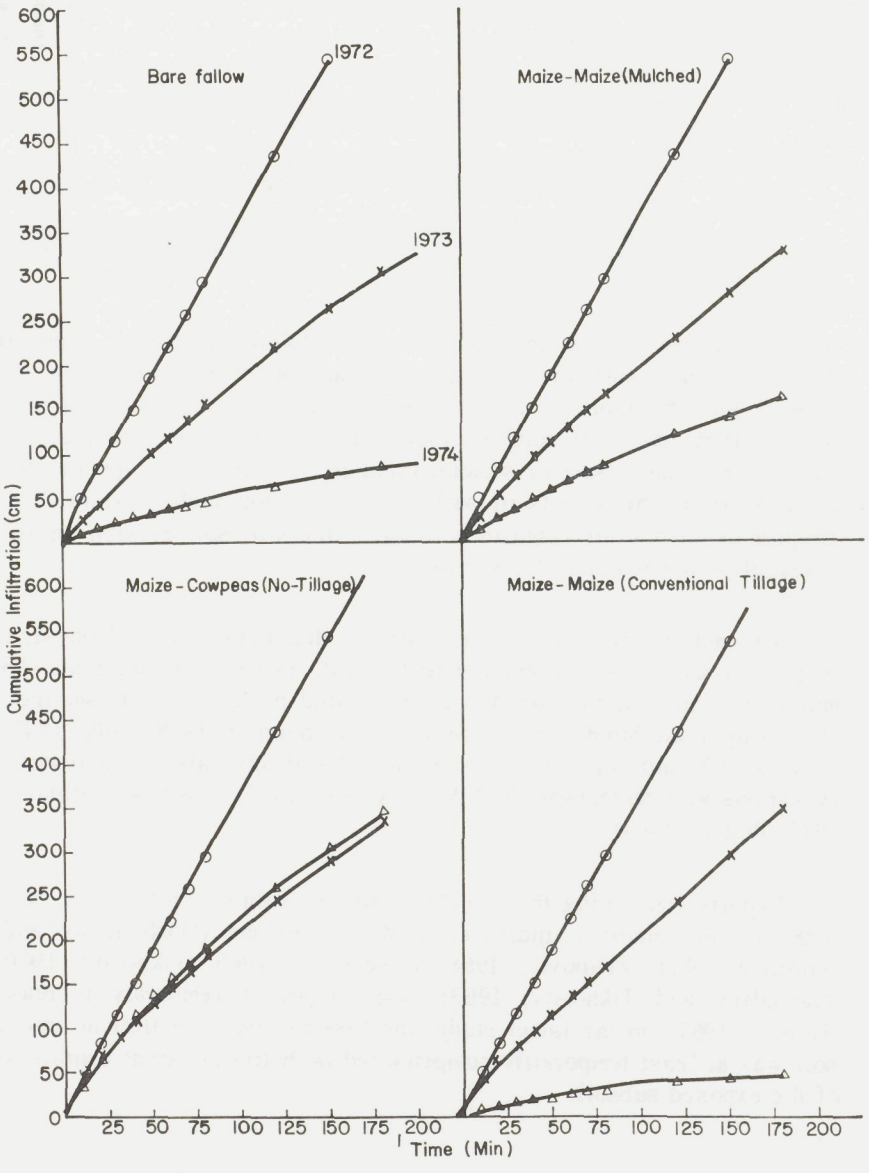


Fig. 13.1 Infiltration capacity of the soil as influenced by time after forest clearing under different soil management and crop rotation treatments.

Infiltration Rate. Infiltration rates of the soil on the 10-percent slope plots, measured during the dry seasons of 1972, 1973 and 1974, are shown in Figure 13.1. In general, the infiltration rate decreased with time. In bare-fallow plots the infiltration rates after two hours were 3.5 cm min^{-1}, 1.5 cm min^{-1} and 0.2 cm min^{-1} for 1972, 1973 and 1974,

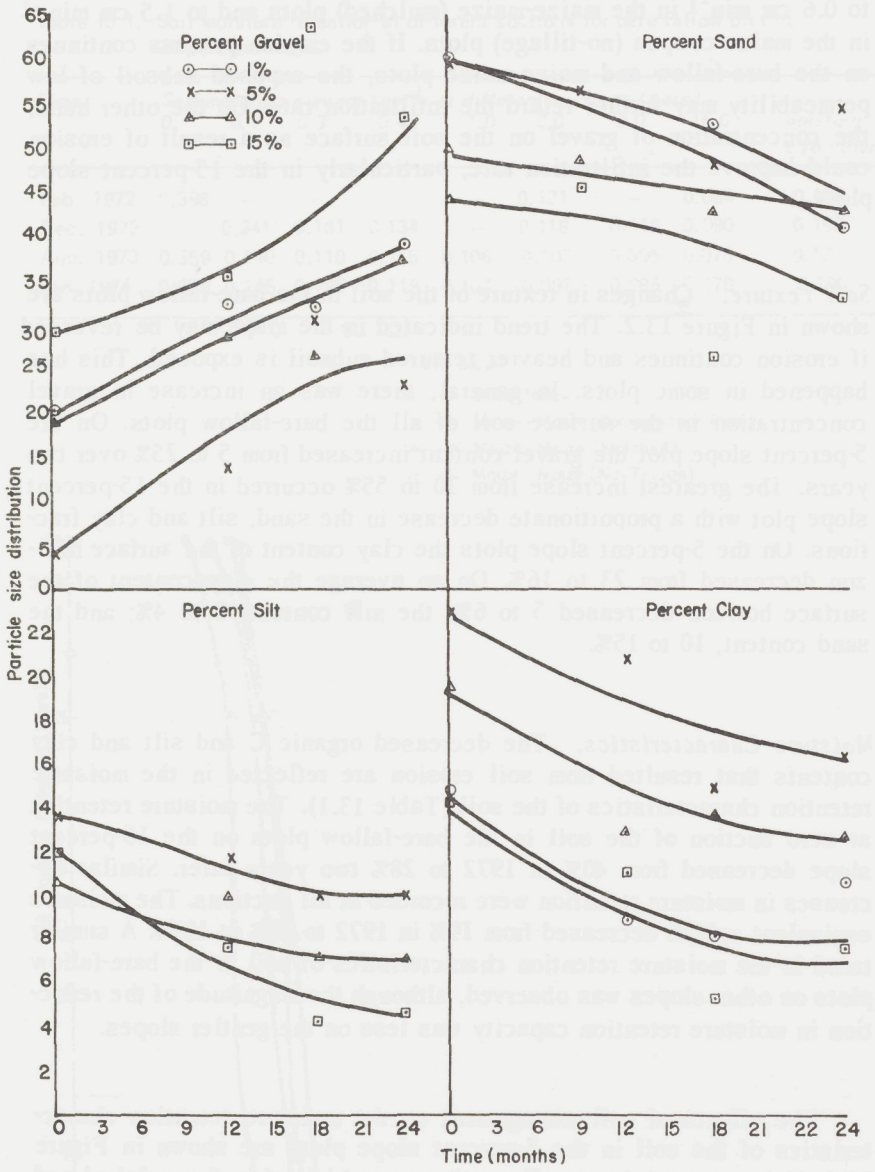


Fig. 13.2 Changes in texture of the soil in bare fallow plots during 1972–1973.

respectively. Similar values were 3.5 cm min^{-1}, 1.5 cm min^{-1} and 0.6 cm min^{-1} in the maize-maize (mulched) plots; 3.5 cm min^{-1}, 1.5 cm min^{-1} in the maize-cowpea (no-tillage) plots; and 3.5 cm min^{-1}, 1.75 cm min^{-1} and 0.1 cm min^{-1} in the maize-maize (plowed) plots. The infiltration rate decreased from an initial rate of 3.5 cm min^{-1} to 0.1 cm min^{-1} in the maize-maize (plowed) plots, to 0.2 cm min in the bare-fallow plots,

to 0.6 cm min^{-1} in the maize-maize (mulched) plots and to 1.5 cm min^{-1} in the maize-cowpea (no-tillage) plots. If the erosion process continues on the bare-fallow and maize-maize plots, the exposed subsoil of low permeability may further retard the infiltration rate. On the other hand, the concentration of gravel on the soil surface as a result of erosion could improve the infiltration rate, particularly in the 15-percent slope plots.

Soil Texture. Changes in texture of the soil in the bare-fallow plots are shown in Figure 13.2. The trend indicated in the graph may be reversed if erosion continues and heavier textured subsoil is exposed. This has happened in some plots. In general, there was an increase in gravel concentration in the surface soil of all the bare-fallow plots. On the 5-percent slope plot the gravel content increased from 5 to 25% over two years. The greatest increase from 30 to 55% occurred in the 15-percent slope plot with a proportionate decrease in the sand, silt and clay fractions. On the 5-percent slope plots the clay content of the surface horizon decreased from 23 to 16%. On an average the clay content of the surface horizon decreased 5 to 6%; the silt content, 2 to 4%; and the sand content, 10 to 15%.

Moisture Characteristics. The decreased organic C and silt and clay contents that resulted from soil erosion are reflected in the moisture retention characteristics of the soil (Table 13.1). The moisture retention at zero suction of the soil in the bare-fallow plots on the 15-percent slope decreased from 40% in 1972 to 28% two years later. Similar decreases in moisture retention were recorded at all suctions. The moisture equivalent values decreased from 19% in 1972 to 10% in 1974. A similar trend in the moisture retention characteristics of soil in the bare-fallow plots on other slopes was observed, although the magnitude of the reduction in moisture retention capacity was less on the gentler slopes.

The effects of soil management on the moisture retention characteristics of the soil in the 5-percent slope plots are shown in Figure 13.3. Moisture retention at all suctions was highest in the mulched and no-tillage plots followed by that in the conventionally plowed maize plots. The soil in the bare-fallow plots had the lowest water-holding capacity. The moisture retention at zero suction was 30% in the bare-fallow plots, 34% in the conventionally plowed maize plots and 36% in the mulched and no-tillage maize plots.

Crop Response. Maize yields as affected by different slopes and management practices are shown in Figure 13.4. Although the yields on the no-tillage plots were equivalent to or higher than those on the mulched

Table 13.1. Soil moisture retention at different suctions for bare fallow plot at 24 percent slope.

Time	*Soil moisture content (gg^{-1}) at different suctions (bars)*								
	0	*0.1*	*0.3*	*0.4*	*1.0*	*2.0*	*3.0*	*15.0*	*moisture equivalent*
Feb. 1972	0.398	–	–	–	–	0.121	–	0.084	0.188
Dec. 1973	–	0.241	0.161	0.134	–	0.118	0.118	0.090	0.150
Aug. 1973	0.359	0.140	0.110	0.115	0.106	0.103	0.095	0.075	0.127
Jan. 1974	0.279	0.145	0.123	0.119	0.104	0.092	0.085	0.076	0.100

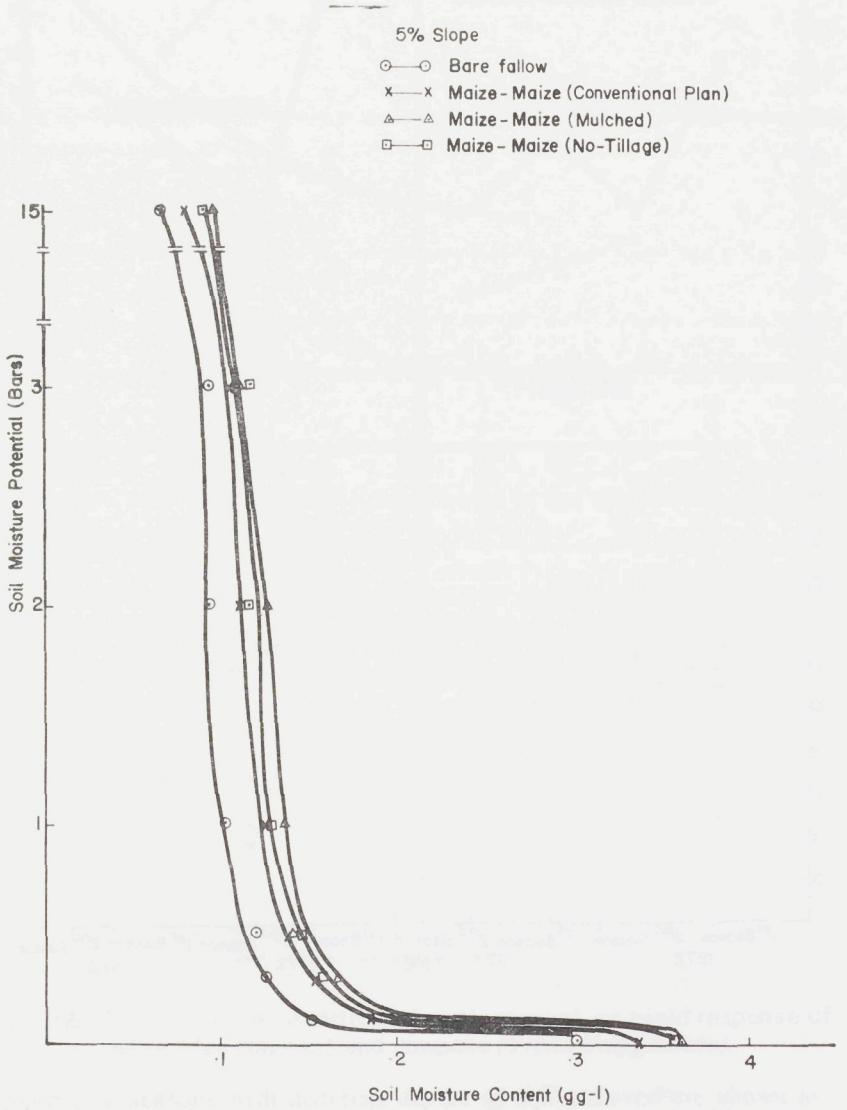


Fig. 13.3 Soil moisture retention characteristics as influenced by soil management and crop rotation treatments.

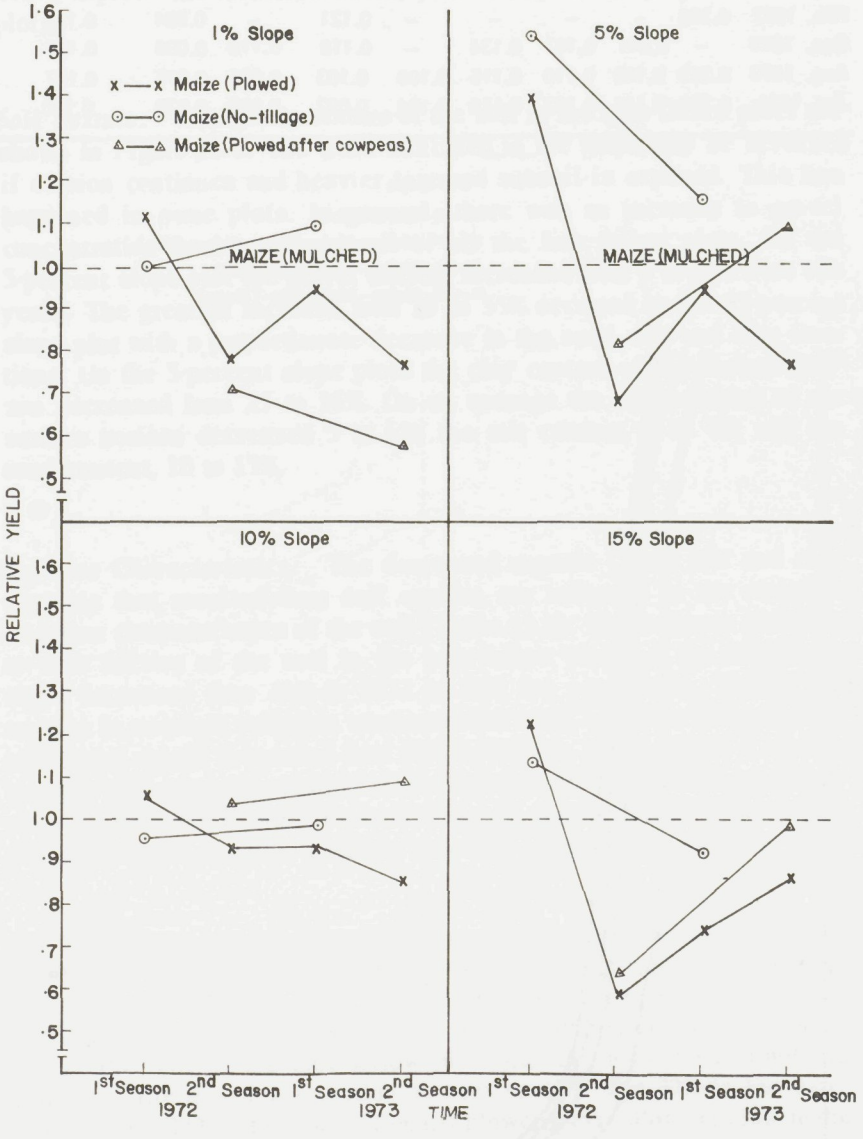


Fig. 13.4 Relative maize yield during 1972 and 1973.

plots, the yields on the conventionally plowed maize plots declined progressively over the four growing seasons. Maize grown in rotation with cowpeas yielded more than continuous maize.

B. *Effect of Artificial Soil Removal*

The height of maize and cowpeas was significantly depressed by surface soil removal. The combined yields of maize and cowpeas for two

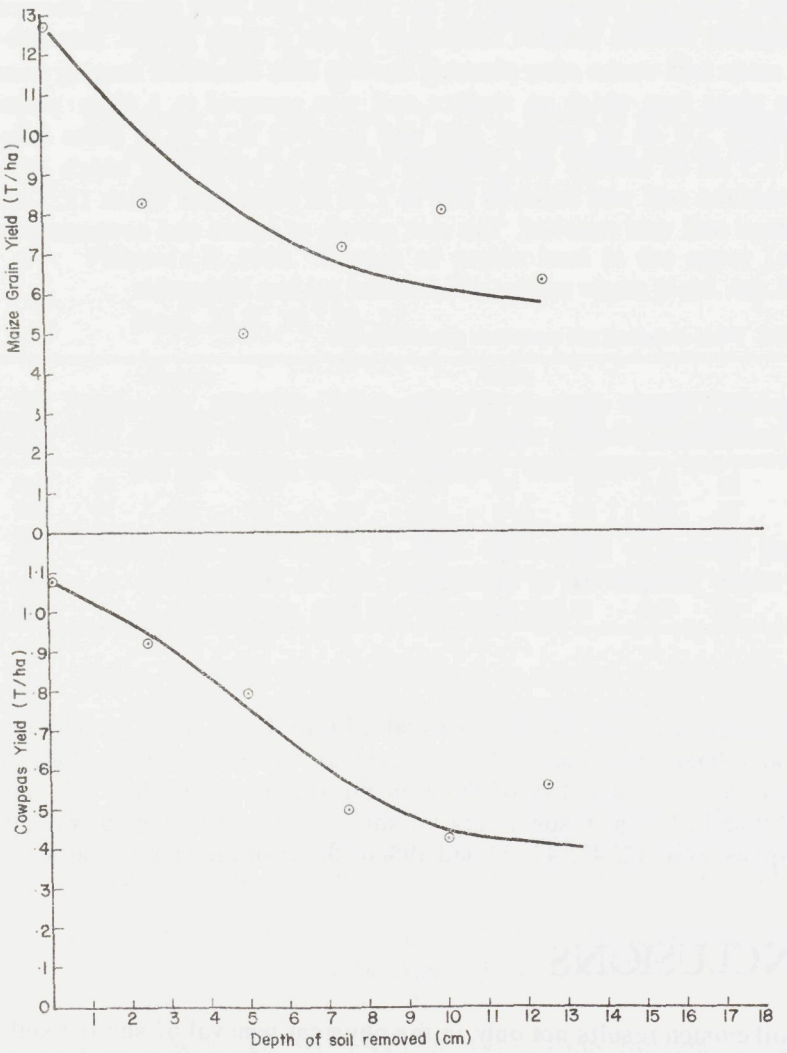


Fig. 13.5 The influence of artificial soil removal on yield response of maize *(Zea mays* L.) and cowpeas *(Vigna Unguiculata).*

consecutive seasons with different depths of soil removed are shown in Figure 13.5. Relative maize yields were 77, 62, 51, 47 and 44% of the yield on the control plots when 2.5, 5.0, 7.5, 10.0 and 12.5 cm, respec-

tively, of soil were removed. Removing 2.5 cm of surface soil has a greater detrimental effect on maize yield than on cowpea yield.

Weekly measurements of soil moisture content on these plots showed that the control plots had higher moisture contents than the others. There were no significant differences in soil moisture content among the plots when different depths of soil were removed.

Bulk densities measurement of the surface soil after removal showed that exposed subsoil became compacted within a short period. Measurements made four weeks after planting showed bulk densities ranging from 1.28 in plots from which no surface soil was removed to 1.43 in plots from which 5.0 cm of surface soil was removed to 1.45 in plots from which 7.5 cm of surface was removed to 1.43 in plots from which 10.0 cm of surface soil was removed and to 1.45 in plots from which 12.5 cm of surface soil was removed. The root growth of maize and cowpeas was

Table 13.2. Effect of depth of soil removed on root development

Depth of soil removed (cm)	Maize					Cowpeas				
	Root number	Average length (cm)	Max. depth (cm)	Lateral spread (cm)	Dry weight g/plant	Root number	Average length (cm)	Max. depth (cm)	Lateral spread (cm)	Dry weight g/plant
0	51	21.4	25	55	5.07	15	10.7	27	29	0.26
2.5	24	19.8	18	40	1.24	10	7.4	17	10	0.11
5.0	24	15.3	13	50	1.03	10	9.1	25	12	0.11
7.5	20	18.1	14	40	0.71	9	8.2	30	11	0.11
10.0	22	13.2	14	35	0.42	8	8.1	24	12	0.05
12.5	21	15.0	11	35	0.67	9	6.7	12	7	0.05

significantly affected by soil removal (Table 13.2). Root weight per plant was drastically reduced by soil removal. The root weights of maize were 24, 20, 14, 8 and 13% of those in the control plots when 2.5, 5.0, 7.5, 10.0 and 12.5 cm, respectively, of soil were removed. Similar weights of cowpeas were 42, 42, 42, 23 and 19% of those in the control plots.

CONCLUSIONS

Soil erosion results not only in the physical removal of surface soil, but also in losses of organic matter and nitrogen. In addition to nutrient losses, the moisture retention characteristics, infiltration rate are also significantly affected. The yield depression that results can be attributed to degradation of the physical properties of the soil and losses of organic matter and soil nitrogen. Physical characteristics of the subsoil may dominate the crop response on eroded lands and addition of fertilizer may not compensate for removal of surface soil by erosion.

REFERENCES

1. Doshchanov, M. B., and Muratova, G. G., 1953. The effect of the erosion of upland soils on the yield of agricultural crops. Pochvovedenie N. 8 : 75–81.

2. Ensminger, L. E., 1952. Loss of phosphates by erosion. Soil Sci. Soc. Amer. Proc. 16 : 338–342.

3. Ensminger, L. E. and Cope, J. T., 1947. Effect of soil reaction on the efficiency of various phosphates for cotton and on loss of P by erosion. J. Amer. Soc. Agron. 39 : 1–11.

4. Filipovic, D., 1968. Erosion of arable land in the upper Jasenica watershed and its influence on winter wheat yield. Arh. Poljopr. Nauk. 21 N. 74 : 16–27.

5. Grosse, B., 1967. The productivity of severely eroded Parabraunerde formed from loss under moderate climatic conditions. Trans. 8th Int. Congr. Soil Sci. 1964, 2 : 729–735.

6. Gupta R.N., and Singh, N., 1967. Selectivity of erosion processes with respect to soil phosphorus in the alluvial tracts of U.P. J. Indian Soc. Soil Sci. 15: 261–268.

7. Hegyi, G., 1970. Model experiment on erosion in brown forest soil subject to clay illuviation. Preliminary report. Novenytermele's 19 : 71–78.

8. Kowal, J., 1972. The hydrology of a small catchment basin at Samaru, Nigeria. IV. Assessment of soil erosion under varied land management and vegetation cover. Nigeria Agric. J. 7 : 134–147.

9. Massey, H. F., Jackson, M. L., and Hays, O. E., 1953. Fertility erosion on two Wisconsin Soils. Agron. J. 45 : 543–547.

10. Osborn, W. M., and Mathews, O. R., 1955. Crop rotation, tillage and fertility experiments at Lawton field station 1917–49. U.S.D.A. Circ. 951 : 58

11. Pasev, P., Dundakov, P., and Dekov, L., 1968. The effect of some soil relief conditions and slopes on the growth of vines and the quality of grapes and wine. Grad. lozar. Nauka 5, No. 6 : 63–70.

12. Rogers, H. T., 1944. Plant nutrient losses from a corn, wheat, clover rotation on Dunmore silt loam. Soil Sci. Soc. Amer. Proc. 6 : 263–271.

13. Scarseth, G. D., and Chandler, W. V., 1938. Losses of phosphate from a light-textured soil in Alabama and its relation to some aspects of soil conservation. Agron. J. 30 : 361– 375.

14. Thomas, A. W., Carter, R. L., and Carreker, J. R., 1968. Soil, water and nutrient losses from Tifton loamy sand. Trans. Amer. Soc. Agr. Eng. 11 : 677–679.

15. Tikhonov, A. V., 1960. Soil erosion and its effect on yield in regions of the Volga hills. Pochvovedenie N. 2 : 80–86.

16. Trashliev, Kh., and Milchev, M., 1963. Effect of surface erosion on soil properties and on yield of some agricultural crops. Izv. Inst. Pochvoznan. Agrotexh. Pushkarov. 8 : 213–222.

17. Volk, G. W., 1945. Response to residual phosphorus of cotton in continuous culture. Agron. J. 35 : 330–340.

Appendices & Units

APPENDIX 1a *Run-off and soil loss records for individual rain storms during 1972*

Run-off (mm), losses under

APPENDIX 1a *Run-off and soil loss records for individual rain storms during 1972*

Run-off (mm) losses under slopes and soil management treatments.

Date	Rainfall mm	Intensity mm/hr Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
2/3/72	50.8	–	–	14.6	0.0	4.9	4.2	4.5	1.6	1.6	25.5	3.7	18.3	3.7	0.0	14.0	16.4	5.7	3.7	0.4	4.7	3.7	3.7
16/3/72	5.1	–	–	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2
5/4/72	12.7	–	–	0.5	0.0	0.3	0.2	0.1	0.6	0.2	0.9	0.2	1.1	0.5	0.5	0.6	0.4	0.5	0.6	0.3	0.6	0.6	0.6
7/4/72	14.0	–	–	0.1	0.0	0.1	0.2	0.2	0.2	0.2	0.4	1.6	0.4	0.2	0.3	0.4	0.3	0.3	0.5	0.3	0.5	0.5	0.6
14/4/72	23.5	–	–	0.6	0.0	0.3	0.4	0.3	0.5	0.4	0.6	0.3	0.6	0.4	0.5	0.6	0.6	0.5	0.5	0.4	0.5	0.6	0.4
20/4/72	13.3	–	–	0.9	0.0	0.9	0.5	0.4	0.8	0.4	2.1	4.0	1.4	0.7	0.7	1.0	1.4	0.8	0.8	0.5	0.8	1.2	1.3
23/4/72	22.2	–	–	0.4	0.0	0.8	0.2	0.1	0.5	0.0	1.5	2.6	0.9	0.3	0.2	0.3	0.9	0.2	0.2	0.1	0.2	0.7	0.5
30/4/72	10.8	81.28	14.22	0.5	0.0	0.3	0.3	0.1	1.4	0.1	1.8	2.0	1.8	0.5	0.2	0.5	0.4	0.4	0.3	0.2	0.3	0.4	0.5
4/5/72	20:0	60.96	23.11	0.8	0.0	0.3	0.2	0.1	0.6	0.2	1.8	2.1	3.6	0.6	0.5	0.6	0.7	0.7	0.3	0.3	0.6	0.7	1.3
8/5/72	13.3	36.58	7.62	0.6	0.0	0.5	0.3	0.2	0.2	0.2	1.8	0.9	1.7	0.8	0.3	0.6	0.7	0.6	0.5	0.3	0.5	0.6	0.9
11/5/72	12.7	30.48	10.92	0.9	0.0	0.5	0.1	0.1	0.7	0.1	1.3	1.1	2.2	0.3	0.2	0.3	0.4	0.3	0.4	0.2	0.3	0.4	0.7
14/5/72	13.3	50.80	16.00	0.8	0.0	0.5	0.2	0.1	3.1	0.1	2.0	1.3	2.3	2.0	0.3	0.6	1.2	0.6	1.2	0.2	0.3	1.2	1.2
27/5/72	5.1	36.57	6.86	0.3	0.0	0.2	0.1	0.1	0.2	0.1	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
28/5/72	61.0	124.24	33.73	54.5	0.0	3.7	1.4	0.7	42.0	0.6	25.6	12.5	7.3	56.5	1.6	2.8	11.7	2.3	25.6	1.1	2.4	10.5	2.7
29/5/72	6.4	40.64	8.38	2.4	0.3	0.5	0.2	0.6	3.0	0.1	1.1	0.6	0.6	3.4	0.1	0.4	1.1	0.4	1.9	0.1	0.5	0.7	0.3
31/5/72	10.8	50.80	13.46	2.9	0.0	0.6	0.1	0.1	3.6	0.1	2.1	1.0	0.6	1.8	0.2	0.3	0.6	0.3	0.6	0.2	0.1	0.5	0.3
1/6/72	47.0	101.60	51.30	11.3	0.1	8.3	2.6	0.5	23.5	0.9	25.9	33.0	5.8	33.0	1.0	21.6	26.3	5.1	40.7	1.0	23.3	27.9	3.2
2/6/72	5.1	30.48	6.86	0.2	0.0	0.1	0.0	0.1	0.1	0.0	0.2	0.1	0.1	1.1	0.1	0.2	0.6	0.2	0.6	0.0	0.4	0.7	0.2
4/6/72	9.5	50.80	12.70	1.2	0.0	0.6	0.2	0.2	0.2	0.0	3.7	1.8	0.5	2.6	0.2	0.6	1.9	0.3	1.2	0.3	0.8	1.7	0.3
7/6/72	9.4	30.48	11.94	1.7	0.0	0.3	0.1	0.1	3.1	0.2	0.7	0.6	0.3	1.8	0.2	0.3	0.7	0.3	0.9	0.1	0.2	0.6	0.3
9/6/72	10.8	66.04	11.94	3.7	0.0	0.5	0.2	0.1	6.3	0.1	1.6	0.9	0.3	3.3	0.1	0.5	1.1	0.3	2.1	0.2	0.3	0.9	0.3
13/6/72	47.0	71.12	31.24	34.4	0.0	3.7	1.7	0.6	51.2	0.5	24.1	7.1	1.9	39.3	1.1	3.4	8.8	1.4	26.8	0.9	5.2	14.8	1.3

Run-off (mm) losses under slopes and soil management treatments.

Date	Rainfall mm	Intensity mm/hr Max.	Intensity mm/hr Mean	1% 1	1% 2	1% 3	1% 4	1% 5	5% 1	5% 2	5% 3	5% 4	5% 5	10% 1	10% 2	10% 3	10% 4	10% 5	15% 1	15% 2 I	15% 2 II	15% 3	15% 4	15% 5
16/6/72	11.4	55.88	15.24	0.9	0.0	0.3	0.1	0.1	4.3	0.3	1.4	0.6	0.3	3.0	0.2	0.5	0.8	0.3	0.3	0.4	0.3	1.1	0.3
17/6/72	105.4	142.24	106.43	54.6	0.0	34.2	6.6	1.8	54.6	7.02	31.3	31.4	34.1	54.6	4.1	34.3	34.2	5.6	54.6	4.0	34.3	35.5	7.3
20/6/72	10.9	30.48	5.84	2.1	0.0	0.5	0.3	0.2	0.3	0.3	0.6	0.5	0.5	3.0	0.2	0.3	0.4	0.3	0.3	0.7	0.1	0.4	0.3
23/6/72	6.9	40.64	8.38	3.0	0.0	0.4	0.1	0.1	2.1	0.0	0.6	0.4	0.2	2.7	0.2	0.3	0.4	0.3	1.8	0.1	0.2	0.6	0.4
24/6/72	34.3	60.00	21.08	13.6	0.0	2.7	0.7	0.4	20.1	0.4	7.1	2.5	0.8	18.2	0.8	3.0	7.0	0.9	23.5	0.6	3.1	7.0	0.9
28/6/72	7.6	50.80	8.38	0.6	0.0	0.2	0.0	0.0	1.3	0.0	0.3	0.2	0.1	0.8	0.0	0.3	0.4	0.2	0.7	0.1	0.1	0.6	0.3
3/7/72	15.2	91.44	20.32	5.7	0.0	1.0	0.4	0.2	8.3	0.2	1.3	0.7	0.4	7.1	0.5	1.0	1.3	0.5	7.0	0.2	0.6	0.2	0.6
4/7/72	8.3	50.80	11.18	3.1	0.0	0.5	0.1	0.0	3.7	0.1	0.7	0.4	0.2	3.7	0.2	0.6	0.8	0.2	3.6	0.1	0.5	1.2	0.3
12/7/72	30.5	71.12	35.56	8.0	0.0	1.5	0.5	0.4	21.2	0.3	1.2	0.8	0.7	11.9	0.7	1.3	1.4	0.7	11.0	0.4	1.0	2.2	0.9
17/7/72	8.9	30.48	10.92	0.6	0.0	0.2	0.1	0.1	2.2	0.1	0.3	0.3	0.2	0.9	0.2	0.2	0.1	0.1	1.0	0.1	0.2	0.3	0.3
7/9/72	12.7	52.83	14.99	1.7	0.0	0.3	0.2	0.1	3.0	0.3	1.4	0.5	0.9	0.9	0.9	0.5	0.9	0.4	1.4	0.4	0.5	0.4	0.6
8/9/72	11.4	40.64	8.38	0.4	0.0	0.0	0.1	0.1	0.5	0.1	0.3	0.2	0.4	0.6	0.2	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.5
16/9/72	12.5	50.80	17.02	0.7	0.0	0.2	0.2	0.1	0.9	0.2	0.4	0.3	0.2	1.2	0.4	0.6	0.4	0.5	0.5	0.3	1.1	0.9	0.7
19/9/72	31.8	–	42.18	8.3	0.0	0.7	0.4	0.2	9.6	0.2	4.5	0.6	6.1	5.0	0.6	0.9	0.6	0.9	1.7	0.5	1.1	0.9	3.2
21/9/72	30.5	101.60	22.86	9.6	0.0	2.0	0.3	3.7	13.6	0.2	5.0	0.6	12.3	4.7	0.6	4.4	0.8	2.7	11.0	0.5	4.6	0.9	8.5
25/9/72	13.3	60.96	15.24	2.7	0.0	0.3	0.2	0.2	3.6	0.1	1.9	0.4	6.4	3.7	0.5	0.8	0.5	0.6	1.6	0.4	0.8	0.6	1.6
26/9/72	10.9	25.4	5.08	1.4	0.0	0.1	0.1	0.1	3.6	0.1	0.6	0.3	0.3	3.4	0.2	0.5	0.3	0.3	1.6	0.0	0.4	0.2	1.0
3/10/72	12.7	30.48	8.38	0.4	0.0	0.4	0.1	0.1	0.9	0.1	0.4	0.4	0.4	0.8	0.3	0.5	0.4	0.4	0.5	0.3	0.4	0.5	0.5
7/10/72	15.8	91.44	20.32	3.7	0.0	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	3.7	0.3	0.5	0.5	0.4	3.4	0.2	0.4	0.5	0.5
18/10/72	8.6	50.30	10.16	1.2	0.0	0.3	0.2	0.1	2.9	0.2	0.3	0.3	0.3	3.6	0.2	0.5	0.5	0.4	3.4	0.3	0.4	0.5	0.5

Soil loss (ton/ha under different slopes and soil management treatments

Soil loss (ton/ha under different slopes and soil management treatments

Date	Rainfall mm	Intensity mm/hr Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
2/3/72	50.8	–	–	0.00	0.00	0.05	0.05	0.07	0.19	0.00	0.20	0.19	0.13	0.63	0.00	0.83	0.50	1.12	0.80	0.80	1.00	0.64	1.06
16/3/72	5.1	–	–	0.01	0.00	0.01	0.01	0.02	0.01	0.00	0.02	0.02	0.01	0.01	0.00	0.03	0.03	0.03	0.01	0.00	0.01	0.01	0.01
5/4/72	12.7	–	–	0.06	0.00	0.04	0.02	0.02	0.08	0.00	0.08	0.05	0.13	0.11	0.00	0.13	0.11	0.12	0.06	0.00	0.05	0.07	0.05
7/4/72	14.0	–	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14/4/72	23.5	–	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20/4/72	13.3	–	–	0.06	0.00	0.05	0.02	0.05	0.11	0.04	0.12	0.16	0.07	0.08	0.03	0.14	0.19	0.09	0.09	0.06	0.14	0.11	0.15
23/4/72	22.2	–	–	0.02	0.00	0.17	0.00	0.00	0.01	0.00	0.03	0.02	0.03	0.04	0.00	0.02	0.00	0.01	0.03	0.00	0.01	0.06	0.04
30/4/72	10.8	81.28	14.22	0.04	0.00	0.02	0.02	0.01	0.01	0.00	0.13	0.09	0.08	0.06	0.00	0.03	0.07	0.03	0.03	0.00	0.04	0.05	0.08
4/5/72	20.0	50.80	23.11	0.06	0.00	0.05	0.03	0.02	0.09	0.04	0.20	0.13	0.26	0.06	0.00	0.12	0.15	0.09	0.04	0.00	0.05	0.04	0.12
8/5/72	13.3	36.58	7.62	0.04	0.00	0.03	0.00	0.00	0.00	0.00	0.06	0.06	0.10	0.02	0.00	0.03	0.04	0.00	0.04	0.06	0.05	0.00	0.12
11/5/72	12.7	30.48	8.38	0.03	0.00	0.01	0.02	0.00	0.02	0.00	0.03	0.04	0.10	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01
14/5/72	13.3	40.64	15.74	0.04	0.00	0.10	0.00	0.00	0.22	0.00	0.06	0.02	0.05	0.16	0.00	0.00	0.14	0.02	0.11	0.00	0.00	0.09	0.10
27/5/72		36.57	19.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28/5/72	61.0	91.44	33.02	0.57	0.00	0.03	0.04	0.00	1.52	0.00	0.33	0.03	0.06	1.67	0.00	0.07	0.50	0.00	0.01	0.00	0.50	0.40	0.00
29/5/72	10.80	50.80	12.95	0.03	0.00	0.00	0.00	0.00	0.11	0.00	0.02	0.00	0.01	0.12	0.00	0.00	0.03	0.01	1.73	0.00	0.02	0.02	0.00
31/5/72	10.8	50.80	12.95	0.04	0.00	0.00	0.00	0.00	0.16	0.00	0.03	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.18	0.00	0.01	0.00	0.00
1/6/72	47.0	101.60	51.30	0.39	0.00	0.06	0.02	0.00	2.75	0.00	0.24	0.14	0.05	3.85	0.02	0.94	0.73	0.02	13.56	0.00	3.55	2.08	0.00
2/6/72	5.1	20.32	4.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.09	0.00	0.94	0.00	0.19	0.15	0.00
4/6/72	9.5	40.64	11.93	0.07	0.00	0.02	0.00	0.00	1.34	0.00	0.19	0.03	0.00	1.79	0.00	0.08	0.21	0.00	2.49	0.00	0.21	0.30	0.00
7/6/72	9.4	–	–	0.04	0.00	0.00	0.00	0.00	0.67	0.00	0.06	0.02	0.00	0.79	0.00	0.00	0.05	0.00	1.34	0.00	0.03	0.03	0.00
9/6/72	10.8	54.86	9.91	0.10	0.00	0.01	0.00	0.00	1.20	0.00	0.04	0.03	0.00	1.30	0.00	0.02	0.03	0.00	3.20	0.00	1.00	0.57	0.00
13/6/72	47.0	71.12	31.24	0.60	0.00	0.10	0.05	0.00	5.08	0.00	0.29	0.13	0.05	3.95	0.00	0.03	0.37	0.52	15.0	0.00	1.00	0.58	0.00
16/6/72	11.4	50.80	14.48	0.03	0.00	0.01	0.00	0.00	0.92	0.00	0.07	0.01	0.00	0.84	0.00	0.00	0.03	0.00	3.83	0.00	0.00	0.04	0.00
17/6/72	105.4	121.92	97.53	0.80	0.00	0.18	0.03	0.00	4.27	0.01	0.27	0.22	0.10	4.27	0.09	2.58	1.43	0.03	29.80	0.02	5.48	1.55	0.01
20/6/72	10.9	30.48	5.84	0.04	0.00	0.00	0.00	0.00	0.18	0.00	0.02	0.02	0.00	2.02	0.00	0.00	2.02	0.00	0.68	0.00	0.00	0.00	0.00
23/6/72	6.9	30.48	5.08	0.15	0.00	0.00	0.00	0.00	0.71	0.00	0.01	0.00	0.00	0.83	0.00	0.00	0.00	0.00	2.35	0.00	0.05	0.04	0.00

Soil loss (ton/ha) under different slopes and soil management treatments.

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
25/6/72	34.3	81.28	19.05	0.24	0.00	0.05	0.00	0.00	3.73	0.00	0.16	0.03	0.00	8.30	0.00	0.09	0.21	0.00	7.30	0.00	0.89	1.10	0.00
28/6/72	7.6	45.72	8.38	0.03	0.00	0.01	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.02	0.00
3/7/72	14.6	101.60	19.05	0.19	0.00	0.01	0.00	0.00	2.02	0.00	0.04	0.02	0.00	4.39	0.00	0.04	0.07	0.00	5.10	0.00	0.03	0.17	0.00
4/7/72	7.6	54.86	11.18	0.11	0.00	0.00	0.07	0.00	1.61	0.00	0.01	0.00	0.00	2.56	0.00	0.01	0.05	0.00	5.00	0.00	0.06	0.08	0.00
12/7/72	29.8	55.88	34.04	0.12	0.00	0.00	0.00	0.00	3.22	0.00	0.00	0.00	0.00	5.11	0.00	0.02	0.02	0.00	4.88	0.00	0.01	0.00	0.00
17/7/72	8.9	26.41	10.67	0.01	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00
7/9/72	12.7	52.83	14.99	0.12	0.00	0.00	0.00	0.06	0.69	0.00	0.01	0.00	0.01	0.24	0.00	0.00	0.00	0.01	0.39	0.00	0.06	0.00	0.01
8/9/72	11.4	30.48	7.37	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16/9/72	12.5	50.80	15.75	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19/9/72	31.8	–	–	0.35	0.00	0.00	0.00	0.00	2.56	0.00	0.08	0.00	0.29	2.38	0.00	0.00	0.00	0.05	0.55	0.00	0.00	0.91	0.01
21/9/72	30.5	101.60	20.83	0.26	0.00	0.05	0.00	0.20	2.56	0.00	0.29	0.00	0.77	3.86	0.00	0.56	0.00	0.88	6.03	0.00	1.22	0.05	2.90
25/9/72	13.3	50.80	14.99	0.15	0.00	0.00	0.00	0.00	1.52	0.00	0.02	0.00	0.04	2.47	0.00	0.01	0.00	0.00	1.89	0.06	0.09	0.01	0.85
26/9/72	10.9	36.58	9.91	0.00	0.00	0.00	0.00	0.00	1.58	0.00	0.00	0.00	0.00	1.76	0.00	0.00	0.00	0.00	1.79	0.00	0.00	0.00	0.64
3/10/72		30.48	7.37	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
7/10/72	15.8	26.42	18.80	0.01	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
18/10/72	29.5	50.80	9.91	0.11	0.00	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.00	2.12	0.00	0.00	0.00	0.00	4.15	0.00	0.00	0.00	0.00

Effect of contour length on soil and water loss under maize-cowpea rotation

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.4%	13.4%
2/3/72	50.3	–	–	13.71	7.38	2.78	0.24	22.53	2.46	1.41	0.23
16/3/72	5.1	–	–	0.09	0.09	0.13	0.01	0.05	0.09	0.02	0.01
5/4/72	12.7	–	–	1.01	1.01	0.39	0.10	0.31	0.27	0.16	0.04
7/4/72	14.0	–	–	1.05	0.91	0.00	0.00	0.31	0.24	0.00	0.00
14/4/72	23.5	–	–	0.91	1.00	0.00	0.00	0.31	0.18	0.00	0.00
20/4/72	13.3	–	–	1.82	1.66	0.91	0.82	0.67	0.49	1.00	0.88
23/4/72	22.2	–	–	1.29	1.00	0.28	0.04	0.30	0.12	0.04	0.02
30/4/72	10.8	81.28	14.22	1.45	0.73	0.42	0.09	0.39	0.30	0.08	0.04
4/5/72	20.0	50.80	23.11	1.20	1.85	0.42	0.12	0.52	1.85	0.09	0.22
8-9/5/72	13.3	36.58	7.62	2.49	1.45	0.36	0.06	0.62	0.62	0.00	0.03
11/5/72	12.7	30.48	8.38	1.66	0.92	0.19	0.00	0.19	0.00	0.00	0.00
14/5/72	13.3	40.64	15.74	2.77	8.95	0.18	0.12	0.89	0.86	0.05	0.04
27/5/72		36.57	19.30	0.56	0.46	0.00	0.00	0.19	0.19	0.00	0.00
28/5/72	61.0	91.44	33.02	32.73	26.58	1.42	0.45	6.22	7.01	0.11	0.06
29/5/72	10.8	50.80	12.95	1.75	1.29	0.23	0.00	0.49	0.39	0.12	0.13
1/6/72	47.0	101.60	51.30	49.55	36.69	5.24	1.10	53.13	53.13	2.91	1.34
2/6/72	5.1	20.32	4.95	1.18	1.64	0.00	0.07	0.45	0.54	0.21	0.30
4/6/72	9.5	40.64	11.93	3.09	2.36	0.53	0.24	1.94	1.39	0.79	0.45
7/6/72	9.4	–	–	1.82	1.09	0.07	0.06	0.54	0.39	0.13	0.07
9/6/72	10.8	54.86	9.91	2.54	1.27	0.13	0.06	0.48	0.78	0.07	0.05

Effect of contour length on soil and water loss under maize-cowpea rotation

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.4%	13.4%
13/6/72	47.0	71.12	31.24	8.96	22.43	0.64	1.73	7.21	14.00	0.86	0.31
16/6/72	11.4	50.80	14.48	1.64	2.18	0.04	0.06	0.61	0.94	0.05	0.05
17/6/72	105.4	121.92	97.53	68.51	68.51	5.11	1.09	22.26	22.35	1.33	0.98
20/6/72	10.9	30.48	5.84	1.09	1.27	0.14	0.11	0.24	0.36	0.03	0.06
23/6/72	6.9	30.48	5.08	1.09	1.45	0.12	0.10	0.31	0.54	0.04	0.07
25/6/72	34.3	81.28	19.05	12.31	11.34	6.70	0.53	6.92	8.73	1.20	0.24
28/6/72	7.6	45.72	8.38	1.10	1.20	0.06	0.05	0.49	0.88	0.07	0.02
3/7/72	14.6	101.60	19.05	3.69	4.28	0.28	0.35	1.58	2.18	0.22	0.13
4/7/72	7.6	54.86	11.18	1.82	2.36	0.15	0.19	0.95	1.09	0.13	0.10
12/7/72	29.8	55.88	34.04	4.54	4.73	0.15	0.07	1.70	2.39	0.10	0.03
17/7/72	8.9	26.41	10.67	0.55	0.36	0.00	0.00	0.12	0.27	0.00	0.00
7/9/72	12.7	52.83	14.99	0.82	0.91	0.01	0.12	0.27	0.36	0.00	0.02
8/9/72	11.4	20.48	7.37	0.73	0.55	0.00	0.00	0.18	0.21	0.00	0.00
16/9/72	12.5	50.80	15.75	1.00	0.90	0.00	0.00	0.31	0.27	0.00	0.00
19/9/72	31.5	–	–	2.32	3.09	0.29	0.10	0.73	0.55	0.25	0.01
21/9/72	30.5	101.60	20.83	7.28	8.36	2.30	2.78	4.89	4.10	0.99	1.10
25/9/72	13.3	50.80	14.99	2.46	3.46	0.07	0.15	0.73	0.79	0.05	0.01
26/9/72	10.9	36.58	9.91	1.27	1.64	0.01	0.00	0.70	0.55	0.09	0.00
3/10/72		30.48	7.37	0.91	0.91	0.00	0.00	0.36	0.30	0.00	0.00
7/10/72	15.8	26.42	18.80	1.27	0.93	0.01	0.01	0.67	0.31	0.00	0.00
18/10/72	29.5	50.80	9.91	0.73	0.91	0.00	0.00	0.30	0.30	0.00	0.00

APPENDIX 1b *Run-off and soil loss records for individual rain storm during 1973*

APPENDIX 1b *Run-off and soil loss records for individual rain storm during 1973*

Run-off (mm) losses under different slopes and soil management treatments.

Date	Rainfall mm	Intensity mm/hr Max.	Intensity mm/hr Mean	1% 1	1% 2	1% 3	1% 4	1% 5	5% 1	5% 2	5% 3	5% 4	5% 5	10% 1	10% 2	10% 3	10% 4	10% 5	15% 1	15% 2	15% 3	15% 4	15% 5
17/2/73	8.9	50.80	11.68	1.5	0.0	0.2	0.0	0.1	2.2	0.1	0.1	0.0	0.0	1.3	0.0	0.1	0.0	0.0	0.2	0.1	0.1	0.0	0.1
14/3/73	21.6	30.48	13.20	1.9	0.0	0.3	0.3	0.3	3.5	0.2	0.4	0.1	0.4	2.2	0.4	0.6	0.5	0.4	0.5	0.3	0.5	0.5	0.6
22/3/73	8.4	15.24	5.08	1.9	0.0	0.3	0.3	0.2	2.5	0.1	0.4	0.2	0.3	2.2	0.5	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8
25/3/73	10.4	50.80	10.16	3.6	0.0	0.5	0.4	0.3	3.6	0.1	0.6	0.2	0.5	3.7	0.6	0.9	0.7	0.6	0.7	0.5	0.7	0.8	1.0
4/4/73	34.0	71.12	35.56	3.7	0.0	0.6	0.6	0.5	9.0	0.6	0.9	0.4	0.5	4.4	1.1	1.3	1.1	1.1	1.5	0.9	1.4	1.5	1.5
21-23/4/73	48.8	172.72	49.78	17.6	0.0	9.6	0.6	7.7	7.7	0.6	17.2	0.9	15.2	15.6	1.5	6.5	1.5	19.5	14.9	1.0	7.7	1.7	8.4
25/4/73	4.1	32.51	5.33	0.4	0.0	0.1	0.0	0.0	1.0	0.0	0.7	0.0	0.5	0.8	0.0	0.2	0.1	0.1	0.3	0.1	0.3	0.1	0.3
27/4/73	24.5	91.44	32.27	5.7	0.0	6.9	0.2	5.5	9.6	0.3	13.4	0.5	13.6	9.6	0.6	5.1	0.6	7.7	9.0	0.5	5.7	0.7	6.9
6/5/73	16.5	40.64	21.83	6.3	0.0	3.2	0.2	0.9	6.3	0.2	5.7	0.4	0.5	7.0	0.4	1.2	0.4	1.5	5.7	0.5	3.2	0.6	2.0
24/5/73	17.0	60.96	22.61	3.6	0.0	0.7	0.3	0.3	8.3	0.2	6.5	0.4	7.7	5.0	0.5	0.7	0.5	0.7	2.8	0.3	1.8	0.6	2.0
31/5/73	13.5	91.44	17.78	5.7	0.0	1.3	0.2	0.1	6.3	0.1	6.9	0.1	1.7	6.3	0.4	0.7	0.4	0.5	6.3	0.4	2.3	0.5	0.5
5/6/73	19.1	71.12	20.32	7.7	0.0	0.9	0.2	0.1	8.6	0.1	7.7	0.2	2.1	5.7	0.4	0.9	0.4	0.6	9.6	0.3	2.6	0.5	0.8
8/6/73	7.6	40.64	10.16	0.7	0.0	0.2	0.1	0.1	0.2	0.2	1.2	0.2	0.3	0.9	0.2	0.2	0.1	0.2	0.3	0.1	0.1	0.2	0.3
10/6/73	44.2	–	–	27.1	0.0	3.7	0.6	0.4	30.1	0.5	13.6	0.8	12.8	24.2	0.9	5.7	0.9	1.7	33.4	0.8	14.8	1.0	2.2
13/6/73	22.9	71.12	27.94	8.3	0.0	2.8	0.2	0.0	7.0	0.2	8.0	0.3	6.9	10.3	0.4	1.5	0.4	0.6	10.3	0.3	6.9	0.4	0.6
21/6/73	6.9	30.48	9.14	1.1	0.0	0.1	0.1	0.1	0.9	0.1	0.2	0.1	0.1	0.6	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2
23/6/73	39.4	50.80	25.40	22.2	0.0	1.2	0.6	0.1	26.1	0.4	14.0	0.2	1.4	22.8	0.8	2.3	0.9	1.1	22.8	0.7	4.9	1.0	1.3
25/6/73	5.3	30.48	7.11	1.9	0.0	0.2	0.2	0.1	0.2	0.1	0.4	0.1	0.1	1.8	0.1	0.2	0.1	0.1	0.7	0.1	0.3	0.1	0.2
1/7/73	19.8	20.32	11.94	4.7	0.0	1.8	1.0	0.3	16.2	0.3	6.9	1.1	0.8	9.6	0.7	1.6	0.7	1.1	15.6	0.8	4.1	0.8	1.2
2/7/73	25.4	55.80	23.62	16.2	0.0	2.1	0.4	0.2	20.2	0.1	7.7	0.1	0.7	10.3	0.6	1.4	0.5	0.7	16.9	0.4	5.7	0.5	0.6
5/7/73	14.5	50.80	13.46	7.0	0.0	0.5	0.2	0.1	4.4	0.1	2.1	0.3	0.2	5.7	0.3	0.5	0.3	0.3	2.8	0.2	1.0	0.3	0.5

Run-off (mm) losses under different slopes and soil management treatments.

Date	Rainfall mm	Intensity mm/hr Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
12/7/73	30.5	50.80	28.19	16.9	0.0	1.3	0.4	0.2	16.9	0.2	6.3	0.5	0.8	10.6	0.5	0.9	0.5	0.6	11.9	0.5	0.7	0.6	0.7
23/7/73	50.8	111.76	65.79	36.7	0.0	6.1	0.7	0.3	38.7	0.2	23.9	0.7	0.7	40.0	0.9	11.2	1.0	1.1	33.4	0.7	12.0	1.0	0.8
27/7/73	11.4	30.48	10.16	2.2	0.0	0.1	0.2	0.1	2.1	0.2	0.5	0.2	0.2	0.5	0.1	0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.3
30/7/73	20.8	30.48	15.24	9.2	0.0	0.5	0.5	0.3	9.3	0.2	0.8	0.3	0.3	5.0	0.4	0.3	0.5	0.5	3.7	0.5	0.6	0.7	0.6
1/8/73	9.4	20.32	9.91	3.0	0.0	0.2	0.2	0.1	5.0	0.1	0.4	0.1	0.3	3.1	0.2	0.4	0.4	0.2	1.8	0.2	0.3	0.3	0.3
5/8/73	131.8	81.28	45.72	55.0	0.0	7.7	2.0	1.1	55.2	1.3	8.6	2.3	4.5	55.2	6.1	7.7	5.7	6.3	55.2	3.2	4.7	3.8	9.0
8/8/73	63.0	101.60	72.64	44.0	0.0	2.2	0.8	0.5	45.3	0.7	4.9	1.0	2.4	46.6	1.6	4.9	2.0	3.2	55.2	2.8	6.9	1.7	0.4
3/9/73	26.20	60.96	21.59	5.0	0.0	1.1	0.8	0.4	5.7	0.5	1.8	0.7	1.0	5.0	1.1	2.0	1.4	1.7	3.5	1.1	1.7	1.4	3.4
10/9/73	50.80	91.44	50.80	24.8	0.0	1.4	0.8	6.5	36.7	0.5	7.3	0.8	15.6	27.5	1.4	4.5	1.5	3.6	23.5	1.4	8.8	1.0	15.6
12/9/73	37.10	40.64	30.48	16.9	0.0	2.0	0.4	10.8	21.5	0.3	11.2	0.4	9.6	14.9	0.8	3.0	0.8	3.3	16.9	0.6	11.2	0.8	11.6
16-17/9/73	6.40	50.80	8.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23/9/73	27.9	152.40	33.02	13.6	0.0	1.4	0.4	0.9	15.6	0.2	5.0	0.4	2.3	20.1	0.6	2.7	0.9	2.1	15.6	0.6	6.5	0.9	7.7

Run-off (mm) losses under different slopes and soil management treatments.

Date	Rainfall mm	Intensity mm/hr Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
24/9/73	34.3	81.28	30.48	28.8	0.0	1.6	0.6	0.4	24.2	0.3	10.4	0.5	8.0	30.8	0.8	8.4	0.8	0.4	17.2	0.5	8.4	0.7	10.0
29/9/73	19.56	60.96	23.62	4.6	0.0	1.0	0.4	0.4	10.3	0.3	5.7	0.5	4.9	14.3	1.0	3.3	0.7	3.2	16.2	0.8	6.9	1.1	7.7
29/9/73	25.9	76.20	31.00	18.9	0.0	3.1	0.5	1.1	20.2	0.3	11.6	0.5	11.6	20.2	0.7	5.7	0.8	5.7	23.5	0.7	10.8	0.8	14.4
3/10/73	11.2	30.48	11.94	6.6	0.0	0.4	0.2	0.2	7.0	0.3	0.6	0.1	0.6	5.0	0.1	0.4	0.2	0.5	6.3	0.1	0.1	0.5	1.9
13/10/73	18.2	60.96	23.62	6.7	0.0	0.1	0.3	0.2	7.7	0.4	1.9	0.4	0.8	6.3	0.7	1.2	0.6	1.0	8.3	0.5	1.3	0.7	1.1
18/10/73	5.8	46.74	7.62	0.7	0.0	0.0	0.1	0.1	1.0	0.1	0.2	0.2	0.1	1.5	0.1	0.1	0.1	0.1	1.1	0.1	0.1	0.2	0.1
20-21/10/73	15.0	40.64	13.46	6.3	0.0	0.2	0.2	0.1	6.0	0.1	0.5	0.3	0.2	4.1	0.2	0.4	0.4	0.4	0.3	0.2	0.5	0.5	0.4
23/10/73	37.0	76.20	28.70	14.6	0.0	0.6	0.5	0.1	17.6	0.2	2.7	0.6	2.7	10.9	0.5	1.5	0.7	2.1	16.2	0.3	3.3	0.8	14.8
25/10/73	15.4	30.48	15.24	5.7	0.0	0.4	0.2	0.8	5.7	0.2	0.9	0.3	0.8	6.3	0.2	0.5	0.3	0.9	6.3	0.1	1.1	0.3	2.2
27/10/73	15.8	81.28	20.83	4.6	0.0	0.5	0.2	0.1	11.6	0.1	1.9	0.3	2.8	12.9	0.2	0.8	0.4	1.9	11.6	0.2	3.3	0.4	5.3
30/10/73	29.8	60.96	20.32	12.3	0.0	0.8	0.4	0.1	5.0	0.2	3.3	0.5	3.5	13.3	0.6	1.5	0.6	3.6	18.9	0.3	6.5	0.6	9.2

Soil loss (ton/ha) under different slopes and soil management treatments.

Soil loss (ton/ha) under different slopes and soil management treatments.

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
17/2/73	8.9	50.80	11.68	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14/3/73	21.6	24.38	13.20	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22/3/73	8.4	14.22	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25/3/73	10.4	30.48	9.65	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14/4/73	34.0	71.12	34.79	0.46	0.00	0.00	0.00	0.00	2.36	0.00	0.00	0.00	0.00	2.01	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00
21-23/4/73	48.0	172.72	49.78	0.47	0.00	0.30	0.01	0.24	1.60	0.02	0.52	0.03	0.65	8.36	0.00	0.92	0.00	1.71	3.62	0.00	1.94	0.10	1.22
25/4/73	4.1	26.42	5.33	0.03	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.32	0.00	0.14	0.00	0.00
27/4/73	24.6	71.12	31.50	0.19	0.00	0.15	0.00	0.13	1.83	0.00	0.59	0.00	2.77	7.62	0.00	0.97	0.01	1.14	8.34	0.00	4.15	0.00	2.93
6/5/73	16.5	40.64	20.83	0.26	0.00	0.03	0.00	0.19	2.13	0.00	0.17	0.00	0.47	4.62	0.00	0.17	0.00	0.26	3.91	0.00	1.77	0.00	2.02
24/5/73	17.0	60.96	16.51	0.19	0.00	0.01	0.00	0.01	1.62	0.00	0.23	0.00	0.68	2.46	0.00	0.06	0.00	0.11	1.79	0.00	0.38	0.00	0.37
31/5/73	13.5	91.44	17.53	0.24	0.00	0.07	0.00	0.00	2.00	0.00	0.23	0.00	0.22	5.66	0.00	0.12	0.01	0.03	4.99	0.00	0.65	0.00	0.11
5/6/73	19.1	71.12	19.81	0.18	0.00	0.02	0.00	0.00	3.92	0.00	0.21	0.00	0.15	5.00	0.00	0.09	0.00	0.00	6.76	0.00	0.88	0.00	0.03
8/6/73	7.6	30.48	9.91	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
10/6/73	44.2	–	–	0.24	0.00	0.04	0.00	0.00	3.76	0.00	2.81	0.00	0.35	12.66	0.00	0.41	0.00	0.00	17.11	0.00	4.07	0.00	0.04
13/6/73	22.9	60.96	24.89	0.17	0.00	0.06	0.00	0.00	5.54	0.00	0.48	0.01	0.19	9.23	0.00	0.13	0.00	0.00	8.77	0.00	2.23	0.00	0.01
21/6/73	6.9	30.48	8.38	0.03	0.00	0.00	0.00	0.00	0.86	0.00	0.02	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
23/6/73	39.4	40.64	15.00	0.45	0.00	0.04	0.00	0.00	6.05	0.00	0.55	0.02	0.00	7.08	0.01	0.06	0.00	0.00	8.71	0.00	1.65	0.00	0.05
25/6/73	5.3	20.32	13.21	0.03	0.00	0.00	0.00	0.00	2.41	0.00	0.01	0.00	0.01	0.92	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.01
1/7/73	19.8	20.32	13.21	0.21	0.00	0.11	0.00	0.00	7.58	0.00	0.49	0.11	0.00	6.25	0.01	0.11	0.00	0.01	6.91	0.00	1.38	0.00	0.00
2/7/73	25.4	50.80	23.11	0.22	0.00	0.04	0.00	0.00	9.84	0.00	0.56	0.01	0.01	5.42	0.00	0.02	0.00	0.00	5.48	0.00	0.99	0.00	0.00
5/7/73	14.5	50.80	12.45	0.17	0.00	0.00	0.00	0.00	3.81	0.00	0.14	0.03	0.00	2.39	0.00	0.02	0.00	0.00	1.81	0.00	0.15	0.00	0.00
12/7/73	30.5	40.64	28.19	0.27	0.00	0.02	0.00	0.00	5.46	0.00	0.34	0.01	0.00	3.85	0.00	0.09	0.00	0.00	2.64	0.00	0.08	0.00	0.00
23/7/73	50.8	111.76	48.26	0.45	0.00	0.07	0.00	0.00	3.62	0.00	0.37	0.00	0.00	7.34	0.00	0.12	0.00	0.00	5.91	0.00	1.80	0.00	0.00
27/7/73	11.4	24.38	9.91	0.03	0.00	0.00	0.00	0.00	1.37	0.00	0.01	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.00	0.00
30/7/73	20.8	30.48	13.97	0.06	0.00	0.00	0.00	0.00	2.74	0.00	0.01	0.00	0.00	2.37	0.00	0.01	0.00	0.00	1.98	0.00	0.00	0.00	0.00

Soil loss (ton/ha) under different slopes and soil management treatments.

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 1	2	3	4	5	5% 1	2	3	4	5	10% 1	2	3	4	5	15% 1	2	3	4	5
1/8/73	9.4	20.32	8.81	0.13	0.00	0.00	0.00	0.00	1.37	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00
5/8/73	181.8	50.80	29.71	2.12	0.00	0.15	0.00	0.00	3.53	0.00	0.27	0.01	0.03	34.01	0.02	0.38	0.01	0.02	30.51	0.01	0.47	0.01	0.37
8/8/73	63.0	121.92	69.34	0.95	0.00	0.15	0.00	0.00	2.61	0.00	0.23	0.00	0.02	19.64	0.01	0.39	0.01	0.02	33.34	1.87	0.88	0.00	0.46
3/9/73	26.2	50.80	21.59	0.23	0.00	0.00	0.00	0.01	1.14	0.00	0.03	0.00	0.01	0.97	0.01	0.01	0.01	0.04	1.96	0.01	0.18	0.01	0.35
10/9/73	50.8	91.44	49.53	0.21	0.00	0.10	0.00	0.12	7.46	0.01	0.47	0.00	0.57	11.45	0.01	0.59	0.01	0.34	7.97	0.01	1.76	0.00	6.90
12/9/73	37.1	40.64	28.19	0.28	0.00	0.09	0.00	0.01	5.32	0.01	0.55	0.00	0.72	8.62	0.00	0.25	0.01	0.19	10.90	0.00	2.85	0.00	7.10
16-17/9/73	6.4	40.64	7.64	0.00	0.00	0.00	0.00	0.00	1.95	0.00	0.00	0.00	0.00	2.42	0.09	0.00	0.00	0.00	1.77	0.00	0.13	0.00	0.15
23/9/73	27.9	121.92	33.02	0.26	0.00	0.03	0.00	0.02	3.17	0.00	0.29	0.01	0.16	11.40	0.00 +	0.33	0.01	0.21	8.04	0.01	2.64	0.00	6.97
24/9/73	34.3	20.32	5.84	0.42	0.00	0.04	0.00	0.01	8.18	0.00	0.42	0.00	0.42	7.89	0.00	0.90	0.00	0.41	6.42	0.00	2.44	0.00	2.70
27/9/73	66.0	81.28	28.70	0.34	0.00	0.01	0.00	0.01	10.48	0.00	0.37	0.00	0.41	8.11	0.01	0.13	0.00	0.32	9.31	0.00	1.83	0.00	3.77
29/9/73	25.9	60.96	27.99	0.36	0.00	0.01	0.00	0.00	6.76	0.00	0.15	0.00	0.42	6.39	0.00	0.40	0.00	0.31	8.42	0.00	2.63	0.00	3.35
3/10/73	11.2	30.48	11.19	0.35	0.00	0.01	0.00	0.01	3.97	0.00	0.01	0.00	0.02	3.09	0.00	0.02	0.00	0.01	2.56	0.00	0.13	0.00	0.37
13/10/73	18.2	71.12	22.35	0.07	0.00	0.00	0.00	0.01	3.51	0.01	0.02	0.00	0.15	2.69	0.00	0.02	0.00	0.14	1.51	0.00	0.11	0.00	0.02
18/10/73	5.3	40.64	6.86	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00
20-21/10/73	15.0	40.64	12.95	0.10	0.00	0.01	0.00	0.00	1.82	0.00	0.14	0.00	0.00	1.23	0.00	0.03	0.00	0.02	0.39	0.00	0.01	0.00	0.02
23/10/73	37.0	71.12	26.42	0.28	0.01	0.00	0.01	0.00	4.34	0.00	0.04	0.01	0.27	4.97	0.00	0.02	0.00	0.03	4.15	0.00	0.44	0.01	0.94
25/10/73	15.4	30.48	14.99	0.42	0.00	0.01	0.00	0.06	5.10	0.00	0.01	0.00	0.02	2.56	0.00	0.01	0.00	0.02	0.76	0.00	0.02	0.00	0.26
27/10/73	15.8	91.44	19.81	0.14	0.00	0.01	0.00	0.07	3.75	0.00	0.08	0.01	0.71	3.05	0.00	0.03	0.03	0.22	4.13	0.00	0.58	0.00	0.88
30/10/73	29.5	81.28	18.29	0.22	0.00	0.01	0.00	0.00	7.7	0.00	0.24	0.01	0.10	4.54	0.00	0.03	0.00	0.23	5.31	0.00	1.31	0.00	1.65

Effect of contour length on soil and water loss under maize-cowpea rotation

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.3%	13.4%
17/2/73	8.9	50.80	11.68	0.18	0.09	0.00	0.00	0.03	0.09	0.00	0.00
14/3/73	21.6	24.38	13.20	0.92	0.92	0.00	0.00	0.31	0.25	0.00	0.00
22/3/73	8.4	14.22	3.30	1.11	1.11	0.00	0.00	0.31	0.34	0.00	0.00
25/3/73	10.4	30.48	9.65	1.48	1.48	0.00	0.00	0.37	0.40	0.00	0.00
4/4/73	34.0	71.12	34.79	2.21	2.58	0.00	0.00	0.68	0.86	0.00	0.00
21-23/4/73	48.8	172.72	49.78	31.15	17.68	6.94	2.51	11.43	6.80	2.06	1.28
25/4/73	4.1	26.42	5.33	0.92	0.92	0.00	0.00	0.31	0.31	0.26	0.15
27/4/73	24.6	71.12	31.50	10.54	12.92	3.94	1.38	7.08	5.63	4.03	2.60
6/5/73	16.5	40.64	20.83	6.09	6.64	2.09	1.13	3.78	4.88	2.13	1.39
24/5/73	17.0	60.96	16.51	1.48	6.27	1.16	0.55	1.38	1.85	0.43	0.45
31/5/73	13.5	91.44	17.53	4.41	5.54	1.07	0.92	1.91	2.03	0.84	0.72
5/6/73	19.1	71.12	19.81	5.72	6.64	1.17	1.37	2.46	2.99	1.02	0.62
8/6/73	7.6	30.48	9.91	0.28	0.37	0.00	0.00	0.19	0.15	0.00	0.00
10/6/73	44.2	–	–	24.81	30.35	3.80	5.94	11.70	13.29	3.00	2.35
13/6/73	22.9	60.96	24.89	9.76	13.72	2.07	1.83	6.42	4.83	1.73	1.77
21/6/73	6.9	30.48	8.38	2.77	3.69	0.01	0.02	0.62	0.60	0.01	0.00
23/6/73	39.4	40.64	15.00	16.89	9.76	2.31	1.12	8.01	2.99	1.34	1.33
25/6/73	5.3	20.32	13.21	0.74	1.11	0.02	0.02	0.18	0.34	0.00	0.01
1/7/73	19.8	20.32	13.21	9.76	16.09	1.41	1.15	5.63	2.44	0.80	0.58
2/7/73	25.4	50.80	23.11	13.72	9.76	1.31	0.78	4.57	4.65	0.80	0.62
5/7/73	14.5	50.80	12.45	2.21	2.77	0.51	0.17	0.13	0.68	0.13	0.08
12/7/73	30.5	40.64	28.19	3.97	4.71	0.34	0.33	1.01	1.35	0.13	0.11

Effect of contour length on soil and water loss under maize-cowpea rotation

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.3%	13.4%
23/7/73	50.8	111.76	48.26	19.26	28.77	1.50	1.72	11.17	7.74	1.69	1.18
27/7/73	11.4	24.38	9.91	0.65	0.65	0.01	0.60	0.19	0.19	0.01	0.00
30/7/73	20.8	30.48	13.97	1.29	1.29	0.37	0.03	0.34	0.43	0.00	0.00
1/8/73	9.4	20.32	8.81	00.92	0.74	0.00	0.00	0.25	0.25	0.00	0.00
5/8/73	181.8	50.80	29.71	8.96	9.76	0.24	0.61	4.04	4.31	0.07	0.20
8/8/73	63.0	121.92	69.34	15.30	6.64	1.04	0.59	4.05	6.16	0.42	0.40
3/9/73	26.2	50.80	21.59	3.14	3.14	0.01	0.01	0.98	1.29	0.02	0.14
10/9/73	50.8	91.44	49.53	15.30	8.96	1.71	0.44	2.99	4.84	0.48	0.56
12/9/73	37.1	40.64	28.19	13.72	8.96	1.23	0.35	4.57	5.10	0.41	0.48
23/9/73	27.9	121.92	33.02	13.72	5.72	1.19	0.04	4.31	4.05	0.30	0.09
24/9/73	34.3	20.32	5.84	11.34	4.98	0.51	0.06	3.16	3.78	0.14	0.05
27/9/73	66.0	81.28	28.70	6.18	4.89	0.09	0.03	2.61	2.58	2.02	0.02
29/9/73	25.9	60.96	27.4	11.34	4.24	0.33	0.01	3.52	3.25	0.07	0.02
3/10/73	11.2	30.48	11.18	1.48	0.55	0.02	0.00	0.37	0.31	0.01	0.01
13/10/73	18.2	71.12	25.35	1.75	1.11	0.01	0.00	0.49	0.62	0.01	0.02
18/10/73	5.3	40.64	6.86	0.37	0.37	0.00	0.00	0.09	0.12	0.00	0.00
20-21/10/73	15.0	40.64	12.95	0.92	0.92	0.01	0.00	0.25	0.31	0.02	0.01
23/10/73	37.0	71.12	26.42	3.97	1.57	0.03	0.00	0.68	0.62	0.01	0.00
25/10/73	15.4	30.48	14.99	2.21	0.65	0.01	0.00	0.28	0.25	0.00	0.00
27/10/73	15.8	91.44	19.81	3.23	0.92	0.02	0.00	0.49	0.31	0.00	0.00
30/10/73	29.5	81.28	18.29	5.90	1.48	00.03	0.00	0.92	0.55	0.00	0.00

APPENDIX 1c *Runoff and soil loss record for individual rainstorms during 1974*

APPENDIX 1c *Runoff and soil loss record for individual rainstorms during 1974*

Effect of mulch rate (ton/hr) on run-off (mm)

Date	Rainfall	Intensity (mm/hr)		1%					5%					10%					15%				
	mm	Max.	Mean	0	2	4	6	NT	0	2	4	6	NT	0	2	4	6	NT	0	2	4	6	NT
8-10/4/74	28.70	40.64	9.12	23.51	0.05	0.20	0.00	0.46	24.83	1.20	0.65	0.65	0.83	20.87	1.38	1.38	0.20	1.20	21.53	1.38	1.48	0.83	1.38
22/4/74	21.59	101.60	25.34	13.27	0.42	0.10	0.00	0.37	15.91	0.65	0.65	0.37	0.32	10.30	0.92	0.65	0.65	0.65	8.31	0.78	0.83	0.65	0.74
28/4/74	38.61	91.44	43.94	21.53	0.60	0.92	0.00	0.37	26.81	0.97	0.46	0.37	0.32	16.24	0.55	0.92	0.78	0.83	20.21	1.06	1.06	0.55	0.23
3/5/74	54.61	91.44	52.36	23.75	0.46	0.28	0.00	0.46	37.05	1.55	0.74	0.52	0.88	21.53	2.21	1.43	1.15	1.20	37.38	1.57	1.48	0.92	1.15
6/5/74	13.72	81.28	15.20	7.65	0.09	0.09	0.00	0.14	6.99	0.40	0.14	0.19	0.28	6.00	0.55	0.32	0.28	0.28	5.67	0.32	0.37	0.23	0.37
7/5/74	21.34	40.64	12.50	9.64	0.23	0.19	0.00	0.46	18.22	0.65	0.23	0.23	0.32	6.33	0.97	0.97	0.37	0.46	6.33	0.37	1.02	0.65	0.37
31/5/74	17.78	40.64	21.96	6.99	0.09	0.09	0.00	0.19	6.99	0.51	0.19	0.23	0.28	5.01	0.83	0.51	0.46	0.51	1.57	0.51	0.55	0.37	0.46
4/6/74	10.16	40.64	11.82	2.49	0.05	0.05	0.00	0.09	0.28	0.19	0.09	0.09	0.19	3.69	0.37	0.37	0.23	0.28	2.12	0.28	0.32	0.19	0.28
5/6/74	13.21	50.80	13.51	5.67	0.19	0.19	0.00	0.28	5.67	0.55	0.28	0.23	0.37	6.00	0.92	0.65	0.55	0.65	3.69	0.65	0.69	0.37	0.60
6/6/74	41.91	71.12	25.33	33.41	0.46	0.23	0.00	0.19	32.75	1.11	0.46	0.46	0.60	16.25	1.85	1.06	0.92	1.02	36.72	1.11	1.29	0.65	1.11
9/6/74	10.16	30.48	13.46	5.67	0.09	0.09	0.00	0.09	5.94	0.19	0.14	0.14	0.19	3.51	0.37	0.28	0.28	0.28	1.38	0.19	0.23	0.19	0.28
16/6/74	14.48	30.48	5.07	6.33	0.28	0.37	0.00	0.37	10.29	0.92	0.55	0.46	0.55	6.33	1.01	0.83	0.65	0.78	5.67	0.74	0.97	0.55	0.83
21/6/74	22.86	121.92	28.71	16.57	0.32	0.14	0.00	0.28	23.18	3.32	0.55	0.19	0.37	9.97	3.60	0.83	0.55	0.69	14.92	1.66	0.55	0.46	0.55
29/6/74	9.65	20.32	6.38	1.01	0.09	0.05	0.00	0.13	0.92	0.37	0.18	0.18	0.18	0.83	0.28	0.28	0.18	0.28	0.28	0.28	0.37	0.28	0.37
3/7/74	64.01	121.92	64.00	45.97	1.29	0.37	0.00	0.92	59.84	16.57	1.48	0.74	1.06	37.71	15.18	3.55	1.89	2.21	59.84	14.00	3.32	1.85	1.85
6/7/74	36.83	71.12	42.16	26.81	0.46	0.28	0.00	0.55	28.13	11.42	1.01	0.37	0.74	22.19	8.84	2.63	1.11	1.48	38.11	7.26	1.85	1.29	1.11
21/7/74	52.07	71.12	45.72	30.11	0.65	0.37	0.00	0.88	35.07	19.35	1.75	0.69	0.97	22.19	4.48	3.50	1.48	1.75	25.82	13.60	2.77	1.57	1.66

Effect of mulch rate (ton/hr) on run-off (mm)

Date	Rainfall	Intensity (mm/hr)		1%					5%					10%					15%				
	mm	Max.	Mean	0	2	4	6	NT	0	2	4	6	NT	0	2	4	6	NT	0	2	4	6	NT
27/7/74	21.08	50.80	10.13	2.77	0.19	0.19	0.00	0.19	6.99	1.25	0.55	0.51	0.46	3.60	1.20	0.78	0.55	0.60	4.73	1.11	0.83	0.46	0.74
3/9/74	14.80	20.32	5.08	3.69	0.46	0.37	0.00	0.92	5.67	1.52	0.74	0.74	0.83	3.69	1.20	1.20	1.57	1.75	5.67	1.66	1.48	1.06	1.57
6/9/74	43.70	50.80	17.02	18.88	0.46	0.46	0.00	0.88	21.38	2.03	1.38	0.60	0.46	26.81	1.29	1.85	1.94	1.52	12.28	1.29	1.94	1.10	1.57
27/9/74	11.50	30.48	12.70	5.67	0.28	0.09	0.00	0.37	9.31	0.92	0.56	0.28	0.37	4.35	0.46	0.74	0.65	0.65	2.17	0.65	0.92	0.37	0.74
2/10/74	18.80	50.80	23.88	16.90	0.28	0.09	0.00	0.18	12.28	1.20	0.46	0.18	0.37	4.35	0.27	0.56	0.46	0.42	2.95	0.42	0.56	0.28	0.46

Effect of mulch rate (ton/hr) on run-off (mm)

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 0	2	4	6	NT	5% 0	2	4	6	NT	10% 0	2	4	6	NT	15% 0	2	4	6	NT
4/10/74	21.20	40.64	13.46	8.64	0.42	0.18	0.00	0.37	5.34	3.51	0.56	0.18	0.46	6.00	0.78	0.83	0.69	0.65	7.32	0.92	0.92	0.46	0.69
7/10/74	10.20	50.80	11.94	5.01	0.09	0.05	0.00	0.09	5.67	1.06	0.18	0.09	0.24	6.33	0.28	0.28	0.18	0.18	2.12	0.23	0.37	0.18	0.32
8/10/74	11.20	36.58	13.51	7.65	0.18	0.09	0.00	0.18	8.97	2.26	0.18	0.18	0.28	7.00	0.27	0.32	0.28	0.18	1.85	0.32	0.37	0.18	0.32
9-10/10/74	61.10	81.28	43.91	40.41	14.44	0.83	0.00	1.38	37.37	29.44	7.07	1.01	1.75	14.92	13.60	4.48	1.50	1.75	29.45	21.13	19.54	2.40	1.38
11/10/74	5.2	10.16	5.08	1.38	0.09	0.00	0.00	0.14	1.48	0.37	0.14	0.00	0.14	0.92	0.14	0.14	0.09	0.09	0.28	0.23	0.32	0.09	0.09
18-20/10/74	16.2	60.96	12.67	5.27	0.14	0.18	0.00	0.28	7.65	3.14	0.28	0.14	0.28	1.98	0.37	0.37	0.43	0.46	0.46	0.46	0.46	0.37	0.46
4/11/74	34.8	101.60	42.23	15.00	13.2	0.18	0.00	0.37	21.53	20.14	6.66	0.60	0.74	8.05	9.64	3.00	0.97	1.11	15.58	12.61	3.69	1.29	0.97

Effect of mulch rate (tons/ha) on soil loss (ton/hr)

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 0	2	4	6	NT	5% 0	2	4	6	NT	10% 0	2	4	6	NT	15% 0	2	4	6	NT
8-10/4/74	28.70	40.64	9.12	1.23	0.00	0.00	0.00	0.00	2.34	0.06	0.05	0.00	0.06	5.00	0.02	0.04	0.00	0.00	5.89	0.03	0.00	0.02	0.01
22/4/73	21.59	101.60	25.34	0.74	0.03	0.00	0.00	0.00	3.59	0.02	0.03	0.01	0.01	7.69	0.01	0.01	0.00	0.00	0.76	0.01	0.01	0.00	0.00
28/4/74	38.61	91.44	42.22	0.43	0.00	0.25	0.00	0.00	8.68	0.01	0.02	0.00	0.03	11.98	0.03	0.01	0.00	0.00	12.20	0.08	0.01	0.00	0.00
3/5/74	54.61	81.28	52.36	0.49	0.00	0.00	0.00	0.00	7.11	0.01	0.00	0.00	0.00	12.41	0.02	0.01	0.00	0.00	15.10	0.02	0.01	0.00	0.00
6/5/74	13.72	81.28	15.20	0.26	0.00	0.00	0.00	0.00	2.68	0.01	0.01	0.00	0.00	5.28	0.12	0.00	0.01	0.00	4.56	0.01	0.01	0.00	0.00
7/5/74	21.34	40.64	12.50	0.18	0.01	0.00	0.00	0.00	5.03	0.10	0.05	0.00	0.00	4.58	0.03	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.00
31/5/74	17.78	81.28	21.96	0.10	0.00	0.00	0.00	0.00	2.58	0.01	0.00	0.00	0.00	1.92	0.01	0.00	0.00	0.10	0.44	0.08	0.00	0.09	0.00
4/6/74	10.16	40.64	11.82	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00
5/6/74	13.21	40.64	13.51	0.08	0.00	0.00	0.00	0.00	2.48	0.01	0.00	0.00	0.00	1.88	0.02	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00
6/6/74	41.91	71.12	25.33	0.27	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	5.57	0.02	0.01	0.00	0.00	3.04	0.01	0.00	0.00	0.00
9/6/74	10.16	25.50	12.67	0.06	0.00	0.00	0.00	0.00	2.91	0.00	0.00	0.00	0.00	0.91	0.01	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
16/6/74	14.48	30.48	5.07	0.17	0.00	0.00	0.00	0.00	4.85	0.00	0.00	0.00	0.00	4.69	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00
21/6/74	22.86	132.08	28.71	0.54	0.00	0.00	0.00	0.00	7.62	0.26	0.12	0.06	0.00	4.82	0.42	0.04	0.06	0.00	4.14	0.12	0.11	0.06	0.03
29/6/74	9.65	15.24	6.76	0.01	0.00	0.00	0.00	0.00	1.62	0.01	0.01	0.00	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3/7/74	64.01	132.08	43.91	1.41	0.01	0.00	0.00	0.00	19.40	0.83	0.16	0.08	0.49	28.14	0.91	0.11	0.03	0.02	12.89	0.84	0.31	0.08	0.03
6/7/74	36.83	60.96	33.78	0.23	0.01	0.00	0.00	0.00	12.24	0.83	0.01	0.00	0.01	12.94	0.81	0.05	0.00	0.01	5.86	0.63	0.01	0.01	0.00
21/7/74	52.07	71.12	43.91	0.40	0.09	0.00	0.00	0.00	11.29	0.43	0.09	0.00	0.01	6.46	0.57	0.10	0.01	0.01	4.19	1.10	0.00	0.00	0.00

Effect of mulch rate (ton/hr) on soil loss (tons/ha)

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 0	2	4	6	NT	5% 0	2	4	6	NT	10% 0	2	4	6	NT	15% 0	2	4	6	NT
27/7/74	48.80	50.80	10.13	0.02	0.00	0.00	0.00	0.00	3.00	0.26	0.01	0.00	0.03	0.14	0.13	0.01	0.00	0.00	2.40	0.13	0.00	0.00	0.00

Effect of mulch rate (ton/hr) on soil loss (tons/ha)

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	1% 0	2	4	6	NT	5% 0	2	4	6	NT	10% 0	2	4	6	NT	15% 0	2	4	6	NT
27/7/74	48.80	50.80	10.13	0.02	0.00	0.00	0.00	0.00	3.00	0.26	0.01	0.00	0.02	0.14	0.13	0.01	0.00	0.00	0.46	0.12	0.00	0.09	0.00
3/9/74	14.80	20.32	3.38	0.08	0.00	0.00	0.00	0.00	1.02	0.01	0.00	0.00	0.00	1.18	0.02	0.04	0.00	0.00	1.59	0.01	0.02	0.01	0.00
6/9/74	43.70	35.56	16.29	0.48	0.07	0.00	0.00	0.00	2.00	0.04	0.02	0.00	0.00	2.89	0.08	0.02	0.00	0.00	0.85	0.01	0.01	0.01	0.00
27/9/74	11.50	30.48	8.78	0.09	0.01	0.00	0.00	0.00	1.23	0.01	0.01	0.00	0.02	0.55	0.00	0.00	0.00	0.00	0.33	0.00	0.01	0.00	0.00
2/10/74	18.80	35.56	21.95	0.26	0.00	0.00	0.00	0.00	2.32	0.01	0.13	0.00	0.03	0.85	0.05	0.05	0.06	0.00	0.60	0.01	0.00	0.00	0.00
4/10/74	21.20	46.74	14.19	0.28	0.01	0.00	0.00	0.00	2.54	0.27	0.01	0.00	0.01	1.53	0.01	0.00	0.00	0.00	1.41	0.01	0.00	0.00	0.00
7/10/74	10.20	50.80	20.27	0.26	0.00	0.00	0.00	0.00	2.25	0.04	0.02	0.00	0.01	1.29	0.01	0.00	0.00	0.00	1.28	0.01	0.00	0.00	0.00
8/10/74	11.20	36.58	13.51	0.15	0.00	0.00	0.00	0.00	2.38	0.06	0.01	0.00	0.01	0.91	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00
9-10/10/74	61.10	81.28	43.91	0.60	0.27	0.01	0.00	0.00	6.03	1.17	0.36	0.01	0.00	5.12	1.35	0.26	0.01	0.01	7.55	7.18	1.64	0.18	0.02
11/10/74	5.2	10.16	3.38	0.02	0.00	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.00
18-20/10/74	16.2	60.96	12.67	0.17	0.01	0.00	0.00	0.00	2.36	0.21	0.01	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.24	0.18	0.01	0.02	0.00
4/11/74	34.8	101.60	42.23	0.43	0.41	0.06	0.00	0.00	6.56	1.66	0.41	0.07	0.00	6.65	0.88	0.26	0.02	0.00	9.43	6.32	0.47	0.09	0.00

Effect of contour length on soil and water loss under barefallow.

Date	Rainfall mm	Intensity (mm/hr) Max.	Mean	12.5 m Run-off (mm) 10.2%	19.2%	Soil loss (tons/ha) 10.2%	19.2%	37.5 m Run-off (mm) 9.3%	13.4%	Soil loss (tons/ha) 9.3%	13.4%
10/4/74	28.70	40.64	9.12	6.46	0.20	0.81	0.01	4.58	2.03	0.16	0.01
22/4 /74	21 .6	101.60	25.34	11.34	10.95	1.71	3.11	4.05	4.58	1.81	0.01
28/4/74	38.6	91.44	42.22	16 89	19.27	2.26	2.08	13.83	14.67	4.80	8.35
3/5/74	54.6	81.28	52.36	25.61	17.69	2.95	2.96	16.74	10.92	4.34	2.76
6 /5/74	13.7	81.28	15.20	6 .27	6.09	1.74	0.63	5.63	3.78	3.76	2.56
7/5/74	31.3	40.64	12.50	15 .31	7:38	2.61	2.61	10.39	2.46		

Effect of contour length on soil and water loss under barefallow.

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.3%	13.4%
10/4/74	27.70	40.64	9.12	6.46	0.20	0.81	0.01	4.58	2.03	0.16	0.01
22/4/74	21.6	101.60	25.34	11.34	10.95	1.71	3.11	4.05	4.58	1.81	1.23
28/4/74	38.6	91.44	42.22	16.89	19.27	2.26	2.08	13.83	14.67	4.80	8.35
3/5/74	54.6	81.23	52.36	25.61	17.69	2.95	2.96	16.74	10.92	3.34	2.76
6/5/74	13.7	81.28	15.20	6.27	6.09	1.74	0.63	5.63	3.78	3.76	2.56
7/5/74	21.3	40.64	12.50	15.31	7.38	2.61	2.61	10.39	2.46	5.95	2.67
31/5/74	17.8	81.28	21.96	6.09	6.09	0.53	0.69	2.60	2.40	2.71	0.59
4/6/74	10.2	40.64	11.82	3.41	5.17	0.15	0.39	1.72	2.28	1.31	0.60
5/6/74	13.2	40.64	13.51	6.82	7.20	2.14	1.27	2.46	2.46	3.10	1.42
6/6/74	41.9	71.12	25.33	31.95	40.18	5.59	4.35	22.29	7.75	6.47	2.41
9/6/74	10.2	25.40	12.67	2.77	3.51	0.37	0.41	1.57	1.54	1.98	0.81
16/6/74	14.50	30.48	5.07	12.14	12.93	1.88	1.08	5.24	4.98	2.32	1.99
21/6/74	22.9	132.08	28.71	14.52	14.91	6.80	4.61	14.09	18.32	11.55	5.44
29/6/74	9.7	15.24	6.76	0.92	1.66	0.01	0.02	0.18	0.31	0.00	0.01
3/7/74	64.0	132.08	43.91	52.57	49.00	22.10	3.88	24.93	24.94	24.75	19.96
6/7/74	36.8	60.96	33.78	33.54	20.86	14.30	2.68	24.93	23.61	18.28	9.72

Effect of contour length on soil and water loss under barefallow

Effect of contour length on soil and water loss under barefallow.

Date	Rainfall mm	Intensity (mm/hr)		12.5 m				37.5 m			
				Run-off (mm)		Soil loss (tons/ha)		Run-off (mm)		Soil loss (tons/ha)	
		Max.	Mean	10.2%	19.2%	10.2%	19.2%	9.3%	13.4%	9.3%	13.4%
21/7/74	52.1	72.12	43.91	39.88	27.99	9.86	4.03	15.68	24.93	13.56	5.72
27/7/74	46.80	50.80	10.13	16.18	9.36	2.42	0.25	4.71	5.37	7.47	2.37
3/9/74	14.8	20.32	3.38	7.38	11.34	1.81	2.70	3.25	2.73	1.65	2.34
6/9/74	43.7	35.56	16.89	40.67	25.61	2.23	1.03	6.69	6.96	1.50	0.98
27/9/74	11.5	30.48	8.78	6:09	6.64	0.40	0.30	1.60	1.48	0.24	0.46
2/10/74	18.8	35.56	21.95	6.18	8.57	1.15	0.55	3.52	2.86	0.63	0.52
4/10/74	21.2	46.74	14.19	14.45	12.14	1.70	1.20	3.78	5.37	1.50	1.43
7/10/74	10.2	50.80	20.27	4.06	4.98	0.69	0.54	2.03	3.52	1.17	1.31
8/10/74	11.2	36.58	13.51	4.98	4.24	0.42	0.31	1.64	2.00	0.88	0.84
9-10/10/74	61.1	81.28	43.91	43.05	35.91	10.01	3.95	15.94	23.61	22.73	11.07
11/10/74	5.2	10.16	3.38	2.31	2.03	0.10	0.08	0.22	0.25	0.19	0.14
18-20/10/74	16.2	20.96	12.67	4.80	5.17	1.01	0.61	1.23	1.42	1.28	1.06
4/11/74.	34.8	101.60	42.23	28.39	24.03	10.33	2.68	12.38	2.46	8.39	6.67

APPENDIX 2 *Texture of the eroded sediments from bare fallow plots for Individual rain storms*

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope (%)*	*Gravel*	*Sand*	*Silt*	*Clay*
13/6/72	1	16.1	21.6	35.1	72.2
13/6/72	5	10.0	59.2	12.4	18.4
13/6/73	10	11.7	52.0	15.1	21.2
13/6/72	15	17.6	58.3	8.9	15.2
16/6/72	1	3.1	41.0	21.3	34.6
16/6/72	5	8.4	62.1	14.5	15.0
16/6/72	10	18.5	22.6	24.3	34.6
16/6/72	15	9.4	71.4	5.2	14.0
17/6/72	1	18.0	31.5	24.0	26.5
17/6/72	5	2.6	18.9	46.0	32.5
17/6/72	10	13.1	31.6	25.0	30.3
17/6/72	15	12.3	44.5	20.9	22.3
20/6/72	1	9.9	27.4	32.3	30.4
20/6/72	5	9.3	38.5	27.9	24.3
20/6/72	10	9.6	67.2	7.1	16.1
20/6/72	15	8.7	53.0	14.6	23.7
23/6/72	1	21.9	35.0	12.8	30.3
23/6/72	5	10.2	50.6	21.7	17.5
23/6/72	10	8.3	71.9	6.2	13.6
23/6/72	15	13.4	34.6	24.3	27.7
25/6/72	1	7.4	59.6	17.4	15.6
25/6/72	5	9.4	76.6	5.7	8.3
25/6/72	10	12.0	63.9	8.9	15.2
25/6/72	15	10.5	65.2	9.3	15.0
28/6/72	1	12.1	25.0	28.4	35.5
28/6/72	5	8.8	62.0	11.9	17.3
28/6/72	10	7.8	70.8	6.3	15.1
28/6/72	15	6.2	74.5	7.7	11.6
3/7/72	1	20.2	39.4	19.3	21.1
3/7/72	5	11.2	62.5	13.5	12.8
3/7/72	10	13.3	66.2	8.0	12.5
3/7/72	15	9.7	59.6	11.7	19.0
4/7/72	1	18.6	23.1	25.4	32.9
4/7/72	5	10.4	62.2	12.4	15.0
4/7/73	10	7.3	67.1	8.5	17.1

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope (%)*	*Gravel*	*Sand*	*Silt*	*Clay*
4/7/72	15	10.0	70.5	9.7	9.8
8/9/72	1	31.0	24.6	17.4	27.0
8/9/72	5	7.5	64.4	4.8	23.3
8/9/72	10	11.0	48.0	15.0	26.0
8/9/72	15	11.8	62.4	9.8	15.0
21/9/72	1	13.5	59.4	0.4	26.7
21/9/72	5	7.0	48.4	17.5	27.1
21/9/72	10	13.2	48.1	21.2	17.5
21/9/72	15	13.3	57.6	13.4	15.7
25/9/72	1	27.1	21.6	22.8	28.5
25/9/72	5	6.7	50.4	17.5	25.4
25/9/72	10	6.3	54.9	16.1	22.7

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
25/9/72	15	9.1	52.7	13.5	24.7
26/9/72	1		No soil loss		
26/9/72	5	7.9	71.5	10.5	10.3
26/9/72	10	13.0	37.1	19.3	30.6
26/9/72	15	12.0	52.8	11.3	23.9
3/10/72	1		No soil loss		
3/10/72	5	5.3	66.9	9.7	18.1
3/10/72	10	5.3	71.4	7.8	15.3
3/10/72	15	8.6	65.4	11.2	14.8
7/10/72	1		No soil loss		
7/10/72	5	8.8	44.4	20.3	26.5
7/10/72	10	15.2	53.1	12.9	18.8
7/10/72	15	11.5	42.1	21.4	25.0
11/10/72	1		No soil loss		
11/10/72	5	12.3	40.9	27.3	19.5
11/10/72	10	8.7	63.6	10.2	17.5
11/10/72	15	9.2	66.8	9.3	14.7
19/10/72	1		No soil loss		
18/10/72	5	8.6	59.1	14.8	17.5
18/10/72	10		No data		
18/10/72	15	12.7	60.7	10.7	15.9

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
4/4/73	1	36.0	55.6	4.2	4.2
4/4/73	5	33.6	45.2	10.1	11.1
4/4/73	10	22.2	56.0	8.6	13.2
4/4/73	15	20.4	41.4	17.5	20.7
23/4/73	1	17.9	23.0	24.6	34.5
23/4/73	5	16.0	31.9	26.9	25.2
23/4/73	10	16.0	60.5	9.2	14.3
23/4/73	15	20.4	41.4	17.5	20.7
25/4/73	1	No soil loss			
25/4/73	5	8.7	58.4	14.6	18.3
25/4/73	10	9.7	34.7	6.5	9.1
25/4/73	15	7.6	62.6	10.7	19.1
27/4/73	1	15.0	24.7	3.8	29.6
27/4/73	5	14.0	50.8	17.4	17.8
27/4/73	10	38.8	43.3	4.7	13.2
27/4/73	15	17.2	58.8	11.4	12.2
6/5/73	1	23.0	30.8	20.2	26.0
6/5/73	5	12.3	62.3	11.4	14.0
6/5/73	10	12.3	64.9	9.8	13.0
6/5/73	15	9.1	70.9	7.3	12.7
24/5/73	1	30.6	41.4	13.6	24.4
24/5/73	5	12.3	57.7	12.8	17.2
24/5/73	10	19.0	56.1	11.0	13.9
24/5/73	15	15.4	66.6	7.3	10.7
31/5/73	1	27.1	18.4	25.9	28.6
31/5/73	5	21.0	44.4	17.9	16.7
31/5/73	10	31.3	44.8	10.0	13.9
31/5/73	15	28.5	51.0	11.2	23.8
5/6/73	1	24.7	29.2	22.3	23.28
5/6/73	5	18.4	59.0	8.6	14.0
5/6/73	10	14.2	62.8	10.0	13.0
5/6/73	15	10.2	70.8	8.6	10.4
8/6/73	1	No soil loss			
8/6/73	5	14.2	68.0	7.4	10.4
8/6/73	10	11.9	68.9	7.6	11.6

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
8/6/73	15	7.5	77.0	5.2	10.3
10/6/73	1	30.9	24.0	23.2	21.9
10/6/73	5	21.7	57.0	9.9	11.4
10/6/73	10	25.0	63.3	6.5	5.2
10/6/73	15	14.6	63.0	9.9	12.5
13/6/73	1	22.3	27.3	26.1	24.3
13/6/73	5	16.1	65.2	8.9	9.7
13/6/73	10	14.6	65.9	6.5	13.0
13/6/73	15	19.3	59.1	11.0	10.6
21/6/73	1	No soil loss			
21/6/73	5	6.6	80.1	7.1	6.2
21/6/73	10	10.4	71.8	7.7	10.1
21/6/73	15	11.5	71.0	8.5	9.0
23/6/73	1	31.1	40.8	14.9	13.2
23/6/73	5	9.5	71.3	8.7	10.5
23/6/73	10	9.1	61.1	14.2	15.6
23/6/73	15	11.7	67.8	8.5	12.0
25/6/73	1	No soil loss			
25/6/73	5	9.9	70.4	9.5	10.2
25/6/73	10	4.3	78.5	8.2	14.9
25/6/73	15	8.6	77.0	6.0	8.4
1/7/73	1	22.8	27.8	25.9	23.5
1/7/73	5	10.7	70.8	8.8	9.7
1/7/73	10	8.2	58.9	9.5	13.4
1/7/73	15	24.4	59.1	7.6	8.9
2/7/73	1	31.2	36.6	17.6	14.6
2/7/73	5	6.9	78.2	5.6	9.3
2/7/73	10	8.2	73.5	7.0	11.3
2/7/73	15	13.0	71.4	9.6	9.0
5/7/73	1	25.0	28.5	22.2	24.3
5/7/73	5	10.0	75.8	8.8	5.4
5/7/73	10	18.6	62.8	7.3	11.3
5/7/73	15	11.5	69.1	9.0	10.4
12/7/73	1	20.9	45.3	18.2	15.6
12/7/73	5	9.5	66.1	12.3	12.1
12/7/73	10	8.9	72.0	7.5	11.6
12/7/73	15	6.9	73.5	11.2	8.4

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
23/7/73	1	33.1	32.9	20.1	13.9
23/7/73	5	12.6	66.5	10.1	10.8
23/7/73	10	17.0	59.1	9.6	14.3
23/7/73	15	14.3	59.3	13.4	13.0
27/7/73	1		No soil loss		
27/7/73	5	13.9	65.4	9.6	11.1
27/7/73	10	12.0	73.7	9.4	14.9
27/7/73	15	18.9	59.2	10.6	10.3
30/7/73	1		No soil loss		
30/7/73	5	8.3	71.7	9.7	10.3
30/7/73	10	13.8	68.1	7.4	10.7
30/7/73	15	10.2	74.7	5.9	9.2
1/8/73	1	25.5	45.6	13.4	15.5
1/8/73	5	5.9	76.4	8.1	9.6
1/8/73	10	20.6	66.7	4.1	8.6
1/8/73	15	8.8	75.7	6.4	9.1
5/8/73	1	8.2	31.4	31.0	29.4
5/8/73	5	13.6	46.6	22.5	17.3
5/8/73	10	11.6	43.5	23.7	21.2
5/8/73	15	18.0	63.3	8.9	9.8
8/8/73	1	27.0	30.7	25.5	16.8
8/8/73	5	9.0	42.0	31.7	17.3
8/8/73	10	19.2	64.0	7.1	9.7
8/8/73	15	17.2	67.6	6.6	8.6
3/9/73	1		No soil loss		
3/9/73	5	16.7	43.3	16.7	23.3
3/9/73	10	8.8	40.1	26.4	24.7
3/9/73	15	8.2	72.9	8.4	10.5
10/9/73	1	7.9	33.3	33.0	25.8
10/9/73	5	25.2	59.5	6.0	9.3
10/9/73	10	2.0	29.4	33.3	35.3
10/9/73	15	6.3	40.5	27.9	25.3
12/9/73	1	24.2	49.7	11.6	14.5
12/9/73	5	6.6	24.7	38.5	30.2
12/9/73	10	6.8	35.0	98.0	30.2
12/9/73	15	15.2	58.0	13.7	13.1
17/9/73	1		No soil loss		

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
17/9/73	5	15.7	62.4	11.8	10.1
17/9/73	10	8.3	77.5	5.6	9.6
17/9/73	15	12.9	67.3	8.5	11.3
23/9/73	1	27.5	17.7	24.8	30.0
23/9/73	5	12.8	42.2	24.6	20.4
23/9/73	10	26.9	56.7	6.6	9.8
23/9/75	15		No soil loss		
24/9/73	1	23.5	41.3	19.1	16.1
24/9/73	5	22.8	60.5	7.1	9.6
24/9/73	10	19.1	67.8	4.4	8.7
24/9/73	15	24.8	59.4	6.8	9.0
27/9/73	1	25.2	36.1	20.0	18.7
27/9/73	5	13.1	68.9	9.4	8.7
27/9/73	10	12.1	73.6	3.9	10.4
27/9/73	15	12.6	68.2	7.0	12.2
29/9/73	1	26.7	56.3	9.1	7.9
29/9/73	5		No soil loss		
29/9/73	10	24.8	61.4	6.0	7.8
29/9/73	15	23.2	63.1	6.0	7.7
3/10/73	1	22.2	38.7	19.8	19.3
3/10/73	5	5.4	7.9	4.9	9.8
3/10/73	10	18.6	69.0	3.6	8.8
3/10/73	15	12.3	77.1	3.5	7.1
13/10/73	1		No soil loss		
13/10/73	5	7.1	69.8	11.9	11.2
13/10/73	10	19.3	62.0	7.6	11.1
13/10/73	15	19.1	68.1	4.7	8.1
18/10/73	1		No soil loss		
18/10/73	5	7.7	77.7	4.4	10.2
18/10/73	10	18.6	64.3	5.7	11.4
18/10/73	15	14.3	69.4	7.7	8.6
20/10/73	1	23.2	61.1	8.0	7.7
20/10/73	5	9.4	67.2	12.5	10.9
20/10/73	10	8.3	70.6	8.3	12.8
20/10/73	15	11.0	73.3	9.4	9.3
23/10/73	1	22.8	37.5	18.1	16.6
23/10/73	5	17.6	63.3	8.6	10.5
23/10/73	10	11.5	67.3	7.1	14.1

Soil texture of the sediments eroded from bare fallow plots (%)

Date	*Slope %*	*Gravel*	*Sand*	*Silt*	*Clay*
23/10/73	15	14.8	69.5	6.0	9.7
25/10/73	1	11.1	12.4	39.1	37.4
25/10/73	5	50.0	34.4	7.2	8.4
25/10/73	10	16.6	73.8	2.6	7.0
25/10/73	15	11.3	75.2	3.9	9.6
27/10/73	1	8.8	75.7	7.3	8.2
27/10/73	5	14.8	59.6	14.5	11.1
27/10/73	10	17.2	63.9	7.3	11.6
27/10/73	15	27.1	23.1	24.8	25.0
30/10/73	1	27.3	30.0	23.1	19.6
30/10/73	5	13.0	67.3	8.9	10.8
30/10/73	10	19.5	67.3	4.8	8.4
30/10/73	15	15.7	68.3	7.6	8.4

Appendix erosivity indices

Date	Total E foot-ton per acre	I_{30} in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
19/5/72	464.1	0.85	394.5	464.1	3.95
4/5/72	673.9	1.20	808.7	2000.0	8.09
8/5/72	199.1	0.43	86.0	168.7	0.86
9/5/72	292.9	0.65	190.4	141.3	1.90
11 5/72	400.2	0.85	320.2	282.6	3.20
14/5/72	586.4	1.10	645.0	508.0	6.45
27/5/72	176.8	0.40	70.7	0.0	0.71
28/5/72	1614.2	1.50	2421.3	801.3	24.21
29/5/72	236.0	0.50	118.0	196.8	1.18
31/5/72	381.6	0.80	305.3	254.0	3.05
1/6/72	1778.2	2.40	4267.7	1611.4	42.68
2/6/72	127.6	0.30	38.3	0.0	0.38
4/6/72	327.4	0.70	229.2	254.0	2.29
7/6/72	308.4	0.70	215.9	114.5	2.16
9/6/72	358.1	0.70	250.7	358.1	2.51
11/6/72	165.6	0.40	66.4	0.0	0.66
13/6/72	1633.8	1.10	1797.2	1163.0	17.97
16/6/72	415.9	0.90	374.3	254.0	3.74
17/6/72	4563.2	4.80	21903.2	4523.8	219.03
18/6/72	249.4	0.30	74.8	0.0	0.75
20/6/72	301.1	0.30	90.3	254.0	0.90
22/6/72	126.6	0.20	25.3	0.0	0.25
23/6/72	236.0	0.50	118.0	196.8	1.18
24/6/72	192.9	0.45	86.8	114.5	0.87
25/6/72	966.0	1.10	1062.6	569.2	10.62
28/6/72	254.0	0.50	127.0	254.0	1.27
1/7/72	88.4	0.20	17.2	0.0	0.17
2/7/72	102.4	0.15	15.4	0.0	0.15
3/7/72	613.8	1.15	705.9	557.5	7.06
4/7/72	332.4	0.70	232.7	254.0	2.33
5/7/72	166.8	0.20	33.4	0.0	0.33
12/7/72	1031.2	1.70	1753.0	766.0	17.53
17/7/72	256.1	0.60	153.7	114.5	1.54

APPENDIX EROSIVITY INDICES

Date	Total E foot-ton per acre	I_{30} in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
25/8/72	663.6	1.10	730.0	433.2	7.30
5/9/72	191.0	0.30	57.3	0.0	0.57
6/9/72	441.2	0.60	264.7	196.8	2.65
7/9/72	429.7	1.00	429.7	430.0	4.30
8/9/72	390.8	0.50	195.4	254.0	1.95
11/9/72	201.0	0.30	60.3	0.0	0.60
16/9/72	473.7	1.0	473.7	395.3	4.74
21/9/72	1136.3	1.25	1420.4	754.3	14.20
24/9/72	230.2	0.35	80.6	0.0	0.81
25/9/72	474.4	1.00	474.4	312.6	4.74
26/9/72	309.4	0.60	185.6	196.8	1.86
27/9/72	127.6	0.30	38.3	0.0	0.38
3/10/72	278.1	0.45	125.1	141.3	1.25
7/10/72	170.8	0.40	68.3	114.5	0.68
9/10/72	575.5	1.20	690.4	495.0	6.90
10/10/72	196.8	0.40	78.7	197.0	0.79
12/10/72	175.5	0.50	87.8	141.3	0.88
18/10/72	293.2	0.68	199.4	254.0	2.00
19/10/72	156.8	0.30	47.0	0.0	0.47

UNIT II

APPENDIX EROSIVITY INDICES
(b) 1973

Date	Total E foot-ton per acre	I 30 in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
2/1/73	532.0	1.00	532.0	338.1	5.32
2/2/73	156.8	0.40	62.7	0.0	0.63
17/2/73	342.4	0.70	239.7	254.0	2.40
4/3/73	105.5	0.25	26.4	0.0	0.26
16/3/73	689.3	0.70	482.5	141.3	4.83
22/3/73	235.2	0.20	47.0	0.0	0.47
25/3/73	332.4	0.70	232.7	254.0	2.33
29/3/73	400.7	0.40	160.3	141.3	1.60
30/3/73	268.9	0.50	134.5	141.3	1.35
4/4/73	1253.5	1.90	2381.6	967.6	23.82
6/4/73	166.8	0.50	83.4	0.0	0.83
9/4/73	126.4	0.30	37.9	0.0	0.38
14/4/73	173.9	0.25	43.5	0.0	0.44
15/4/73	43.8	0.10	4.38	0.0	0.04
20/4/73	1618.2	3.00	4854.6	1441.4	48.55
23/4/73	343.6	0.80	274.9	0.0	2.75
25/4/73	152.6	0.32	48.8	0.0	0.49
27/4/73	945.8	1.80	1702.4	867.4	17.02
4/5/73	196.8	0.40	78.7	196.8	0.79
6/5/73	557.8	1.30	623.2	479.4	6.23
9/5/73	201.0	0.52	104.5	0.0	1.05
22/5/73	381.0	0.70	266.7	312.6	2.67
24/5/73	634.4	1.30	824.7	595.2	8.25
28/5/73	133.4	0.36	48.0	94.2	0.48
31/5/73	555.5	1 06	588.8	495.0	5.89
5/6/73	704.7	1.20	845.6	513.7	8.46
8/6/73	270.2	0.60	162.1	197.0	1.62
13/6/73	861.0	1.40	1205.4	685.0	12.05
21/6/73	268.9	0.60	161.3	141.3	1.61
23/6/73	1402.6	1.0	1402.6	873.0	14.03
25/6/73	187.1	0.42	78.6	0.0	0.79
30/6/73	718.6	0.90	646.7	513.7	6.47
1/7/73	627.2	0.80	501.8	0.0	5.02
2/7/73	963.1	1.50	1444.7	707.9	14.45
5/7/73	489.0	0.90	440.1	254.0	4.40
12/7/73	1063.8	1.30	1382.9	450.8	13.83

APPENDIX EROSIVITY INDICES
(b) 1973

Date	Total E foot-ton per acre	I 30 in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
23/7/73	2199.2	3.50	7697.2	1934.0	76.97
27/7/73	366.5	0.60	220.0	141.3	2.20
30/7/73	513.9	0.90	462.5	141.3	4.63
1/8/73	299.4	0.50	150.0	0.0	1.50
2/8/73	111.4	0.30	33.4	0.0	0.33
4/8/73	2774.8	2.00	5549.6	2323.6	55.50
5/8/73	3083.3	1.80	5549.9	1382.4	55.50
8/8/73	2578.2	3.70	9539.3	2298.8	95.39
16/8/73	276.8	0.40	110.7	208.4	1.11
23/8/73	265.2	0.60	159.1	0.0	1.59
24/8/73	372.8	0.70	261.0	0.0	2.61
1/9/73	366.5	0.90	329.9	141.3	3.30
3/9/73	842.8	1.20	1011.4	450.8	10.11
8/9/73	489.6	0.40	195.8	0.0	1.96
10/9/73	2017.8	2.90	5851.6	1552.4	58.52
12/9/73	1447.3	1.10	1592.0	928.5	15.92
14/9/73	167.6	0.40	67.0	0.0	0.67
17/9/73	254.0	0.50	127.0	0.0	1.27
23/9/73	1203.0	2.10	2526.3	1134.5	25.26
24/9/73	1281.1	1.65	2113.8	771.3	21.13
27/9/73	773.8	1.30	1005.9	509.4	10.06
28/9/73	269.0	0.50	134.0	234.8	1.34
29/9/73	1038.7	1.90	1973.5	881.8	19.74
1/10/73	363.6	0.80	290.9	198.7	2.91
3/10/73	386.6	0.70	270.6	141.3	2.71
6/10/73	201.0	0.50	105.0	0.0	1.05
13/10/73	666.2	1.10	732.8	509.4	7.33
18/10/73	244.7	0.46	112.6	245.0	1.13
20/10/73	363.6	0.80	290.9	197.0	2.91
21/10/73	128.4	0.30	38.5	94.2	0.39
23/10/73	797.5	1.30	1036.8	453.9	10.37
25/10/73	440.8	0.90	396.7	141.3	3.97
27/10/73	630.0	1.20	756.0	630.0	7.56
30/10/73	1064.1	1.1	1170.5	907.3	11.71
31/10/73	78.4	0.20	15.7	0.0	0.16
14/12/73	265.2	0.50	132.6	0.0	1.33

APPENDIX EROSIVITY INDICES
(c) 1974

Date	Total E foot-ton per acre	I30 in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
7 /3/74	371.6	0.88	327.0	254.0	3.27
11/3/74	358.0	0.50	179.0	0.0	1.79
24/3/74	1472.0	1.80	2649.6	1226.7	26.50
25/3/74	652.9	1.30	848.8	574.5	8.49
1/4/74	1621.0	2.70	4376.7	2120.2	43.78
3/4/74	180.5	0.40	72.2	141.3	0.72
10/4/74	300.3	0.50	150.0	197.0	1.50
14/4/74	777.2	1.40	1088.1	699.0	10.88
15/4/74	214.9	0.50	107.5	141.3	1.08
16/4/74	391.5	0.70	274.0	141.3	2.74
21/4/74	208.4	0.20	41.7	0.0	0.42
22/4/74	808.6	1.50	1212.9	1265.4	12.13
3/5/74	2040.1	2.50	5100.2	1520.8	51.00
6/5/74	467.4	1.00	467.4	433.2	4.67
7 /5/74	720.2	0.50	360.1	338.1	3.60
13/5/74	150.0	0.30	45.0	0.0	0.45
31/5/74	662.5	1.20	795.0	534.9	7.95
4/6/74	285.2	0.80	228.1	196.8	2.28
5/6/74	463.8	0.80	371.0	395.3	3.71
6/6/74	1486.9	1.40	2081.7	655.0	20.82
9/6 /74	357.3	0.80	285.8	141.3	2.86
11/6/74	175.5	0.40	70.2	141.3	0.70
15/6 /74	568.5	1.0	568.5	372.4	5.69
16/6/74	483.0	0.3	144.9	170.0	1.45
21/6/74	977.8	1.8	1760.0	938.6	17.60
29/6/74	269.4	0. 4	107.8	0.0	1.08
30/6/74	78.4	0.20	15.7	0.0	0.16
3/7/74	4003.8	2.10	8408.0	1536.8	84.08
6 /7/74	1265.7	1.90	2404.8	1020.5	24.05
10/7/74	150.0	0.30	45.0	0.0	0.45
17/7/74	214.7	0.50	107.3	141.3	1.07
21/7/74	1690.5	2.10	3550.1	1331.1	35.50
27/7/74	651.2	0.60	390.7	254.0	3.91

APPENDIX EROSIVITY INDICES
(c) 1974

Date	Total E foot-ton per acre	I30 in/hr	EI 30 foot-ton per acre inch	KE 71 foot-ton per acre	R
30/7/74	270.2	0.40	108.1	196.8	1.08
15/8/74	141.3	0.30	42.4	141.3	0.42
28/8/74	327.4	0.74	242.3	254.0	2.42
30/8/74	505.1	0.90	454.4	348.2	4.54
1/9/74	923.1	1.20	1107.7	521.1	11.08
4/9/74	362.4	0.30	108.7	0.0	1.09
5/9/74	254.4	0.40	127.2	0.0	1.27
6/9/74	1312.4	0.9	1181.2	196.8	11.81
17/9/74	231.1	0.50	115.5	196.8	1.16
23/9/74	305.3	0.60	183.2	168.7	1.83
27/9/74	316.8	0.70	221.8	282.6	2.22
2/10/74	693.5	1.20	832.2	536.6	8.32
4/10/74	798.0	0.80	638.4	558.2	6.38
5/10/74	376.5	0.40	150.6	141.3	1.51
7/10/74	381.4	0.70	267.0	268.5	2.67
8/10/74	358.6	0.70	251.0	196.8	2.51
9/10/74	1487.2	1.50	2230.8	1379.5	22.31
10/10/74	543.5	0.90	489.1	141.3	4.89
11/10/74	137.0	0.20	27.4	0.0	0.27
20/10/74	432.8	0.70	303.0	330.0	3.03
30/10/74	166.8	0.40	66.7	0.0	0.67
3/11/74	1330.1	1.40	1862.1	1207.5	18.62

APPENDIX 4a *Soil moisture records for 1972*

NEUTRON PROBE EVALUATION

APPENDIX 4a *Soil moisture records for 1972*

NEUTRON PROBE EVALUATION

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72
1	30	.986	.151	.130	.124	.126	.104	.123	.125	.071	.148	.100
	60	.196	.220	.207	.211	.221	.223	.207	.205	.157	.214	.207
	90	.271	.274	.265	.282	.284	.286	.283	.280	.257	.275	.259
	120	.298	.288	.288	.295	.292	.297	.295	.295	.294	.305	.285
2	30	.033	.070	.066	.058	.064	.054	.050	.054	.005	.054	.131
	60	.130	.232	.229	.226	.229	.218	.227	.233	.120	.193	.225
	90	.282	.271	.265	.270	.268	.263	.269	.266	.263	.283	.260
	120	.278	.273	.270	.277	.274	.273	.276	.277	.270	.280	.277
3	30	.032	.076	.078	.073	.067	.063	.059	.054	.016	.088	.118
	60	.105	.176	.185	.175	.172	.172	.167	.166	.085	.142	.196
	90	.253	.259	.260	.262	.254	.253	.256	.251	.236	.266	.223
	120	.276	.268	.275	.290	.268	.267	.267	.268	.271	.299	.256
4	30	.028	.096	.084	.085	.075	.075	.072	.067	.016	.072	.098
	60	.036	.179	.182	.179	.175	.174	.172	.168	.124	.174	.177
	90	.235	.289	.251	.252	.251	.248	.246	.240	.218	.247	.237
	120	.305	.305	.298	.304	.302	.295	.293	.289	.271	.297	.256
5	30	.051	.075	.082	.082	.075	.070	.067	.080	.027	.103	.109
	60	.134	.188	.200	.200	.190	.192	.190	.198	.100	.163	.174
	90	.251	.265	.272	.271	.264	.265	.266	.273	.228	.252	.198
	120	.284	.282	.288	.286	.280	.284	.281	.287	.269	.282	.205

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72
6	30	.116	.101	.075	.081	.085	.075	.076	.074	.024	.128	.119
	60	.204	.204	.187	.193	.192	.187	.187	.190	.131	.203	.225
	90	.253	.252	.254	.254	.263	.249	.248	.251	.231	.251	.289
	120	.286	.282	.281	.265	.281	.277	.278	.276	.264	.279	.300
7	30	.143	.114	.103	.103	.102	.086	.100	.104	.003	.104	.123
	60	.216	.207	.209	.205	.205	.206	.203	.206	.192	.259	.271
	90	.250	.243	.248	.242	.242	.335	.241	.143	.219	.250	.277
	120	.279	.266	.267	.266	.265	.263	.269	.263	.252	.270	.290
8	30	.102	.089	.084	.076	.079	.071	.063	.065	.010	.075	.075
	60	.193	.183	.178	.176	.179	.176	.175	.177	.109	.132	.174
	90	.248	.236	.236	.239	.239	.232	.232	.229	.221	.251	.256
	120	.269	.258	.257	.260	.259	.254	.252	.255	.251	.249	.300
9	30	.153	.136	.110	.119	.114	.095	.094	.092	–	.032	.049
	60	.190	.180	.169	.175	.177	.169	.170	.170	.132	.135	.141
	90	.243	.227	.223	.229	.230	.223	.226	.225	.198	.193	.260
	120	.271	.261	.257	.264	.259	.257	.260	.255	.234	.254	.275
10	30	.113	.090	.079	.070	.079	.073	.073	.069	.027	.094	.102
	60	.171	.159	.154	.154	.152	.146	.143	.143	.105	.166	.209
	90	.207	.195	.192	.188	.194	.186	.189	.189	.171	.196	.263
	120	.227	.218	.211	.208	.215	.204	.206	.206	.190	.206	.282

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72
11	30	–	.019	.030	–	–	.026	.037	.035	.014	.074	.066
	60	–	.098	.118	–	–	.119	.137	.140	.062	.123	.132
	90	–	.197	.201	–	–	.194	.200	.198	.190	.202	.206
	120	–	.186	.193	–	–	.185	.196	.191	.196	.207	.194
12	30	–	.046	.049	.047	.043	.037	.054	.059	–	.056	.084
	60	–	.146	.156	.153	.150	.147	.162	.160		.123	.179
	90	–	.205	.203	.206	.198	.198	.211	.204	.190	203	.214
	120	–	.216	.213	.211	.206	.207	.214	.212	.211	.229	.223
13	30	–	.033	.032	.037	.025	.024	.028	.083	–	.068	.068
	60	.170	.147	.149	.148	.138	.143	.145	.154	.091	.148	.170
	90	–	.189	.187	.186	.183	.185	.190	.192	.181	.192	.203
	120	–	.202	.200	.198	.194	.200	.206	.207	.205	.214	.218
14	30	–	.041	.061	.059	.054	.051	.051	.058	–	.091	.086
	60	–	.156	.154	.147	.144	.144	.143	.162	.077	.128	.169
	90	–	.197	.197	.195	.188	.188	.197	.197	.184	.199	.198
	120	–	.205	.208	.206	.197	.200	.208	.212	.208	.212	.211
15	30	–	.037	.010	.018	.017	.048	.005	.018	.009	.047	068
	60	–	.127	.109	.117	.109	.094	.097	.103	.050	.105	.121
	90	–	.179	.171	.171	.166	.159	.166	.165	.145	.154	.165
	120	–	.244	.237	.235	.228	.223	.226	.227	.195	.199	.228

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72
16	30	–	.043	.026	.028	.015	.014	.003	.021	–	.039	.053
	60	–	.181	.165	.167	.158	.158	.139	.160	.061	.147	.166
	90	–	.206	.202	.197	.197	.196	.202	.203	.194	.213	.211
	120	–	.216	.212	.209	.207	.205	.211	.213	.203	.214	.218
17	30	–	.028	.012	.021	.010	.012	.012	.011	–	.003	.048
	60	–	.125	.119	.127	.114	.113	.121	.127	.056	.098	.164
	90	–	.175	.173	.174	.167	.170	.176	.175	.171	.172	.172
	120	–	.175	.194	.194	.191	.193	.199	.201	.187	.189	.209
18	30	–	–	–	.009	.011	.008	.014	.018	.011	.036	.041
	60	–	–	–	.029	.028	.027	.035	.035	.027	.058	.045
	90	–	–	–	.061	.062	.060	.068	.066	.050	.065	.066
	120	–	–	–	.074	.073	.075	.081	.078	.069	.078	.087
19	30	–	–	.005	.007	.008	.002	.004	.005	.007	.032	.038
	60	–	–	.020	.018	.018	.018	.026	.027	.019	.063	.057
	90	–	–	.024	.024	.025	.026	.034	.036	.032	.065	.058
	120	–	–	.043	.043	.044	.045	.053	.053	.045	.067	.064
20	30	–	–	.007	.004	.002	.003	.005	.003	.021	.025	.037
	60	–	–	.019	.018	.017	.018	.025	.023	.021	.046	.037
	90	–	–	.027	.025	.025	.025	.034	.032	.028	.043	.045
	120	–	–	.032	.032	.032	.033	.042	.042	.037	.044	.062

Plot No.	Depth in	Moisture Content (g/g)

Plot No.	Depth in cm	Moisture Content (g/g)										
		10/12/71	17/12/71	23/12/71	31/12/71	6/1/72	13/1/72	29/1/72	10/2/72	24/2/72	2/3/72	17/3/72
21	30	–	–	.002	.003	.009	.004	.008	.011	.007	.024	0
	60	–	–	.016	.016	.016	.016	.024	.024	.028	.067	.058
	90	–	–	.023	.024	.025	.028	.034	.033	.030	.069	.060
	120	–	–	.027	.031	.032	.033	.041	.040	.038	.065	.053
22	30	–	–	.008	.005	.005	.003	.008	.007	.007	.009	.050
	60	–	–	.012	.012	.013	.013	.021	.020	.021	.069	.047
	90	–	–	.014	.015	.017	.016	.027	.027	.021	.048	.049
	120	–	–	.034	.041	.042	.044	.053	.056	.038	.053	.070
23	30		.015	.019	.011	.008	.009	.015	.008	.015	.010	.038
	60	–	.021	.025	.022	.021	.022	.030	.028	.026	.058	.043
	90	–	.044	.050	.045	.044	.044	.052	.050	.035	.049	.071
	120	–	.138	.081	.078	.076	.079	.087	.083	.074	.083	.089
24	30	–	.016	.016	.013	.011	.008	.013	.013	.006	.016	.034
	60	–	.011	.011	.012	.011	.012	.018	.018	.022	.049	.036
	90	–	.013	.016	.017	.017	.017	.026	.028	.018	.038	.049
	120	–	.047	.051	.052	.051	.051	.057	.058	.048	.071	.071

Plot No.	Depth in cm	Moisture Content (g/g) 6/4/72	20/4/72	27/4/72	4/5/72	11/5/72	18/5/72	25/5/72	1/6/72	8/6/72	15/6/72	26/6/72
1	30	.115	–	.116	.175	.175	.142	.102	.194	.191	.208	.210
	60	.177	–	.197	.207	.206	.208	.201	.250	.213	.231	.251
	90	.283	–	.267	.266	.257	.267	.261	.287	.278	.293	.281
	120	.300	–	.296	.294	.286	.297	.287	.304	.300	.312	.305
2	30	.85	.149	.136	.132	.125	.096	.076	.131	.121	.128	.140
	60	.241	.268	.267	.261	.253	.237	.219	.242	.228	.241	.245
	90	.295	.276	.279	.285	.298	.281	.256	.260	.274	.280	.278
	120	.283	.279	.279	.283	.296	.285	.269	.271	.275	.278	.283
3	30	–	–	.149	.171	.162	.153	.138	.160	.154	.157	.175
	60	–	–	.211	.216	.228	.223	.213	.215	.209	.206	.235
	90	–	–	.285	.290	.302	.305	.297	.293	.291	.286	.309
	120	–	–	.305	.292	.318	.329	.317	.319	.324	.321	.335
4	30	.067	–	.160	.181	.145	.108	.085	.143	.162	.164	.129
	60	.146	–	.206	.208	.200	.206	.161	.167	.179	.185	.175
	90	.250	–	.283	.289	.281	.296	.264	.266	.272	.278	.274
	120	.274	–	.284	.290	.283	.288	.282	.282	.282	.284	.281
5	30	.083	.144	.123	.138	.129	.102	.076	.142	.149	.151	.165
	60	.188	.225	.222	.198	.210	.198	.177	.229	.230	.233	.234
	90	.162	.267	.272	.265	.263	.268	.250	.274	.273	.271	.271
	120	.287	.288	.287	.292	.280	.290	.280	.292	.297	.295	.285

Plot No.	Depth in	Moisture Content (g/g)

Plot No.	Depth in cm	Moisture Content (g/g)										
		6/4/72	20/4/72	27/4/72	4/5/72	11/5/72	18/5/72	25/5/72	1/6/72	8/6/72	15/6/72	26/6/72
6	30	.072	.110	.102	.116	.119	.100	.066	.122	.104	.134	.149
	60	.171	.172	.171	.200	.181	.178	.170	.164	.074	.202	.208
	90	.261	.245	.252	.254	.251	.249	.246	.243	.376	.254	.261
	120	.285	.279	.282	.282	.286	.283	.282	.279	.276	.285	.282
7	30	–	–	.132	.179	.162	.145	.113	.184	.172	.194	.204
	60	–	–	.199	.218	.199	.211	.181	.246	.245	.246	.234
	90	–	–	.224	.216	.227	.226	.224	.252	.249	.268	.254
	120	–	–	.276	.262	.267	.263	.265	.289	.292	.298	.286
8	30	.084	–	.118	.115	.102	.091	.081	.120	.112	.134	.146
	60	.175	–	.171	.183	.168	.175	.163	.157	.155	.168	.213
	90	.232	–	.229	.239	.225	.231	.228	.220	.225	.233	.235
	120	.256	–	.253	.255	.252	.258	.253	.248	.251	.258	.247
9	30	–	–	.160	.164	.142	.124	.113	.159	.186	.203	.204
	60	–	–	.180	.188	.184	.182	.174	.284	.201	.232	.232
	90	–	–	.221	.226	.221	.222	.208	.223	.213	.262	.260
	120	–	–	.254	.260	.254	.260	.247	.256	.247	.282	.281
10	30	.096	–	.139	.165	.155	.150	.134	.163	.159	.171	.178
	60	.149	–	.178	.188	.188	.181	.177	.186	.180	.190	.185
	90	.182	–	.210	.220	.224	.227	.219	.229	.222	.227	.218
	120	.195	–	.211	.223	.231	.244	.231	.252	.245	.244	.235

Plot No.	Depth in cm	Moisture Content (g/g)										
		6/4/72	20/4/72	27/4/72	4/5/72	11/5/72	18/5/72	25/5/72	1/6/72	8/6/72	15/6/72	26/6/72
11	30	.069	.093	.084	.106	.090	.083	.082	.099	.088	.097	.102
	60	.120	.134	.139	.148	.137	.133	.139	.149	.131	.137	.144
	90	.206	.208	.207	.216	.210	.215	.215	.227	.207	.214	.204
	120	.197	.198	.197	.208	.200	.211	.208	.218	.206	.212	.195
12	30	.068	.107	.076	.115	.090	.073	.053	.106	.109	.112	.120
	60	.153	.142	.146	.147	.145	.150	.141	.181	.164	.188	.172
	90	.210	.198	.196	.199	.196	.200	.193	.217	.208	.214	.210
	120	.221	.221	.215	.217	.218	.219	.216	.231	.232	.237	.224
13	30	.064	.089	.078	.098	.083	.069	.041	.082	.080	.088	.085
	60	.163	.171	.168	.175	.168	.163	.141	.165	.168	.174	.165
	90	.198	.201	.201	.200	.201	.203	.191	.200	.208	.208	.203
	120	.213	.211	.212	.208	.213	.217	.206	.214	.225	.223	.216
14	30	.078	.100	.100	.113	.101	.089	.065	.116	.104	.114	.116
	60	.152	.161	.169	.159	.159	.148	.143	.165	.153	.163	.161
	90	.194	.192	.197	.196	.196	.200	.188	.208	.199	.204	.193
	120	.210	.209	.210	.210	.207	.213	.208	.225	.214	.216	.206
15	30	.057	.096	.083	.100	.079	.068	.038	.094	.075	.085	.092
	60	.110	.122	.128	.124	.110	.104	.087	.132	.115	.111	.125
	90	.173	.165	.168	.163	.163	.170	.154	.162	.161	.157	.167
	120	.231	.225	.225	.226	.221	.227	.219	.216	.208	.209	.227

Plot No.	Depth in	Moisture Content (g/g)

Plot No.	Depth in cm	Moisture Content (g/g)										
		6/4/72	20/4/72	27/4/72	4/5/72	11/5/72	18/5/72	25/5/72	1/6/72	8/6/72	15/6/72	26/6/72
16	30	–	.098	.077	.103	.095	.069	.037	.090	.075	.099	.100
	60	–	.175	.175	.190	.176	.180	.152	.180	.159	.183	.183
	90	–	.205	.210	.206	.216	.211	.198	.207	.201	.215	.206
	120	–	.214	.214	.211	.221	.221	.216	.222	.212	.226	.217
17	30	–	–	.097	.111	.104	.091	.049	.089	.086	.099	.105
	60	–	–	.164	.169	.165	.167	.147	.154	.150	.165	.167
	90	–	–	.170	.170	.169	.175	.169	.177	.166	.172	.176
	120	–	–	.192	.198	.199	.200	.198	.206	.195	.201	.206
18	30	.035	.060	.050	.057	.054	.047	.029	.056	.049	.063	.070
	60	.036	.039	.042	.042	.037	.032	.025	.043	.035	.048	.043
	90	.061	.060	.060	.062	.059	.061	.056	.063	.059	.067	.061
	120	.078	.078	.078	.077	.076	.080	.080	.080	.082	.088	.091
19	30	.035	.054	.046	.048	.043	.035	.025	.059	.049	.054	.056
	60	.049	.050	.049	.048	.044	.040	.033	.053	.048	.049	.050
	90	.057	.055	.054	.055	.053	.050	.040	.045	.050	.052	.066
	120	.063	.061	.061	.060	.060	.060	.048	.050	.055	.055	.071
20	30	.033	.050	.042	.052	.052	.040	.026	.054	.037	.048	.051
	60	.034	.040	.040	.040	.040	.039	.028	.044	.055	.035	.036
	90	.043	.044	.045	.044	.046	.045	.036	.042	.041	.040	.064
	120	.055	.056	.056	.054	.058	.057	.051	.050	.050	.048	.060

Plot No.	Depth in cm	Moisture Content (g/g)										
		6/4/72	20/4/72	27/4/72	4/5/72	11/5/72	18/5/72	25/5/72	1/6/72	8/6/72	15/6/72	26/6/72
21	30	.035	.040	.030	.104	.048	.041	.030	.062	.050	.057	.054
	60	.043	.039	.040	.040	.041	.043	.040	.064	.055	.061	.056
	90	.054	.042	.043	.038	.041	.043	.042	.062	.060	.061	.056
	120	.050	.042	.039	.040	.039	.040	.040	.061	.054	.059	.053
22	30	.046	.071	.058	.071	.067	.052	.038	.030	.066	.068	.073
	60	.044	.050	.051	.048	.047	.047	.034	.059	.054	.060	.064
	90	.046	.046	.048	.048	.045	.044	.036	.055	.049	.054	.063
	120	.065	.065	.066	.071	.065	.058	.056	.076	.069	.074	.077
23	30	.031	.051	.043	.050	.052	.044	.025	.053	.039	.049	.058
	60	.037	.042	.042	.041	.040	.038	.027	.048	.040	.046	.045
	90	.069	.060	.061	.062	.064	.065	.051	.065	.055	.060	.061
	120	.089	.087	.085	.087	.086	.089	.085	.092	.084	.090	.086
24	30	.033	.053	.044	.054	.053	.044	.042	.057	.050	.052	.054
	60	.030	.042	.042	.045	.045	.042	.038	.052	.045	.049	.046
	90	.042	.046	.048	.053	.052	.049	.051	.049	.046	.050	.052
	120	.066	.070	.072	.072	.076	.077	.075	.083	.075	.028	.079

Plot No.	Depth in cm	Moisture Content (g/g)										
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72
1	30	.212	.214	.215	.197	.188	.166	.144	–	.199	.192	.202
	60	.244	.244	.252	.240	.239	.239	.231	–	.239	.252	.252
	90	.282	.281	.284	.274	.277	.276	.273	–	.272	.282	.286
	120	.303	.303	.312	.300	.301	.304	.297	–	.296	.203	.310
2	30	.143	.121	.113	.107	.088	.078	.081	–	.131	.150	.157
	60	.257	.253	.258	.234	.230	.242	.241	–	.244	.274	.279
	90	.290	.281	.276	.277	.273	.278	.275	–	.274	.280	.286
	120	.296	.290	.292	.292	.287	.293	.291	–	.287	.296	.298
3	30	.168	.162	.169	.160	.148	.113	.110	–	.160	.153	.158
	60	.222	.217	.220	.219	.215	.200	.199	–	.215	.224	.223
	90	.304	.293	.299	.292	.292	.284	.296	–	.294	.298	.301
	120	.324	.320	.316	.317	.318	.308	.314	–	.318	.322	.325
4	30	.183	.182	.183	.160	.140	.116	.100	–	.177	.170	.174
	60	.199	.199	.207	.188	.112	.179	.182	–	.208	.210	.216
	90	.184	.179	.187	.282	.273	.277	.277	–	.282	.292	.288
	120	.290	.286	.289	.288	.280	.278	.277	–	.276	.286	.286
5	30	.169	.170	.169	.144	.117	.074	.071	–	.137	.133	.144
	60	.237	.237	.238	.222	.214	.184	.182	–	.184	.225	.232
	90	.281	.276	.283	.271	.275	.260	.260	–	.261	.279	.281
	120	.299	.296	.296	.280	.290	.282	.279	–	.280	.291	.300

Plot No.	Depth in cm	Moisture Content (g/g)										
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72
6	30	.152	.153	.160	.140	.119	.086	.068	–	.142	.146	.143
	60	.224	.218	.224	.210	.198	.189	.182	–	.182	.224	.221
	90	.279	.269	.276	.264	.261	.262	.256	–	.263	.267	.272
	120	.301	.287	.298	.286	.283	.287	.282	–	.294	.293	.298
7	30	.209	.215	.214	.210	.171	.138	.135	–	.178	.196	.188
	60	.232	.230	.231	.230	.227	.214	.208	–	.211	.232	.232
	90	.257	.260	.258	.262	.239	.242	.245	–	.241	.260	.254
	120	.292	.288	.288	.292	.280	.277	.277	–	.272	.289	.284
8	30	.149	.152	.162	.154	.145	.093	.094	–	.145	.150	.166
	60	.222	.226	.227	.222	.220	.204	.204	–	.205	.231	.236
	90	.247	.248	.248	.249	.247	.245	.243	–	.242	.255	.262
	120	.263	.261	.267	.261	.264	.261	.260	–	.260	.274	.283
9	30	.200	.202	.206	.170	.148	.120	.111	–	.166	.183	.187
	60	.226	.227	.227	.214	.196	.189	.189	–	.190	.219	.224
	90	.259	.262	.266	.255	.246	.238	.237	–	.237	.255	.267
	120	.281	.285	.286	.274	.263	.256	.260	–	.261	.274	.281
10	30	.179	.180	.180	.171	.157	.096	.121	–	.168	.164	.167
	60	.190	.183	.188	.192	.180	.170	.160	–	.165	.177	.203
	90	.229	.220	.223	.224	.221	.212	.210	–	.211	.219	.193
	120	.238	.229	.235	.232	.227	.219	.221	–	.221	.226	.253

Plot No.	Depth in	Moisture Content (g/g)

Plot No.	Depth in cm	Moisture Content (g/g)										
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72
11	30	.101	.100	.099	.093	.083	.071	.070	–	.097	.098	.102
	60	.144	.130	.135	.132	.126	.125	.132	–	.121	.140	.139
	90	.215	.197	.202	.204	.208	.201	.200	–	.196	.206	.201
	120	.206	.193	.195	.200	.203	.194	.191	–	.189	.199	.194
12	30	.114	.123	.117	.100	.075	.061	.049	–	.108	.121	.115
	60											
	60	.168	.163	.173	.150	.149	.142	.146	–	.148	.177	.185
	90	.200	.198	.198	.190	.196	.192	.192	–	.197	.208	.219
	120	.230	.227	.219	.220	.214	.214	.215	–	.215	.220	.232
13	30	.085	.071	.073	.068	.052	.051	.020	–	.085	.081	.096
	60	.164	.166	.171	.166	.152	.156	.129	–	.163	.167	.181
	90	.200	.201	.200	.202	.196	.191	.184	–	.196	.196	.208
	120	.215	.213	.215	.214	.214	.209	.206	–	.212	.213	.222
14	30	.115	.119	.121	.122	.107	.075	.063	–	.112	.116	.118
	60	.172	.154	.171	.169	.165	.148	.138	–	.142	.169	.171
	90	.196	.186	.197	.191	.188	.184	.178	–	.184	.198	.200
	120	.209	.203	.208	.203	.201	.199	.198	–	.201	.212	.213
15	30	.100	.078	.077	.065	.050	.044	.041	–	.073	.098	.097
	60	.129	.110	.106	.101	.097	.099	.100	–	.093	.140	.135
	90	.170	.165	.166	.160	.158	.162	.159	–	.160	.176	.170
	120	.231	.224	.220	.219	.223	.221	.219	–	.218	.224	.232

Plot No.	Depth in cm	Moisture Content (g/g)										
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72
16	*30*	.103	.100	.101	.087	.071	.057	.049	–	.088	.098	.103
	60	.193	.168	.169	.173	.160	.175	.173	–	.169	.194	.202
	90	.212	.201	.202	.204	.201	.201	.202	–	.199	.210	.216
	120	.221	.213	.213	.214	.213	.213	.211	–	.210	.213	.225
17	*30*	.109	.111	.108	.096	.092	.076	–	–	.097	.105	.108
	60	.170	.164	.161	.159	.155	.156	–	–	.154	.171	.176
	90	.180	.179	.176	.174	.171	.173	–	–	.169	.179	.184
	120	.213	.213	.207	.206	.208	.204	–	–	.201	.212	.219
18	*30*	.068	.070	.068	.051	.044	.039	–	–	.065	.061	.064
	60	.047	.037	.045	.032	.030	.033	–	–	.033	.046	.048
	90	.062	.059	.058	.058	.066	.060	–	–	.055	.070	.065
	120	.091	.090	.091	.089	.087	.090	–	–	.087	.091	.093
19	*30*	.052	.048	.050	.046	.045	.031	–	–	.071	.064	.068
	60	.051	.045	.046	.047	.045	.045	–	–	.044	.052	.053
	90	.061	.056	.058	.059	.057	.057	–	–	.055	.061	.063
	120	.071	.067	.068	.068	.067	.067	–	–	.064	.071	.073
20	*30*	.046	.042	.051	.041	.033	.026	–	–	.047	.046	.046
	60	.038	.032	.033	.031	.030	.029	–	–	.029	.039	.039
	90	.046	.043	.039	.040	.041	.038	–	–	.039	.048	.049
	120	.060	.057	.053	.060	.056	.050	–	–	.055	.066	.069

Plot No.	Depth in	Moisture Content (g/g)

Plot No.	Depth in cm	Moisture Content (g/g)											
		29/6/72	6/7/72	13/7/72	20/7/72	27/7/72	10/8/72	24/8/72	31/8/72	7/9/72	14/9/72	21/9/72	
21	30	.055	.056	.060	.052	.049	.039	–	–	.054	.056	.060	
	60	.058	.052	.051	.051	.049	.048	–	–	.047	.057	.058	.055
	90	.057	.056	.054	.055	.052	.051	–	–	.050	.061	.061	
	120	.057	.051	.049	.049	.048	.045	–	–	.045	.055	.055	
22	30	.071	.074	.073	.061	.060	.042	–	–	.060	.067	.068	
	60	.060	.060	.068	.061	.052	.042	–	–	.044	.057	.059	.067
	90	.060	.061	.066	.057	.051	.044	–	–	.046	.052	.060	
	120	.074	.060	.079	.065	.062	.058	–	–	–	–	–	
23	30	.045	.044	.047	.043	.042	.040	–	–	.038	.046	.048	
	60	.106	.105	.103	.102	.100	.102	–	–	.099	.109	.107	
	90	.072	.059	.063	.065	.064	.063	–	–	.065	.063	.070	
	120	.088	.086	.087	.086	.087	.086	–	–	.085	.087	.088	
24	30	.053	.054	.052	.046	.039	.030	–	–	.053	.046	.049	
	60	.044	.045	.048	.042	.041	.039	–	–	.036	.043	.043	
	90	.055	.056	.058	.056	.054	.049	–	–	.049	.054	.055	
	120	.080	.079	.081	.079	.079	.074	–	–	.071	.077	.078	

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
1	30	0.213	0.093	0.070	0.049	0.007	0.015	0.002	0.003	0.006	0.015	0.009
		0.144	0.166	0.138	0.117	0.069	0.066	0.055	0.053	0.020	0.040	0.039
	60	0.253	0.199	0.145	0.135	0.085	0.125	0.092	0.081	0.068	0.054	0.082
		0.212	0.246	0.186	0.205	0.156	0.156	0.151	0.155	0.130	0.147	0.149
	90	0.285	0.234	0.227	0.231	0.194	0.201	0.186	0.173	0.168	0.164	0.173
		0.238	0.279	0.282	0.271	0.263	0.254	0.245	0.245	0.229	0.246	0.246
	120	0.306	0.256	0.232	0.243	0.213	0.227	0.214	0.197	0.193	0.177	0.190
		0.256	0.309	0.296	0.299	0.291	0.285	0.278	0.272	0.270	0.268	0.269
2	30	0.169	0.137	0.098	0.082	0.040	0.028	0.018	0.018	0.010	0.001	0.008
		0.162	0.020	0.087	0.100	0.042	0.030	0.028	0.028	0.010	0.027	0.011
	60	0.191	0.112	0.084	0.068	0.052	0.048	0.045	0.045	0.045	0.044	0.049
		0.282	0.260	0.174	0.237	0.174	0.169	0.171	0.171	0.145	0.183	0.163
	90	0.236	0.237	0.179	0.220	0.189	0.174	0.171	0.176	0.151	0.123	0.174
		0.289	0.291	0.275	0.266	0.253	0.250	0.251	0.247	0.247	0.244	0.247
	120	0.254	0.284	0.242	0.241	0.236	0.224	0.215	0.213	0.203	0.198	0.213
		0.302	0.298	0.286	0.358	0.257	0.254	0.249	0.247	0.250	0.249	0.247

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
3	30	0.171	0.160	0.134	0.150	0.100	0.075	0.067	0.058	0.049	0.036	0.039
		0.164	0.157	0.154	0.152	0.107	0.093	0.091	0.084	0.085	0.067	0.064
	60	0.169	0.168	0.162	0.157	0.157	0.141	0.136	0.132	0.121	0.113	0.111
		0.239	0.227	0.212	0.216	0.186	0.178	0.177	0.166	0.151	0.153	0.148
	90	0.231	0.230	0.212	0.224	0.211	0.204	0.202	0.204	0.189	0.189	0.186
		0.308	0.300	0.296	0.292	0.269	0.267	0.273	0.269	0.250	0.258	0.254
	120	0.311	0.299	0.271	0.291	0.268	0.261	0.262	0.266	0.246	0.253	0.251
		0.323	0.319	0.320	0.316	0.316	0.313	0.313	0.307	0.300	0.305	0.301
4	30	0.195	0.164	0.138	0.149	0.042	0.020	0.015	0.008	0.009	0.006	0.018
		0.180	0.185	0.175	0.150	0.080	0.067	0.056	0.054	0.039	0.040	0.032
	60	0.210	0.020	0.133	0.109	0.097	0.087	0.082	0.085	0.087	0.080	0.083
		0.139	0.213	0.196	0.189	0.120	0.119	0.112	0.116	0.099	0.115	0.102
	90	0.289	0.225	0.194	0.206	0.185	0.168	0.164	0.161	0.440	0.166	0.148
		0.222	0.296	0.285	0.279	0.250	0.234	0.233	0.233	0.222	0.231	0.230
	120	0.287	0.255	0.251	0.244	0.239	0.239	0.239	0.230	0.223	0.216	0.220
		0.269	0.288	0.286	0.288	0.281	0.267	0.251	0.248	0.249	0.247	0.246
	30	0.159	0.121	0.112	0.082	0.033	0.025	0.017	0.017	0.008	0.010	0.005
		0.161	0.125	0.120	0.087	0.039	0.040	0.032	0.032	0.022	0.019	0.022

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
5	60	0.233	0.133	0.114	0.110	0.070	0.063	0.060	0.061	0.057	0.059	0.061
		0.178	0.215	0.189	0.174	0.116	0.133	0.110	0.137	0.113	0.131	0.123
	90	0.282	0.252	0.219	0.221	0.179	0.173	0.170	0.174	0.164	0.166	0.175
		0.265	0.282	0.261	0.250	0.218	0.222	0.213	0.223	0.211	0.217	0.216
	120	0.297	0.276	0.272	0.266	0.247	0.233	0.237	0.238	0.229	0.229	0.239
		0.283	0.298	0.308	0.277	0.265	0.264	0.258	0.259	0.254	0.253	0.261
6	30	0.160	0.207	0.155	0.181	0.120	0.095	0.091	0.087	0.073	0.072	0.066
		0.222	0.147	0.127	0.111	0.073	0.060	0.051	0.039	0.022	0.028	0.023
	60	0.232	0.170	0.196	0.154	0.138	0.127	0.125	0.126	0.122	0.124	0.119
		0.175	0.225	0.192	0.170	0.151	0.135	0.141	0.140	0.123	0.136	0.130
	90	0.275	0.241	0.183	0.240	0.203	0.201	0.189	0.188	0.166	0.187	0.171
		0.247	0.269	0.263	0.256	0.246	0.231	0.225	0.225	0.207	0.216	0.211
	120	0.300	0.280	0.268	0.271	0.277	0.239	0.267	0.032	0.234	0.242	0.232
		0.283	0.294	0.295	0.280	0.282	0.273	0.264	0.265	0.244	0.251	0.245
7	30	0.202	0.146	0.130	0.103	0.052	0.042	0.035	0.036	0.026	0.027	0.028
		0.195	0.190	0.117	0.178	0.082	0.055	0.044	0.038	0.011	0.027	0.024
	60	0.231	0.157	0.135	0.137	0.102	0.098	0.097	0.096	0.089	0.090	0.097
		0.193	0.225	0.225	0.200	0.188	0.175	0.176	0.175	0.155	0.168	0.169

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
8	90	0.256	0.237	0.231	0.230	0.204	0.202	0.196	0.196	0.195	0.191	0.197
		0.253	0.261	0.222	0.246	0.221	0.212	0.204	0.202	0.185	0.189	0.192
	120	0.284	0.282	0.275	0.283	0.254	0.246	0.239	0.236	0.235	0.235	0.236
		0.296	0.294	0.266	0.277	0.268	0.266	0.259	0.258	0.233	0.237	0.240
	30	0.189	0.173	0.167	0.140	0.092	0.085	0.082	0.078	0.070	0.068	0.072
		0.196	0.147	0.140	0.153	0.070	0.051	0.042	0.035	0.024	0.024	0.029
	60	0.253	0.225	0.181	0.195	0.160	0.155	0.161	0.159	0.145	0.134	0.154
		0.244	0.216	0.188	0.188	0.154	0.146	0.143	0.143	0.129	0.132	0.141
	90	0.263	0.240	0.238	0.229	0.212	0.208	0.209	0.204	0.207	0.206	0.207
		0.250	0.253	0.235	0.246	0.212	0.207	0.205	0.205	0.202	0.200	0.202
	120	0.284	0.277	0.258	0.273	0.252	0.236	0.235	0.234	0.223	0.223	0.231
		0.282	0.275	0.268	0.269	0.251	0.243	0.238	0.233	0.230	0.228	0.232
9	30	0.213	0.149	0.118	0.114	0.063	0.054	0.044	0.044	0.036	0.037	0.037
		0.177	0.162	0.144	0.142	0.081	0.068	0.060	0.056	0.050	0.054	0.053
	60	0.239	0.168	0.132	0.147	0.110	0.102	0.096	0.098	0.095	0.093	0.095
		0.211	0.205	0.172	0.186	0.152	0.149	0.147	0.146	0.138	0.146	0.144
	90	0.277	0.254	0.208	0.234	0.187	0.186	0.172	0.183	0.175	0.182	0.179
		0.259	0.251	0.228	0.243	0.201	0.191	0.190	0.188	0.182	0.187	0.185

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
10	120	0.299	0.292	0.282	0.283	0.261	0.251	0.243	0.243	0.241	0.240	0.243
		0.294	0.264	0.251	0.272	0.235	0.228	0.221	0.221	0.211	0.223	0.217
	30	0.180	0.154	0.142	0.174	0.119	0.100	0.093	0.089	0.080	0.079	0.069
		0.187	0.163	0.156	0.165	0.127	0.114	0.099	0.098	0.081	0.082	0.073
	60	0.186	0.196	0.191	0.205	0.184	0.175	0.166	0.163	0.150	0.145	0.136
		0.208	0.172	0.179	0.175	0.171	0.166	0.157	0.155	0.140	0.132	0.126
	90	0.228	0.198	0.195	0.210	0.196	0.190	0.109	0.187	0.178	0.178	0.172
		0.198	0.213	0.200	0.217	0.203	0.201	0.199	0.201	0.180	0.183	0.181
	120	0.239	0.224	0.224	0.268	0.233	0.222	0.220	0.224	0.209	0.215	0.273
		0.256	0.233	0.228	0.224	0.233	0.227	0.228	0.228	0.212	0.211	0.209
11	30	0.108	0.090	0.071	0.037	0.037	0.031	0.025	0.021	0.008	0.020	0.011
		0.096	0.099	0.102	0.107	0.069	0.063	0.052	0.044	0.035	0.027	0.028
	60	0.138	0.214	0.186	0.196	0.168	0.174	0.165	0.161	0.142	0.153	0.145
		0.217	0.167	0.130	0.143	0.117	0.126	0.114	0.110	0.096	0.081	0.083
	90	0.203	0.221	0.232	0.216	0.218	0.221	0.236	0.218	0.255	0.206	0.210
		0.224	0.209	0.207	0.213	0.227	0.211	0.198	0.197	0.196	0.180	0.185
	120	0.200	0.231	0.236	0.225	0.224	0.231	0.240	0.225	0.230	0.217	0.219
		0.234	0.217	0.202	0.203	0.196	0.209	0.197	0.198	0.196	0.197	0.188

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
12	30	0.119	0.072	0.042	0.034	0.006	0.014	0.020	0.017	− 0.022	− 0.029	− 0.020
		0.094	0.099	0.064	0.063	0.033	0.029	0.024	0.022	0.022	0.012	0.015
	60	0.177	0.183	0.171	0.160	0.136	0.131	0.118	0.128	0.123	0.115	0.194
		0.195	0.167	0.111	0.142	0.117	0.117	0.113	0.111	0.117	0.096	0.106
	90	0.211	0.195	0.196	0.188	0.177	0.175	0.169	0.170	0.168	0.168	0.170
		0.203	0.209	0.180	0.191	0.171	0.169	0.168	0.167	0.169	0.163	0.162
	120	0.219	0.220	0.215	0.211	0.205	0.200	0.198	0.209	0.181	0.181	0.182
		0.224	0.217	0.211	0.208	0.200	0.191	0.195	0.194	0.195	0.186	0.190
13	30	0.097	0.080	0.070	0.084	0.046	0.032	0.025	0.013	0.003	− 0.001	− 0.001
		0.100	0.090	0.079	0.070	0.042	0.030	0.025	0.017	0.006	0.017	0.006
	60	0.173	0.205	0.174	0.200	0.165	0.161	0.163	0.160	0.142	0.131	0.143
		0.211	0.174	0.150	0.152	0.127	0.123	0.119	0.115	0.106	0.132	0.113
	90	0.204	0.221	0.205	0.219	0.196	0.199	0.194	0.193	0.192	0.189	0.182
		0.224	0.204	0.193	0.195	0.184	0.181	0.176	0.171	0.168	0.175	0.167
	120	0.215	0.234	0.235	0.231	0.228	0.228	0.227	0.222	0.213	0.214	0.216
		0.238	0.215	0.210	0.212	0.208	0.197	0.195	0.189	0.192	0.190	0.189
	30	0.125	0.081	0.041	0.038	− 0.002	− 0.005	− 0.009	− 0.013	− 0.026	− 0.015	− 0.016
		0.123	0.098	0.089	0.065	0.036	0.032	0.025	0.023	0.009	0.022	0.015

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
14	60	0.168	0.170	0.114	0.145	0.122	0.121	0.113	0.118	0.088	0.113	0.118
		0.183	0.147	0.095	0.127	0.093	0.095	0.092	0.092	0.073	0.093	0.093
	90	0.196	0.190	0.184	0.181	0.167	0.160	0.156	0.158	0.154	0.154	0.118
		0.190	0.195	0.183	0.177	0.169	0.171	0.168	0.167	0.158	0.165	0.164
	120	0.208	0.188	0.190	0.181	0.181	0.174	0.165	0.164	0.156	0.161	0.164
		0.189	0.209	0.208	0.179	0.192	0.189	0.188	0.186	0.180	0.183	0.184
15	30	0.102	0.047	0.034	0.039	−0.011	−0.017	0.018	0.024	0.030	− 0.040	− 0.033
		0.073	0.081	0.079	0.063	0.023	0.018	0.010	0.007	−0.011	0.005	− 0.001
	60	0.134	0.154	0.110	0.138	0.074	0.073	0.075	0.070	0.060	0.053	0.058
		0.164	0.118	0.097	0.097	0.068	0.064	0.058	0.061	0.044	0.060	0.058
	90	0.166	0.198	0.181	0.194	0.166	0.160	0.163	0.158	0.156	0.155	0.156
		0.200	0.164	0.151	0.160	0.135	0.132	0.130	0.130	0.124	0.125	0.128
	120	0.229	0.212	0.204	0.210	0.200	0.195	0.194	0.188	0.183	0.184	0.185
		0.215	0.224	0.203	0.225	0.194	0.193	0.188	0.186	0.175	0.178	0.208
16	30	0.107	0.054	0.054	0.037	0.012	0.006	0.000	− 0.005	− 0.010	− 0.018	− 0.015
		0.069	0.096	0.079	0.175	0.056	0.035	0.340	0.020	0.013	0.009	− 0.001
	60	0.200	0.090	0.067	0.062	0.043	0.043	0.042	0.040	0.036	0.030	0.037
		0.107	0.188	0.151	0.207	0.137	0.133	0.127	0.122	0.110	0.111	0.104

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
17	90	0.215	0.164	0.139	0.144	0.105	0.110	0.107	0.108	0.100	0.099	0.101
		0.162	0.215	0.206	0.215	0.201	0.198	0.190	0.189	0.178	0.175	0.180
	120	0.214	0.243	0.224	0.231	0.196	0.199	0.197	0.201	0.193	0.193	0.194
		0.245	0.224	0.223	0.237	0.208	0.206	0.201	0.195	0.186	0.179	0.176
	30	0.110	0.090	0.092	0.101	0.036	0.017	0.005	− 0.002	0.014	−0.015	− 0.019
		0.106	0.082	0.071	0.078	0.043	0.036	0.026	0.022	0.009	0.004	0.009
	60	0.170	0.131	0.121	0.125	0.104	0.094	0.008	0.089	0.078	0.080	0.078
		0.144	0.165	0.137	0.129	0.122	0.121	0.118	0.119	0.113	0.112	0.114
	90	0.180	0.180	0.165	0.188	0.152	0.146	0.144	0.144	0.129	0.113	0.1 2
		0.191	0.176	0.166	0.171	0.160	0.151	0.148	0.148	0.146	0.142	0.141
	120	0.213	0.216	0.210	0.224	0.200	0.200	0.192	0.191	0.215	0.179	0.179
		0.218	0.210	0.197	0.205	0.193	0.183	0.171	0.167	0.164	0.161	0.161
18	30	0.074	0.051	0.035	0.033	0.021	0.020	0.017	0.017	0.014	0.011	0.010
		0.057	0.066	0.067	0.061	0.033	0.025	0.020	0.020	0.013	0.013	0.012
	60	0.049	0.044	0.038	0.048	0.031	0.031	0.033	0.032	0.030	0.029	0.030
		0.068	0.042	0.039	0.032	0.028	0.026	0.025	0.026	0.023	0.023	0.023
	90	0.064	0.082	0.080	0.093	0.074	0.076	0.075	0.077	0.070	0.016	0.074
		0.101	0.061	0.053	0.056	0.046	0.046	0.046	0.046	0.041	0.044	0.043

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
19	120	0.093	0.112	0.112	0.110	0.102	0.101	0.102	0.103	0.099	0.010	0.100
		0.119	0.092	0.083	0.080	0.071	0.072	0.071	0.073	0.069	0.069	0.068
	30	0.052	0.068	0.072	0.069	0.044	0.033	0.032	0.029	0.024	0.026	0.023
		0.078	0.045	0.047	0.045	0.014	0.009	0.006	0.006	0.000	− 0.002	0.001
	60	0.055	0.086	0.076	0.073	0.061	0.055	0.057	0.055	0.053	0.055	0.055
		0.090	0.049	0.044	0.040	0.029	0.027	0.026	0.027	0.024	0.024	0.025
	90	0.063	0.115	0.111	0.112	0.106	0.098	0.100	0.097	0.095	0.095	0.097
		0.117	0.062	0.055	0.052	0.038	0.036	0.036	0.038	0.035	0.036	0.036
	120	0.072	0.128	0.127	0.125	0.127	0.117	0.115	0.115	0.114	0.114	0.115
		0.127	0.067	0.064	0.063	0.046	0.044	0.044	0.046	0.043	0.045	0.044
20	30	0.052	0.051	0.048	0.054	0.028	0.015	0.014	0.010	0.007	0.007	0.005
		0.056	0.055	0.046	0.042	0.023	0.017	0.015	0.012	0.009	0.007	0.006
	60	0.040	0.092	0.059	0.066	0.045	0.039	0.042	0.038	0.037	0.036	0.035
		0.093	0.037	0.035	0.028	0.026	0.024	0.023	0.023	0.022	0.022	0.022
	90	0.049	0.125	0.117	0.119	0.109	0.107	0.108	0.107	0.104	0.105	0.103
		0.125	0.043	0.039	0.040	0.030	0.029	0.027	0.030	0.027	0.031	0.027
	120	0.063	0.127	0.126	0.126	0.120	0.115	0.115	0.114	0.111	0.115	0.112
		0.127	0.057	0.052	0.062	0.040	0.038	0.035	0.037	0.034	0.017	0.036

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
21	30	0.059	0.050	0.031	0.032	0.019	0.019	0.015	0.015	0.008	0.011	0.010
		0.061	0.051	0.043	0.048	0.020	0.015	0.013	0.011	0.009	0.008	0.006
	60	0.057	0.081	0.065	0.070	0.059	0.060	0.056	0.058	0.049	0.053	0.055
		0.087	0.053	0.051	0.045	0.037	0.035	0.035	0.034	0.033	0.033	0.033
	90	0.182	0.120	0.105	0.113	0.101	0.102	0.100	0.100	0.092	0.097	0.098
		0.119	0.057	0.050	0.045	0.041	0.038	0.037	0.037	0.037	0.037	0.037
	120	0.056	0.124	0.121	0.123	0.116	0.115	0.111	0.111	0.107	0.111	0.111
		0.125	0.053	0.047	0.043	0.037	0.035	0.034	0.034	0.034	0.034	0.034
22	30	0.048	0.083	0.083	0.083	0.059	0.043	0.037	0.037	0.036	0.040	0.027
		0.095	0.060	0.026	0.057	0.016	0.011	0.007	0.002	0.001	−0.004	0.000
	60	0.064	0.099	0.092	0.086	0.079	0.077	0.072	0.073	0.071	0.070	0.069
		0.103	0.047	0.050	0.044	0.040	0.035	0.032	0.030	0.030	0.029	0.029
	90	0.061	0.117	0.114	0.115	0.105	0.097	0.006	0.094	0.092	0.094	0.088
		0.119	0.057	0.044	0.046	0.040	0.038	0.036	0.034	0.033	0.034	0.034
	120	0.075	0.121	0.120	0.119	0.121	0.119	0.112	0.111	0.108	0.108	0.106
		0.122	0.073	0.059	0.063	0.052	0.051	0.049	0.047	0.042	0.047	0.048
	30	0.063	0.069	0.050	0.064	0.023	0.021	0.019	0.018	0.014	0.013	0.014
		0.076	0.059	0.041	0.052	0.026	0.014	0.011	0.009	0.004	0.003	0.001

Plot No.	Depth in cm	Moisture Content (g/g)										
		28/9/72	5/10/72	12/10/72	19/10/72	27/10/72	2/11/72	9/11/72	16/11/72	30/11/72	14/12/72	28/12/72
23	60	0.049	0.109	0.095	0.104	0.040	0.079	0.076	0.078	0.069	0.073	0.073
		0.108	0.044	0.040	0.035	0.029	0.026	0.023	0.023	0.022	0.021	0.021
	90	0.063	0.125	0.119	0.122	0.080	0.106	0.104	0.104	0.100	0.102	0.104
		0.127	0.065	0.047	0.053	0.037	0.035	0.034	0.036	0.034	0.038	0.034
	120	0.087	0.134	0.133	0.129	0.109	0.117	0.116	0.116	0.113	0.114	0.115
		0.135	0.089	0.087	0.087	0.076	0.072	0.069	0.070	0.068	0.126	0.068
24	30	0.054	0.071	0.061	0.067	0.049	0.049	0.034	0.032	0.029	0.030	0.024
		0.073	0.048	0.038	0.046	0.021	0.018	0.015	0.011	0.006	0.008	0.006
	60	0.047	0.111	0.097	0.108	0.095	0.096	0.091	0.092	0.086	0.085	0.082
		0.111	0.043	0.046	0.040	0.042	0.042	0.038	0.036	0.033	0.029	0.028
	90	0.054	0.124	0.119	0.121	0.117	0.120	0.117	0.116	0.113	0.111	0.112
		0.124	0.054	0.041	0.054	0.037	0.037	0.036	0.034	0.028	0.031	0.027
	120	0.079	0.119	0.131	0.132	0.128	0.133	0.128	0.129	0.127	0.126	0.126
		0.132	0.078	0.074	0.078	0.071	0.072	0.069	0.067	0.062	0.062	0.059

APPENDIX 4b *Soil moisture records for 1973*

APPENDIX 4b *Soil moisture records for 1973*

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
1	30	0.131	0.128	0.148	0.082	0.043	0.053	0.049	0.135	0.108	0.131	0.171
	60	0.192	0.200	0.205	0.186	0.153	0.149	0.145	0.180	0.197	0.182	0.228
	90	0.259	0.261	0.257	0.264	0.264	0.254	0.240	0.244	0.261	0.251	0.287
	120	0.264	0.272	0.272	0.283	0.281	0.283	0.272	0.279	0.285	0.267	0.302
2	30	0.144	0.153	0.177	0.082	0.063	0.096	0.079	0.179	0.136	0.158	0.181
	60	0.147	0.147	0.137	0.098	0.083	0.092	0.079	0.154	0.132	0.140	0.160
	90	0.158	0.267	0.272	0.262	0.252	0.259	0.251	0.283	0.278	0.259	0.252
	120	0.257	0.263	0.274	0.275	0.270	0.275	0.274	0.291	0.296	0.288	0.282
3	30	0.123	0.132	0.150	0.138	0.115	0.124	0.133	0.165	0.150	0.142	0.163
	60	0.154	0.152	0.158	0.161	0.165	0.158	0.161	0.168	0.167	0.158	0.161
	90	0.232	0.233	0.238	0.243	0.250	0.249	0.247	0.253	0.250	0.236	0.233
	120	0.293	0.297	0.300	0.309	0.315	0.307	0.316	0.334	0.319	0.311	0.303
4	30	0.105	0.117	0.147	0.082	0.047	0.055	0.066	0.157	0.124	0.120	0.143
	60	0.178	0.173	0.152	0.130	0.104	0.111	0.102	0.163	0.154	0.170	0.185
	90	0.237	0.247	0.239	0.243	0.233	0.224	0.222	0.247	0.251	0.230	0.238
	120	0.285	0.290	0.277	0.286	0.278	0.282	0.271	0.292	0.296	0.275	0.280

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
5	30	0.136	0.154	0.165	0.078	0.064	0.087	0.082	0.175	0.142	0.163	0.210
	60	0.183	0.194	0.185	0.133	0.118	0.116	0.118	0.200	0.175	0.180	0.263
	90	0.252	0.279	0.277	0.280	0.256	0.240	0.249	0.291	0.282	0.256	0.320
	120	0.282	0.306	0.309	0.308	0.314	0.299	0.292	0.329	0.317	0.298	0.362
6	30	0.194	0.201	0.188	0.142	0.125	0.130	0.133	0.213	0.148	0.205	0.221
	60	0.209	0.205	0.191	0.174	0.164	0.163	0.158	0.201	0.229	0.198	0.213
	90	0.263	0.256	0.264	0.213	0.253	0.252	0.235	0.242	0.305	0.232	0.255
	120	0.292	0.301	0.302	0.308	0.314	0.298	0.297	0.291	0.327	0.280	0.311
7	30	0.197	0.202	0.191	0.132	0.091	0.097	0.098	0.189	0.180	0.188	0.207
	60	0.215	0.209	0.199	0.170	0.150	0.157	0.155	0.179	0.201	0.182	0.202
	90	0.279	0.278	0.278	0.281	0.262	0.258	0.253	0.251	0.266	0.249	0.259
	120	0.309	0.314	0.314	0.315	0.311	0.298	0.292	0.293	0.299	0.269	0.286
8	30	0.187	0.173	0.197	0.127	0.120	0.132	0.125	0.195	0.163	0.192	0.200
	60	0.262	0.264	0.256	0.211	0.224	0.219	0.221	0.268	0.253	0.285	0.253
	90	0.260	0.275	0.268	0.256	0.257	0.247	0.243	0.272	0.267	0.262	0.268
	120	0.281	0.294	0.285	0.273	0.299	0.288	0.284	0.296	0.296	0.285	0.294
9	30	0.169	0.154	0.182	0.118	0.106	0.131	0.130	0.195	0.187	0.184	0.189
	60	0.207	0.210	0.195	0.168	0.163	0.155	0.160	0.231	0.204	0.215	0.220
	90	0.276	0.280	0.275	0.261	0.268	0.239	0.256	0.290	0.261	0.273	0.264
	120	0.296	0.306	0.293	0.290	0.297	0.283	0.287	0.311	0.282	0.303	0.312

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
10	30	0.159	0.182	0.197	0.156	0.161	0.177	0.175	0.206	0.186	0.178	0.189
	60	0.192	0.201	0.200	0.196	0.199	0.204	0.198	0.201	0.215	0.204	0.212
	90	0.208	0.210	0.211	0.210	0.221	0.216	0.221	0.219	0.220	0.201	0.212
	120	0.244	0.258	0.252	0.256	0.264	0.261	0.260	0.263	0.266	0.235	0.237
11	30	0.080	0.089	0.128	0.083	0.075	0.094	0.096	0.118	0.100	0.053	0.103
	60	0.210	0.224	0.227	0.220	0.211	0.208	0.216	0.232	0.231	0.162	0.218
	90	0.240	0.244	0.247	0.240	0.238	0.233	0.238	0.245	0.246	0.244	0.241
	120	0.239	0.238	0.247	0.242	0.239	0.236	0.240	0.253	0.253	0.245	0.249
12	30	0.094	0.099	0.084	0.047	0.040	0.059	0.051	0.120	0.102	0.098	0.116
	60	0.216	0.220	0.209	0.208	0.189	0.191	0.190	0.222	0.217	0.199	0.212
	90	0.231	0.238	0.231	0.235	0.225	0.225	0.223	0.237	0.231	0.212	0.229
	120	0.244	0.249	0.244	0.250	0.247	0.245	0.243	0.253	0.250	0.227	0.210
13	30	0.083	0.080	0.089	0.033	0.023	0.043	0.037	0.100	0.085	0.088	0.114
	60	0.218	0.224	0.217	0.165	0.183	0.181	0.181	0.221	0.214	0.205	0.248
	90	0.228	0.236	0.230	0.219	0.226	0.214	0.219	0.235	0.241	0.221	0.265
	120	0.250	0.254	0.249	0.252	0.248	0.243	0.229	0.247	0.245	0.245	0.293
14	30	0.080	0.081	0.092	0.044	0.029	0.059	0.054	0.103	0.097	0.104	0.097
	60	0.193	0.195	0.187	0.187	0.173	0.180	0.175	0.206	0.203	0.203	0.192
	90	0.216	0.226	0.220	0.223	0.217	0.209	0.199	0.203	0.219	0.225	0.218
	120	0.208	0.219	0.217	0.226	0.224	0.220	0.214	0.215	0.217	0.224	0.269

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
15	30	0.047	0.046	0.047	0.012	0.001	0.010	0.020	0.073	0.044	0.058	0.068
	60	0.148	0.159	0.146	0.122	0.117	0.107	0.127	0.162	0.156	0.142	0.148
	90	0.219	0.224	0.214	0.226	0.205	0.199	0.202	0.209	0.215	0.198	0.210
	120	0.234	0.237	0.234	0.247	0.241	0.236	0.235	0.234	0.236	0.222	0.234
16	30	0.068	0.065	0.074	0.024	0.007	0.108	0.013	0.073	0.043	0.073	0.084
	60	0.113	0.115	0.102	0.079	0.063	0.058	0.066	0.083	0.079	0.073	0.107
	90	0.160	0.170	0.170	0.172	0.157	0.148	0.145	0.146	0.146	0.126	0.113
	120	0.230	0.230	0.226	0.170	0.238	0.238	0.144	0.150	0.228	0.222	0.154
17	30	0.084	0.102	0.090	0.053	0.029	0.038	0.044	0.101	0.075	0.078	0.096
	60	0.154	0.162	0.152	0.126	0.117	0.111	0.113	0.125	0.124	0.112	0.132
	90	0.196	0.208	0.193	0.195	0.180	0.172	0.180	0.175	0.180	0.159	0.166
	120	0.217	0.229	0.219	0.226	0.224	0.212	0.218	0.219	0.219	0.206	0.209
18	30	0.057	0.052	0.043	0.031	0.027	0.027	0.029	0.037	0.032	0.020	0.036
	60	0.060	0.061	0.061	0.069	0.045	0.046	0.048	0.045	0.047	0.022	0.039
	90	0.094	0.098	0.105	0.114	0.098	0.102	0.099	0.096	0.100	0.057	0.084
	120	0.115	0.118	0.122	0.124	0.124	0.123	0.120	0.119	0.123	0.078	0.113
19	30	0.079	0.069	0.075	0.048	0.040	0.049	0.045	0.074	0.064	0.073	0.080
	60	0.096	0.090	0.093	0.075	0.071	0.072	0.072	0.098	0.094	0.088	0.094

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
	90	0.126	0.124	0.130	0.124	0.119	0.116	0.114	0.126	0.123	0.122	0.127
	120	0.112	0.133	0.134	0.135	0.137	0.131	0.126	0.134	0.137	0.134	0.137
20	30	0.057	0.045	0.047	0.025	0.018	0.026	0.026	0.053	0.046	0.046	0.052
	60	0.078	0.076	0.080	0.084	0.065	0.053	0.063	0.085	0.084	0.072	0.019
	90	0.134	0.130	0.135	0.139	0.133	0.132	0.130	0.136	0.138	0.129	0.132
	120	0.138	0.137	0.139	0.145	0.144	0.138	0.138	0.140	0.141	0.138	0.141
21	30	0.063	0.053	0.052	0.028	0.029	0.036	0.032	0.057	0.051	0.048	0.064
	60	0.097	0.095	0.086	0.075	0.078	0.078	0.078	0.096	0.091	0.089	0.092
	90	0.130	0.127	0.128	0.136	0.125	0.126	0.125	0.127	0.131	0.122	0.124
	120	0.138	0.137	0.135	0.141	0.141	0.140	0.139	0.058	0.139	0.135	0.135
22	30	0.095	0.091	0.090	0.081	0.065	0.069	0.073	0.101	0.094	0.094	0.098
	60	0.109	0.110	0.110	0.105	0.094	0.092	0.093	0.114	0.110	0.110	0.114
	90	0.113	0.118	0.123	0.126	0.126	0.118	0.115	0.129	0.128	0.120	0.123
	120	0.123	0.126	0.130	0.133	0.136	0.133	0.130	0.136	0.136	0.131	0.134
23	30	0.080	0.067	0.059	0.052	0.042	0.050	0.051	0.076	0.056	0.060	0.061
	60	0.110	0.109	0.108	0.106	0.097	0.099	0.099	0.098	0.098	0.090	0.086
	90	0.128	0.126	0.127	0.129	0.127	0.127	0.124	0.126	0.123	0.119	0.117
	120	0.133	0.133	0.132	0.132	0.135	0.135	0.133	0.134	0.134	0.131	0.155

Plot No.	Depth in cm	Moisture Content (g)										
		27/4/73	30/4/73	7/5/73	14/5/73	21/5/73	28/5/73	4/6/73	12/6/73	18/6/73	25/6/73	2/7/73
24	30	0.073	0.064	0.075	0.060	0.055	0.063	0.068	0.076	0.068	0.070	0.063
	60	0.111	0.109	0.115	0.105	0.113	0.113	0.114	0.117	0.116	0.110	0.106
	90	0.130	0.128	0.135	0.134	0.132	0.133	0.132	0.132	0.132	0.132	0.127
	120	0.134	0.133	0.138	0.140	0.139	0.138	0.138	0.140	0.141	0.143	0.138

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
1	30	0.116	0.124	0.145	0.139	0.145	0.164	0.158	0.169	0.190	0.171	0.191
	60	0.174	0.186	0.199	0.200	0.199	0.195	0.187	0.201	0.213	0.202	0.229
	90	0.253	0.254	0.261	0.262	0.261	0.263	0.262	0.270	0.268	0.264	0.277
	120	0.257	0.265	0.355	0.268	0.355	0.268	0.270	0.270	0.275	0.268	0.293
2	30	0.147	0.152	0.174	0.166	0.174	0.177	0.154	0.166	0.200	0.179	0.188
	60	0.136	0.149	0.161	0.160	0.161	0.166	0.154	0.156	0.167	0.148	0.135
	90	0.245	0.255	0.262	0.274	0.262	0.276	0.267	0.267	0.278	0.272	0.292
	120	0.285	0.288	0.289	0.294	0.288	0.299	0.287	0.282	0.312	0.287	0.312 I II
3	30	0.135	0.143	0.141	0.139	0.141	0.143	0.137	0.152	0.177	0.166	0.185
	60	0.172	0.176	0.171	0.172	0.171	0.185	0.177	0.177	0.189	0.193	0.197
	90	0.232	0.241	0.251	0.251	0.251	0.252	0.257	0.252	0.246	0.261	0.275
	120	0.309	0.312	0.350	0.315	0.350	0.334	0.321	0.326	0.318	0.333	0.352
4	30	0.089	0.103	0.138	0.122	0.138	0.123	0.128	0.135	0.165	0.137	0.177
	60	0.166	0.159	0.183	0.178	0.183	0.181	0.182	0.187	0.197	0.185	0.188
	90	0.230	0.236	0.241	0.232	0.241	0.241	0.240	0.243	0.253	0.242	0.264
	120	0.281	0.288	0.319	0.285	0.319	0.293	0.287	0.291	0.316	0.293	0.320

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
5	30	0.139	0.132	0.163	0.141	0.163	0.159	0.148	0.164	0.196	0.170	0.182
	60	0.169	0.163	0.196	0.154	0.196	0.197	0.190	0.195	0.209	0.197	0.171
	90	0.256	0.260	0.325	0.264	0.325	0.291	0.282	0.285	0.298	0.288	0.305
	120	0.298	0.296	0.329	0.311	0.329	0.322	0.318	0.312	0.323	0.322	0.339
6	30	0.186	0.203	0.226	0.212	0.226	0.221	0.224	0.219	0.245	0.229	0.247
	60	0.192	0.203	0.217	0.232	0.217	0.214	0.210	0.209	0.217	0.212	0.219
	90	0.240	0.242	0.246	0.249	0.246	0.263	0.246	0.252	0.256	0.256	0.279
	120	0.296	0.301	0.321	0.318	0.321	0.320	0.315	0.316	0.315	0.317	0.330
7	30	0.175	0.185	0.197	0.186	0.197	0.197	0.201	0.209	0.226	0.210	0.230
	60	0.191	0.194	0.201	0.193	0.201	0.220	0.197	0.216	0.225	0.208	0.230
	90	0.269	0.274	0.272	0.270	0.272	0.278	0.270	0.284	0.287	0.280	0.289
	120	0.307	0.319	0.308	0.309	0.308	0.321	0.318	0.328	0.324	0.321	0.336
8	30	0.172	0.178	0.204	0.198	0.204	0.202	0.196	0.195	0.219	0.206	0.218
	60	0.236	0.246	0.262	0.249	0.262	0.262	0.255	0.261	0.280	0.267	0.270
	90	0.302	0.259	0.275	0.275	0.275	0.269	0.263	0.263	0.280	0.271	0.282
	120	0.302	0.293	0.306	0.299	0.305	0.302	0.296	0.295	0.308	0.304	0.310

Plot No. | Depth in cm | Moisture Content (g)

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
9	30	0.160	0.162	0.195	0.180	0.195	0.185	0.175	0.178	0.204	0.187	0.209
	60	0.207	0.203	0.218	0.206	0.218	0.220	0.212	0.218	0.231	0.219	0.234
	90	0.278	0.277	0.284	0.274	0.284	0.284	0.277	0.281	0.294	0.284	0.302
	120	0.317	0.295	0.320	0.312	0.320	0.323	0.324	0.322	0.322	0.321	0.332
10	30	0.165	0.160	0.173	0.160	0.173	0.175	0.168	0.182	0.214	0.192	0.208
	60	0.213	0.210	0.190	0.211	0.199	0.218	0.202	0.220	0.231	0.226	0.235
	90	0.227	0.223	0.223	0.220	0.223	0.232	0.218	0.225	0.232	0.236	0.240
	120	0.256	0.264	0.251	0.255	0.251	0.275	0.264	0.269	0.274	0.278	0.280
11	30	0.080	0.081	0.066	0.087	0.066	0.088	0.083	0.100	0.124	0.107	0.127
	60	0.205	0.206	0.202	0.219	0.202	0.208	0.212	0.221	0.230	0.221	0.239
	90	0.244	0.237	0.239	0.248	0.239	0.238	0.224	0.248	0.246	0.245	0.250
	120	0.244	0.241	0.240	0.256	0.240	0.250	0.245	0.250	0.254	0.253	0.258
12	30	0.090	0.104	0.082	0.123	0.082	0.122	0.128	0.127	0.149	0.133	0.159
	60	0.210	0.210	0.194	0.209	0.194	0.217	0.211	0.213	0.223	0.216	0.227
	90	0.228	0.225	0.212	0.216	0.212	0.224	0.225	0.217	0.225	0.225	0.229
	120	0.244	0.242	0.236	0.237	0.236	0.253	0.250	0.244	0.258	0.251	0.262
13	30	0.081	0.078	0.058	0.091	0.102	0.091	0.094	0.096	0.116	0.102	0.120
	60	0.201	0.206	0.191	0.210	0.212	0.217	0.211	0.214	0.221	0.221	0.237

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
	90	0.226	0.221	0.221	0.229	0.223	0.223	0.227	0.227	0.230	0.229	0.255
	120	0.249	0.249	0.238	0.252	0.247	0.257	0.249	0.247	0.251	0.252	0.264
14	30	0.088	0.077	0.038	0.080	0.106	0.073	0.065	0.080	0.105	0.086	0.115
	60	0.195	0.192	0.175	0.186	0.199	0.202	0.191	0.201	0.199	0.188	0.211
	90	0.219	0.217	0.209	0.217	0.225	0.219	0.216	0.221	0.212	0.217	0.234
	120	0.221	0.221	0.214	0.221	0.239	0.224	0.222	0.223	0.247	0.223	0.236
15	30	0.040	0.057	0.033	0.059	0.081	0.073	0.067	0.073	0.093	0.075	0.097
	60	0.139	0.154	0.132	0.151	0.162	0.158	0.149	0.155	0.165	0.163	0.175
	90	0.209	0.226	0.206	0.215	0.221	0.223	0.213	0.162	0.215	0.218	0.231
	120	0.229	0.251	0.230	0.234	0.268	0.243	0.232	0.231	0.227	0.236	0.247
16	30	0.056	0.061	0.046	0.073	0.088	0.081	0.075	0.078	0.103	0.086	0.101
	60	0.096	0.100	0.094	0.108	0.126	0.119	0.113	0.114	0.132	0.116	0.133
	90	0.151	0.158	0.156	0.165	0.183	0.169	0.171	0.169	0.175	0.171	0.191
	120	0.226	0.231	0.234	0.240	0.277	0.250	0.247	0.248	0.250	0.247	0.263
17	30	0.068	0.070	0.058	0.093	0.103	0.081	0.087	0.096	0.122	0.103	0.124
	60	0.145	0.140	0.128	0.149	0.158	0.154	0.147	0.157	0.165	0.156	0.164
	90	0.186	0.179	0.177	0.191	0.192	0.189	0.189	0.193	0.193	0.191	0.213
	120	0.221	0.214	0.219	0.226	0.231	0.226	0.225	0.232	0.231	0.235	0.246

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
18	30	0.034	0.032	0.027	0.041	0.064	0.053	0.053	0.055	0.069	0.060	0.062
	60	0.044	0.045	0.042	0.043	0.063	0.062	0.058	0.062	0.068	0.063	0.059
	90	0.054	0.088	0.088	0.089	0.102	0.103	0.101	0.101	0.103	0.106	0.110
	120	0.089	0.117	0.118	0.118	0.127	0.124	0.124	0.128	0.124	0.128	0.128
19	30	0.064	0.067	0.057	0.074	0.076	0.072	0.071	0.073	0.086	0.078	0.084
	60	0.088	0.087	0.084	0.102	0.099	0.096	0.093	0.096	0.102	0. 98	0.104
	90	0.119	0.123	0.121	0.126	0.125	0.122	0.123	0.121	0.120	0.126	0.129
	120	0.132	0.131	0.134	0.138	0.134	0.132	0.134	0.129	0.128	0.135	0.138
20	30	0.042	0.045	0.036	0.050	0.061	0.049	0.047	0.051	0.064	0.056	0.068
	60	0.069	0.072	0.061	0.075	0.075	0.077	0.073	0.074	0.084	0.079	0.091
	90	0.129	0.130	0.126	0.133	0.130	0.132	0.129	0.129	0.134	0.132	0.140
	120	0.137	0.139	0.137	0.141	0.136	0.139	0.136	0.136	0.140	0.139	0.145
21	30	0.048	0.045	0.036	0.036	0.064	0.058	0.052	0.050	0.065	0.058	0.068
	60	0.089	0.089	0.080	0.094	0.098	0.093	0.093	0.095	0.101	0.099	0.101
	90	0.125	0.124	0.121	0.126	0.126	0.125	0.126	0.126	0.133	0.131	0.135
	120	0.134	0.134	0.131	0.134	0.136	0.131	0.137	0.137	0.140	0.138	0.140

Plot No.	Depth in cm	Moisture Content (g)										
		9/7/73	16/7/73	23/7/73	30/7/73	7/8/73	13/8/73	20/8/73	27/8/73	3/9/73	10/9/73	26/9/73
22	30	0.092	0.093	0.079	0.096	0.102	0.099	0.091	0.097	0.106	0.100	0.104
	60	0.111	0.113	0.108	0.116	0.117	0.117	0.115	0.115	0.118	0.115	0.113
	90	0.121	0.120	0.117	0.127	0.126	0.126	0.123	0.126	0.126	0.125	0.130
	120	0.133	0.133	0.129	0.136	0.134	0.137	0.133	0.135	0.134	0.134	0.139
23	30	0.046	0.044	0.039	0.052	0.083	0.075	0.075	0.077	0.090	0.083	0.084
	60	0.088	0.088	0.090	0.090	0.113	0.111	0.108	0.109	0.117	0.114	0.111
	90	0.118	0.117	0.118	0.118	0.130	0.128	0.130	0.129	0.134	0.132	0.136
	120	0.129	0.128	0.130	0.131	0.138	0.140	0.138	0.139	0.142	0.139	0.142
24	30	0.056	0.057	0.050	0.060	0.068	0.060	0.060	0.063	0.075	0.070	0.077
	60	0.106	0.107	0.105	0.108	0.107	0.109	0.106	0.108	0.111	0.110	0.116
	90	0.130	0.129	0.128	0.130	0.129	0.132	0.128	0.125	0.131	0.131	0.133
	120	0.121	0.137	0.139	0.139	0.140	0.139	0.137	0.138	0.141	0.142	0.143

Plot No.	Depth in	Moisture Content (g)

Plot No.	Depth in cm	Moisture Content (g)							
		3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73
1	30	0.185	0.174	0.160	0.194	0.139	0.087	0.062	0.062
	60	0.217	0.204	0.169	0.231	0.186	0.158	0.156	0.149
	90	0.263	0.265	0.258	0.273	0.264	0.255	0.249	0.240
	120	0.293	0.289	0.282	0.427	0.285	0.287	0.277	0.257
2	30	0.186	0.175	0.143	0.197	0.154	0.112	0.088	0.087
	60	0.142	0.120	0.097	0.123	0.112	0.094	0.088	0.089
	90	0.288	0.273	0.261	0.251	0.249	0.251	0.250	0.246
	120	0.299	0.296	0.296	0.288	0.287	0.289	0.285	0.280
3	30	0.176	0.174	0.162	0.189	0.137	0.132	0.110	0.108
	60	0.199	0.199	0.184	0.189	0.189	0.184	0.166	0.163
	90	0.277	0.278	0.276	0.272	0.271	0.271	0.272	0.258
	120	0.344	0.352	0.338	0.367	0.333	0.336	0.331	0.332
4	30	0.170	0.154	0.133	0.186	0.139	0.128	0.064	0.049
	60	0.162	0.139	0.120	0.188	0.155	0.157	0.118	0.101
	90	0.258	0.246	0.232	0.261	0.288	0.236	0.234	0.220
	120	0.302	0.295	0.280	0.317	0.263	0.275	0.269	0.263
5	30	0.167	0.125	0.107	0.146	0.105	0.093	0.067	0.077
	60	0.159	0.138	0.115	0.123	0.115	0.120	0.117	0.121
	90	0.301	0.282	0.263	0.255	0.249	0.253	0.252	0.257
	120	0.338	0.333	0.323	0.327	0.315	0.324	0.315	0.319

Plot No.	Depth in cm	Moisture Content (g)							
		3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73
6	30	0.251	0.232	0.236	0.252	0.222	0.198	0.157	0.139
	60	0.216	0.195	0.186	0.220	0.205	0.195	0.175	0.168
	90	0.279	0.270	0.269	0.268	0.274	0.260	0.244	0.249
	120	0.330	0.325	0.320	0.300	0.312	0.293	0.276	0.276
7	30	0.225	0.198	0.172	0.261	0.178	0.150	0.125	0.106
	60	0.229	0.205	0.180	0.229	0.196	0.180	0.212	0.168
	90	0.292	0.278	0.273	0.280	0.268	0.270	0.388	0.265
	120	0.332	0.325	0.323	0.293	0.304	0.311	0.442	0.300
8	30	0.217	0.211	0.212	0.231	0.198	0.185	0.168	0.167
	60	0.269	0.258	0.248	0.282	0.263	0.261	0.254	0.256
	90	0.279	0.280	0.274	0.295	0.275	0.274	0.267	0.275
	120	0.311	0.317	0.306	0.320	0.309	0.313	0.306	0.306
9	30	0.205	0.197	0.177	0.236	0.175	0.152	0.118	0.110
	60	0.223	0.203	0.177	0.236	0.205	0.193	0.182	0.169
	90	0.299	0.291	0.279	0.265	0.274	0.285	0.275	0.271
	120	0.331	0.334	0.325	0.280	0.311	0.324	0.321	0.310
10	30	0.215	0.213	0.209	0.183	0.178	0.166	0.153	0.126
	60	0.233	0.239	0.230	0.210	0.219	0.213	0.201	0.180
	90	0.242	0.250	0.238	0.204	0.239	0.239	0.240	0.230
	120	0.288	0.292	0.289	0.244	0.283	0.283	0.285	0.276

Plot No.	Depth in cm	Moisture Content (g)							
		3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73

Plot No.	Depth in	Moisture Content (g)							
	cm	3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73
11	30	0.122	0.114	0.115	0.100	0.103	0.111	0.080	0.053
	60	0.231	0.228	0.229	0.189	0.225	0.255	0.216	0.189
	90	0.253	0.246	0.250	0.200	0.243	0.281	0.243	0.232
	120	0.257	0.258	0.256	0.206	0.253	0.292	0.253	0.240
12	30	0.150	0.132	0.137	0.167	0.102	0.083	0.075	0.056
	60	0.226	0.223	0.219	0.226	0.213	0.204	0.199	0.185
	90	0.228	0.230	0.230	0.232	0.231	0.224	0.217	0.204
	120	0.261	0.259	0.255	0.258	0.260	0.264	0.249	0.237
13	30	0.118	0.106	0.113	0.125	0.100	0.072	0.049	0.028
	60	0.236	0.213	0.210	0.225	0.215	0.209	0.197	0.170
	90	0.252	0.239	0.234	0.239	0.226	0.229	0.221	0.200
	120	0.259	0.255	0.255	0.242	0.234	0.237	0.230	0.218
14	30	0.108	0.087	0.081	0.123	0.053	0.039	0.032	0.014
	60	0.205	0.191	0.179	0.202	0.179	0.172	0.172	0.147
	90	0.225	0.227	0.220	0.213	0.222	0.203	0.207	0.191
	120	0.228	0.227	0.231	0.215	0.230	0.223	0.217	0.203
15	30	0.092	0.082	0.071	0.099	0.057	0.036	0.023	0.011
	60	0.179	0.163	0.131	0.177	0.143	0.136	0.135	0.102
	90	0.230	0.223	0.205	0.220	0.208	0.217	0.211	0.194
	120	0.246	0.241	0.232	0.234	0.240	0.249	0.240	0.225

Plot No.	Depth in cm	Moisture Content (g)							
		3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73
16	30	0.096	0.091	0.100	0.111	0.068	0.039	0.017	0.004
	60	0.120	0.102	0.105	0.134	0.121	0.108	0.080	0.053
	90	0.184	0.181	0.169	0.185	0.184	0.187	0.176	0.130
	120	0.263	0.262	0.247	0.256	0.259	0.261	0.259	0.232
17	30	0.127	0.120	0.124	0.136	0.106	0.080	0.045	0.018
	60	0.174	0.152	0.153	0.165	0.161	0.156	0.130	0.104
	90	0.221	0.205	0.196	0.203	0.207	0.208	0.194	0.162
	120	0.264	0.248	0.245	0.238	0.245	0.246	0.237	0.212
18	30	0.060	0.056	0.055	0.069	0.021	0.034	0.026	0.026
	60	0.058	0.056	0.053	0.073	0.337	0.054	0.048	0.043
	90	0.102	0.100	0.102	0.109	0.280	0.106	0.100	0.094
	120	0.124	0.122	0.123	0.124	0.015	0.123	0.122	0.117
19	30	0.087	0.083	0.084	0.090	0.008	0.067	0.051	0.042
	60	0.104	0.092	0.091	0.107	0.113	0.097	0.089	0.071
	90	0.130	0.124	0.120	0.133	0.130	0.125	0.126	0.110
	120	0.138	0.136	0.131	0.137	0.136	0.131	0.133	0.125
20	30	0.067	0.059	0.062	0.072	0.053	0.037	0.022	0.022
	60	0.086	0.081	0.079	0.091	0.083	0.084	0.038	0.061
	90	0.139	0.138	0.137	0.138	0.135	0.138	0.132	0.127
	120	0.143	0.141	0.139	0.143	0.138	0.140	0.135	0.133

Plot No.	Depth in	Moisture Content (g)

Plot No.	Depth in cm	Moisture Content (g)							
		3/10/73	8/10/73	15/10/73	31/10/73	7/11/73	14/11/73	28/11/73	18/12/73
21	30	0.068	0.062	0.051	0.072	0.054	0.043	0.033	0.032
	60	0.100	0.093	0.083	0.102	0.089	0.083	0.082	0.081
	90	0.133	0.132	0.126	0.131	0.129	0.130	0.127	0.125
	120	0.140	0.141	0,137	0,139	0.137	0.138	0.136	0.136
22	30	0.096	0.085	0.082	0.102	0.071	0.065	0.059	0.060
	60	0.105	0.100	0.096	0.103	0.093	0.093	0.093	0.092
	90	0.126	0.123	0.121	0.116	0.113	0.115	0.116	0.116
	120	0.139	0.137	0.137	0.130	0.128	0.129	0.128	0.129
23	30	0.077	0.069	0.062	0.073	0.052	0.049	0.048	0.049
	60	0.108	0.105	0.100	0.099	0.093	0.096	0.097	0.097
	90	0.135	0.129	0.127	0.124	0.121	0.123	0.122	0.120
	120	0.144	0.136	0.135	0.133	0.130	0.134	0.132	0.132
24	30	0.073	0.076	0.077	0.080	0.067	0.061	0.052	0.051
	60	0.119	0.118	0.119	0.119	0.115	0.115	0.111	0.110
	90	0.140	0.136	0.135	0.134	0.132	0.133	0.132	0.131
	120	0.144	0.142	0.145	0.142	0.143	0.142	0.141	0.141

APPENDIX 4c *Soil moisture records for 1974*

Plot No.	Depth in cm	Moisture Content (g)								
		30/4/74	13/5/74	27/5/74	10/6/74	24/6/74	8/7/74	22/7/74	19/8/74	3/9/74
1	30	0.163	0.144	0.118	0.171	0.155	0.177	0.190	0.144	0.174
	60	0.204	0.171	0.160	0.196	0.189	0.196	0.205	0.176	0.197
	90	0.265	0.255	0.251	0,263	0.263	0.258	0.276	0.255	0.268
	120	0.273	0.254	0.250	0.261	0.266	0.267	0.276	0.252	0.265
2	30	0.178	0.146	0.113	0.155	0.146	0.170	0.175	0.130	0.161
	60	0.144	0.142	0.127	0.146	0.147	0.148	0.147	0.127	0.156
	90	0.272	0.256	0.238	0.248	0.264	0.269	0.263	0.250	0.253
	120	0.295	0.285	0.275	0.282	0.289	0.289	0.315	0.273	0.282
3	30	0.100	0.093	0.066	0.104	0.099	0.130	0.132	0.087	0.129
	60	0.130	0.147	0.151	0.142	0.151	0.170	0.165	0.155	0.187
	90	0.227	0.230	0.231	0.229	0.226	0.248	0.246	0.235	0.223
	120	0.321	0.295	0.291	0.288	0.290	0.320	0.319	0.298	0.314
4	30	0.122	0.081	0.051	0.097	0.079	0.094	0.109	0.069	0.100
	60	0.174	0.168	0.158	0.197	0.183	0.185	0.195	0.164	0.193
	90	0.241	0.233	0.212	0.221	0.227	0.230	0.240	0.216	0.236
	120	0.296	0.287	0.278	0.290	0.287	0.291	0.323	0.270	0.292
5	30	0.162	0.139	0.088	0.160	0.154	0.162	0.169	0.127	0.152
	60	0.184	0.185	0.162	0.182	0.195	0.191	0.201	0.167	0.196
	90	0.278	0.272	0.236	0.261	0.285	0.269	0.338	0.249	0.267
	120	0.322	0.326	0.350	0.315	0.326	0.313	0.340	0.297	0.312

Plot No.	Depth in	Moisture Content (g)

Plot No.	Depth in cm	Moisture Content (g)								
		30/4/74	13/5/74	27/5/74	10/6/74	24/6/74	8/7/74	22/7/74	19/8/74	3/9/74
6	30	0.216	0.189	0.159	0.208	0.191	0.216	0.223	0.171	0.217
	60	0.211	0.207	0.193	0.215	0.211	0.215	0.226	0.203	0.221
	90	0.258	0.237	0.230	0.231	0.248	0.243	0.245	0.232	0,249
	120	0.321	0.316	0.306	0.307	0.319	0.317	0.321	0.283	0.325
7	30	0.201	0.168	0.147	0.194	0.184	0.190	0.197	0.161	0.186
	60	0.210	0.089	0.184	0.197	0.207	0.211	0.218	0.188	0.205
	90	0.284	0.276	0.276	0.279	0.283	0.285	0.286	0.269	0.281
	120	0.325	0.316	0.317	0.316	0.329	0.327	0.332	0.318	0.319
8	30	0.206	0.182	0.156	0.204	0.198	0.209	0.217	0.189	0.208
	60	0.277	0.243	0.252	0.254	0.268	0.268	0.269	0.254	0.258
	90	0.284	0.275	0.278	0.272	0.275	0.277	0.286	0.268	0.279
	120	0.325	0.297	0.298	0.290	0.311	0.307	0.314	0.303	0.300
9	30	0.182	0.158	0.127	0.179	0.175	0.189	0.196	0.153	0.182
	60	0.221	0.209	0.195	0.211	0.220	0.222	0.228	0.199	0.221
	90	0.293	0.271	0.263	0.263	0.285	0.290	0.285	0.267	0.279
	120	0.329	0.320	0.313	0.313	0.332	0.315	0.335	0.311	0.327
10	30	0.133	0.136	0.110	0.145	0.138	0.166	0.175	0.137	0.171
	60	0.149	0.176	0.171	0.158	0.186	0.206	0.207	0.185	0.223
	90	0.194	0.238	0.196	0.191	0.194	0.204	0.215	0.213	0.227
	120	0.251	0.221	0.227	0.226	0.232	0.244	0.232	0.244	0.253

Plot No.	Depth in	Moisture Content (g)								
	cm	30/4/74	13/5/74	27/5/74	10/6/74	24/6/74	8/7/74	22/7/74	19/8/74	3/9/74
11	30	0.096	0.073	0.048	0.072	0.069	0.088	0.093	0.049	0.076
	60	0.211	0.197	0.187	0.186	0.207	0.213	0.212	0.190	0.202
	90	0.252	0.243	0.243	0.245	0.249	0.247	0.251	0.245	0.246
	120	0.259	0.233	0.235	0.238	0.246	0.254	0.251	0.249	0.247
12	30	0.123	0.113	0.082	0.126	0.102	0.126	0.126	0.090	0.121
	60	0.207	0.207	0.207	0.212	0.210	0.213	0.212	0.160	0.215
	90	0.213	0.219	0.222	0.225	0.223	0.220	0.222	0.227	0.224
	120	0.241	0.237	0.241	0.241	0.236	0.242	0.239	0.243	0.241
13	30	0.088	0.074	0.039	0.087	0.079	0.090	0.102	0.064	0.090
	60	0.219	0.201	0.194	0.208	0.211	0.212	0.216	0.203	0.217
	90	0.228	0.225	0.219	0.229	0.225	0.227	0.230	0.219	0.227
	120	0.238	0.241	0.242	0.246	0.251	0.251	0.256	0.241	0.250
14	30	0.090	0.063	0.036	0.071	0.064	0.085	0.081	0.061	0.072
	60	0.197	0.184	0.177	0.187	0.191	0.199	0.199	0.180	0.186
	90	0.220	0.219	0.214	0.218	0.220	0.223	0.225	0.210	0.213
	120	0.226	0.218	0.215	0.217	0.217	0.221	0.223	0.212	0.214
15	30	0.072	0.052	0.022	0.061	0.053	0.068	0.075	0.041	0.072
	60	0.153	0.130	0.118	0.135	0.139	0.145	0.150	0.126	0.141
	90	0.216	0.208	0.205	0.208	0.215	0.210	0.211	0.208	0.215
	120	0.237	0.231	0.227	0.232	0.235	0.232	0.234	0.231	0.231

Plot No.	Depth in	Moisture Content (g)

Plot No.	Depth in	Moisture Content (g)								
	cm	30/4/74	13/5/74	27/5/74	10/6/74	24/6/74	8/7/74	22/7/74	19/8/74	3/9/74
16	30	0.079	0.103	0.028	0.075	0.058	0.081	0.088	0.040	0.077
	60	0.119	0.099	0.086	0.102	0.103	0.114	0.123	0.092	0.111
	90	0.147	0.161	0.149	0.153	0.163	0.164	0.171	0.153	0.158
	120	0.251	0.244	0.233	0.237	0.244	0.244	0.249	0.236	0.238
17	30	0.120	0.109	0.075	0.120	0.109	0.124	0.137	0.087	0.129
	60	0.181	0.176	0.171	0.184	0.179	0.184	0.185	0.171	0.186
	90	0.208	0.204	0.209	0.207	0.204	0.213	0.209	0.202	0.211
	120	0.225	0.228	0.226	0.224	0.227	0.234	0.231	0.221	0.234
18	30	0.055	0.045	0.024	0.042	0.038	0.050	0.050	0.033	0.047
	60	0.064	0.055	0.049	0.056	0.058	0.062	0.065	0.055	0.061
	90	0.105	0.098	0.095	0.096	0.100	0.102	0.102	0.100	0.101
	120	0.125	0.121	0.119	0.119	0.124	0.123	0.121	0.123	0.123
19	30	0.073	0.069	0.052	0.076	0.072	0.077	0.079	0.064	0.078
	60	0.099	0.090	0.090	0.096	0.096	0.098	0.101	0.092	0.095
	90	0.126	0.122	0.121	0.123	0.126	0.128	0.125	0.121	0.123
	120	0.134	0.134	0.135	0.136	0.136	0.137	0.136	0.134	0.135
20	30	0.050	0.041	0.024	0.041	0.033	0.052	0.057	0.041	0.056
	60	0.076	0.065	0.063	0.069	0.068	0.072	0.075	0.065	0.071
	90	0.130	0.128	0.128	0.127	0.130	0.129	0.131	0.127	0.107
	120	0.138	0.137	0.137	0.134	0.137	0.136	0.136	0.131	0.137

Plot No.	Depth in	Moisture Content (g)								
	cm	30/4/74	13/5/74	27/5/74	10/6/74	24/6/74	8/7/74	22/7/74	19/8/74	3/9/74
21	30	0.057	0.047	0.029	0.051	0.047	0.055	0.055	0.034	0.052
	60	0.097	0.094	0.091	0.096	0.097	0.098	0.100	0.087	0.098
	90	0.131	0.128	0.125	0.127	0.130	0.130	0.129	0.124	0.126
	120	0.137	0.135	0.137	0.134	0.135	0.137	0.137	0.131	0.135
22	30	0.097	0.090	0.076	0.094	0.093	0.094	0.100	0.078	0.094
	60	0.112	0.111	0.108	0.115	0.115	0.113	0.117	0.105	0.113
	90	0.123	0.117	0.117	0.122	0.122	0.122	0.126	0.117	0.125
	120	0.135	0.130	0.132	0.134	0.136	0.134	0.137	0.129	0.134
23	30	0.074	0.060	0.046	0.061	0.056	0.067	0.073	0.053	0.071
	60	0.112	0.107	0.104	0.110	0.111	0.111	0.110	0.105	0.111
	90	0.130	0.129	0.128	0.130	0.130	0.130	0.130	0.126	0.131
	120	0.138	0.138	0.139	0.138	0.138	0.138	0.138	0.137	0.141
24	30	0.064	0.051	0.040	0.052	0.049	0.060	0.063	0.042	0.059
	60	0.106	0.101	0.099	0.104	0.102	0.107	0.109	0.096	0.104
	90	0.117	0.125	0.124	0.126	0.123	0.127	0.130	0.122	0.126
	120	0.123	0.130	0.130	0.133	0.131	0.137	0.137	0.130	0.134

Printed at IITA, Ibadan Nigeria

Printed at IITA, Ibadan Nigeria