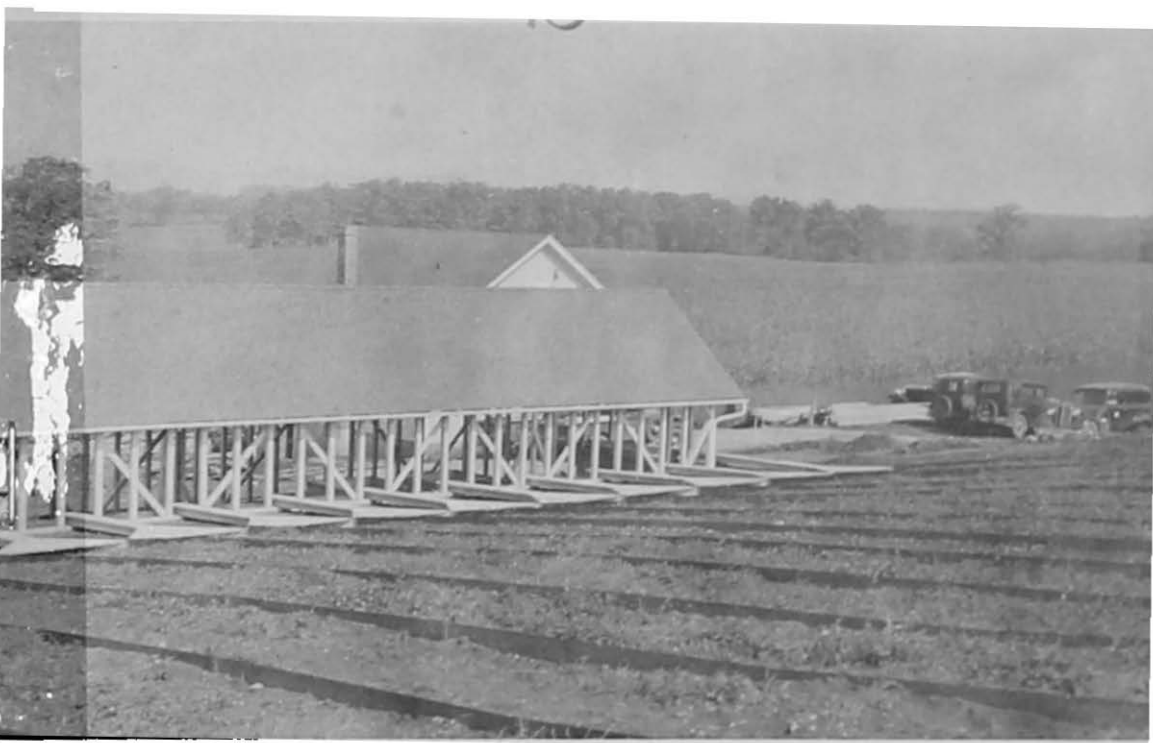


# SOIL EROSION

Experiments at State College, Pennsylvania



Control plots at the Soil Conservation Experiment Station at State College, Pa.

The Pennsylvania State College  
SCHOOL OF AGRICULTURE  
1 Experiment Station, State College, Pa.  
in co-operation with  
Soil Conservation Service, U. S. D. A.

## SUMMARY

1. Total annual rainfall exerts only a minor influence on soil and water losses. Distribution and intensity of individual storms are much more significant.

2. Rainfall intensities are at a maximum during the summer months and it is during this period that the soil usually is least protected.

3. As a rule the longer slopes lose more soil and less water than the shorter slopes. One explanation for this condition is that water, in moving over a larger area, has a greater opportunity to be taken up by the soil but more soil is removed by the scouring action.

4. The critical erosion period for pastures or hay fields is during the time that the new planting is becoming established on thoroughly fitted land. This indicates the need for companion crops or a modified amount of fitting in which the soil is not too thoroughly worked and smoothed.

5. Cultivated and grain crops are erosive, and in planning rotations consideration should be given to the use of grasses and legumes for periods longer than one year, or in shortening the rotation so that a sod crop occupies the land at more frequent intervals.

6. On bare fallow land the greatest soil losses occur during midsummer, the period of highest intensities. Uncropped land may not be excessively erodible if the natural cover of grass and weeds is undisturbed.

7. On severely eroded soil the use of adequate fertilizers to produce heavier covers is important. Also the use of manure will improve the physical condition of the soil, thus increasing permeability and lowering soil and water losses.

8. Contour strip cropping is the "backbone" of conservation planning and in its use the proper width of strips should be carefully determined in accordance with soil type, slope, rotation, and the farming system. Strips which are too narrow will not furnish adequate protection.

9. The direction of cultivation has a great influence on soil and water losses. If cultivation is off the contour, the channels formed by the cultivator shovels greatly increase the flow and velocity of rain water and gullies are rapidly formed and enlarged.

# Soil Erosion Experiments

At State College, Pennsylvania\*

NOLAN F. FARRIS†

THE SOIL CONSERVATION Experiment Station at State College, Pa., was established in 1934 as a cooperative project between the Pennsylvania Agricultural Experiment Station and the Soil Conservation Service, United States Department of Agriculture. Construction of the plots and buildings and installation of the measuring equipment was completed in 1935 and the first runoff records were made in June of that year. The 1935 records are not included in this report since the plots were not completely established and a full year's data were not obtained.

The work reported herein was conducted in cooperation with the Department of Agronomy of The Pennsylvania State College. Two previous publications reported runoff experiments in apple orchards (in cooperation with the Department of Horticulture)<sup>1</sup> and soil and water losses from various corn cover crops.<sup>2</sup>

The results of these experiments are applicable to the limestone soils of central and eastern Pennsylvania.

## PLOT ARRANGEMENT AND EXPERIMENTAL METHODS

The Soil Conservation Experiment Station is located on the College Farms, 2 miles north of the campus. The soil is Hagerstown silty clay loam, and the slope of the area on which the plots are located varies from 8 to 15 per cent.

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\* Authorized for publication, March 2, 1948. This project was conducted jointly by the Pennsylvania Agricultural Experiment Station and the Division of Research of the Soil Conservation Service, U.S.D.A.

† Formerly Project Supervisor, Soil Conservation Experiment Station, and now Experiment Station Administrator, Office of Experiment Stations, U.S.D.A.

<sup>1</sup> Anthony, R. D., Nolan F. Farris, and W. S. Clarke, Jr. 1947. Effects of Certain Cultural Treatments on Orchard Soil and Water Losses and on Apple Tree Growth. *Pennsylvania Agricultural Experiment Station Bulletin 493*.

<sup>2</sup> Farris, Nolan F., 1947. Cover Crops Most Effective in Holding Soil and Water from Fall to Spring. *Supplement 1 to Pennsylvania Agricultural Experiment Station Bulletin 488*, pp. 6-7.

**Acknowledgment.** — The author wishes to express his appreciation to various staff members of the Pennsylvania Agricultural Experiment Station for their assistance in the planning and execution of these studies. F. G. Merkle, professor of soil technology, was Project Leader for these cooperative studies and his assistance and helpful criticism is greatly appreciated.

Earl B. Kinter was Project Supervisor of the Soil Conservation Experiment Station during the author's absence in military service, June, 1941, to February, 1946, and credit is acknowledged for his direction of the work during that period.

Two types of plots were used in these experiments. Fourteen control plots were established; and studies on these plots included effects of length of slope, rotations, fallowing, permanent sods, and soil rebuilding practices. The plots were 6 feet wide and varied in length from 36.5 to 145 feet. They were separated by heavy-gage metal strips set 16 inches deep. The lower end of each plot was provided with a metal flume leading to a tank housed in a building.

The other plots were 21 feet wide and varied in size from one-tenth to one-seventh acre. These plots were equipped with silt boxes, metal tanks, and Geib multiple-slot divisors. The purpose of the divisors was to split the runoff into a number of equal parts, only one of which was conducted to the collecting tank. This system eliminated the necessity of measuring the entire runoff from a plot.

Measurements of soil and water losses were made after each rain producing runoff. The runoff material was thoroughly stirred and sampled and then weighed. Each sample was evaporated to dryness in the laboratory and the percentage of dry soil was determined. This figure was then used to calculate the total amount of soil in the runoff. Runoff data are expressed in pounds or tons of soil per acre, in inches of water, or in percentages of the total precipitation.

## PRECIPITATION INVESTIGATIONS

Since soil erosion in Pennsylvania is caused largely by rainfall, it is necessary to have an adequate knowledge of the characteristics of the annual precipitation in order to interpret the runoff and erosion data. Total rainfall has only a minor influence on erosion, while intensity of individual storms and distribution throughout the year are much more important in analyzing soil and water losses.

*Total Rainfall.*—During the 10-year period, 1936-45, the total annual precipitation averaged 37.63 inches, with the lowest amount, 30.15 inches, occurring in 1941, and the highest, 44.22 inches, in 1945. The 10-year average was 1.20 inches less than the 61-year average of the Weather Bureau Station in State College, table I, fig. I.

Study of the State College records shows that the number of years with rainfall greater than average is higher than the number with less than average.

Figure 2 shows the average accumulated rainfall at the station for the period 1936-45 as compared with the 61-year long-time record. While slightly less than the longer record, the station record closely parallels the 61-year record; and both show a rather uniform distribution from month to month.

Table I.—Monthly, seasonal, and yearly precipitation, 1936-45, and the 61-year normal for these periods.

| MONTH     | 1936      | 1937      | 1938      | 1939      | 1940      | 1941      | 1942      | 1943      | 1944      | 1945      | AVER-<br>AGE | NOR-<br>MAL* |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--------------|--------------|
|           | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i> | <i>in</i>    | <i>in</i>    |
| March     | 8.51      | 1.40      | 3.10      | 3.78      | 4.56      | 1.62      | 6.93      | 2.44      | 4.70      | 4.46      | 4.15         | 3.36         |
| April     | 2.68      | 6.37      | 2.54      | 2.98      | 4.52      | 1.56      | 1.78      | 4.79      | 3.66      | 4.31      | 3.52         | 3.44         |
| May       | 1.99      | 2.36      | 3.05      | 2.79      | 4.02      | 1.50      | 6.21      | 4.07      | 8.05      | 5.94      | 4.00         | 4.05         |
| Total     | 13.18     | 10.13     | 8.69      | 9.55      | 13.10     | 4.68      | 14.92     | 11.30     | 16.41     | 14.71     | 11.67        | 10.85        |
| June      | 4.42      | 1.91      | 3.91      | 4.71      | 2.89      | 3.80      | 3.85      | 1.43      | 5.65      | 2.89      | 3.55         | 4.09         |
| July      | 3.14      | 3.59      | 4.35      | 3.18      | 3.06      | 4.49      | 3.44      | 4.36      | 2.29      | 3.11      | 3.50         | 3.85         |
| August    | 5.40      | 5.29      | 1.05      | 2.22      | 2.51      | 4.44      | 3.45      | 3.80      | 1.76      | 3.10      | 3.30         | 3.47         |
| Total     | 12.96     | 10.84     | 9.31      | 10.11     | 8.46      | 12.73     | 10.74     | 9.59      | 9.70      | 9.10      | 10.35        | 11.41        |
| September | 2.02      | 1.44      | 2.70      | 3.04      | 4.09      | 1.56      | 3.31      | 0.23      | 2.36      | 5.18      | 2.59         | 3.02         |
| October   | 4.80      | 5.97      | 0.92      | 3.29      | 0.99      | 1.88      | 3.21      | 4.82      | 3.07      | 2.34      | 3.13         | 2.92         |
| November  | 2.11      | 1.73      | 2.35      | 1.24      | 3.91      | 2.71      | 2.76      | 2.27      | 1.64      | 5.86      | 2.66         | 2.50         |
| Total     | 8.93      | 9.14      | 5.97      | 7.57      | 8.99      | 6.15      | 9.28      | 7.32      | 7.07      | 13.38     | 8.38         | 8.44         |
| December  | 3.62      | 2.94      | 2.23      | 0.93      | 2.35      | 4.03      | 5.15      | 1.04      | 3.03      | 2.52      | 2.78         | 2.65         |
| January   | 3.27      | 4.77      | 2.93      | 2.87      | 1.13      | 2.32      | 1.71      | 2.56      | 2.14      | 2.17      | 2.59         | 2.91         |
| February  | 1.89      | 2.05      | 2.17      | 3.49      | 2.24      | 0.24      | 1.73      | 0.98      | 1.42      | 2.34      | 1.86         | 2.57         |
| Total     | 8.78      | 9.76      | 7.33      | 7.29      | 5.72      | 6.59      | 8.59      | 4.58      | 6.59      | 7.03      | 7.23         | 8.13         |
| YEAR      | 43.85     | 39.87     | 31.30     | 34.52     | 36.27     | 30.15     | 43.53     | 32.79     | 39.77     | 44.22     | 37.63        | 38.83        |

\* From records of U. S. Weather Bureau, State College, Pa.

*Seasonal Distribution.*—Table 1 shows that there is a fairly uniform distribution of rainfall throughout the year and that, contrary to popular belief, there is no deficiency of rainfall during the summer season. It is recognized that there may be drought periods in certain years but, on the average, there is a greater amount of rainfall during the spring and summer months than during the fall and winter.

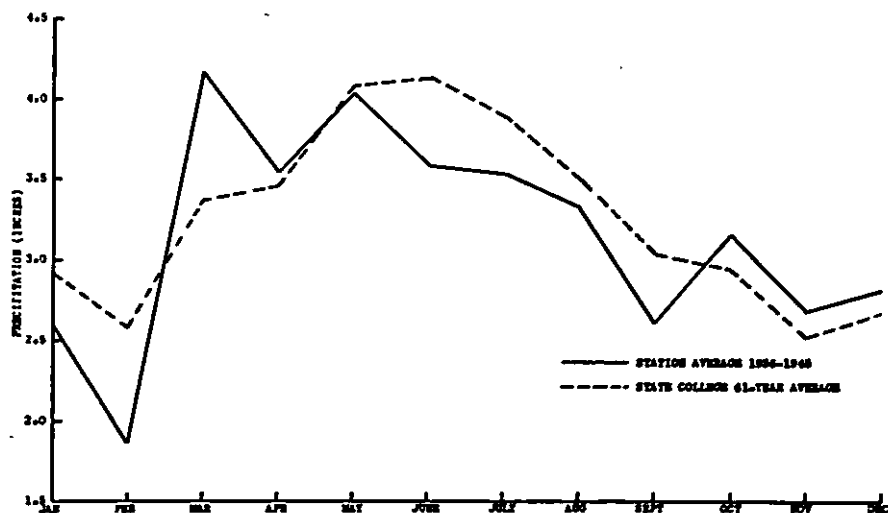


Fig. 1.—Average annual precipitation at the Soil Conservation Experiment Station, 1936-45, compared with the 61-year average at State College.

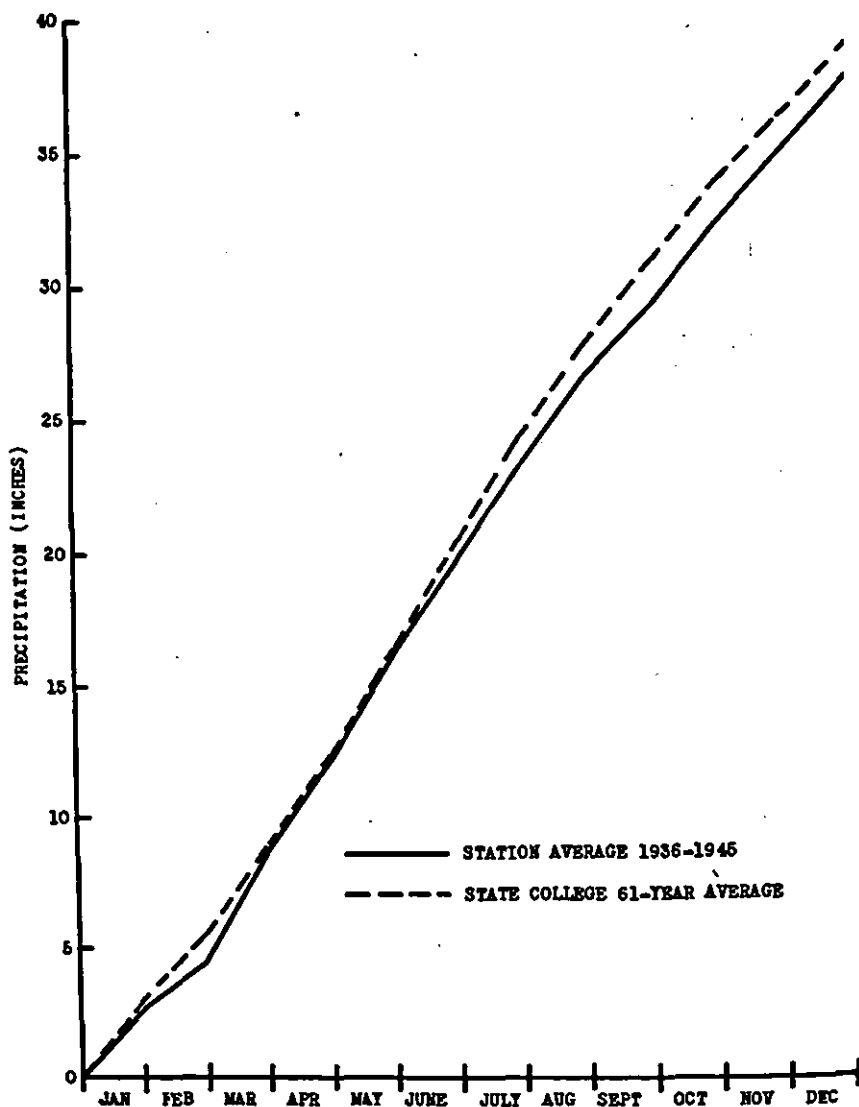


Fig. 2.—Average annual accumulated rainfall at the Soil Conservation Experiment Station, 1936-45, and the normal rainfall for the 61-year period.

This suggests that, during the active growing season, crops do not suffer so much from a lack of rainfall as from the inability of the soil to catch and hold moisture. This is due to more intense rains during the summer and to unfavorable physical condition of the soil.

*Intensity of Precipitation.*—Rainfall intensity is the rate of rainfall, in inches per hour, during a certain period. Maximum intensity is usually expressed as the highest rate per hour during a 5-minute period.

Throughout Pennsylvania low intensities usually prevail during the fall and winter months. On the other hand, during the spring and summer seasons rainfall occurs largely as local thunderstorms with quite high intensities. It is during this period that high soil and water losses occur and these losses are accelerated on unprotected soils and on soils having poor physical condition. Table 2 gives the number of rains that exceeded the expected intensities during the period 1936-45. These figures show the local nature of high intensity rains. Gage 5 was located at the station on a 13 per cent northwest slope while gage 7 was located a mile east of the station on a longer, 20 per cent southeast slope. It is apparent that high intensity rains occurred more frequently at the latter location.

Table 2.—Expected frequency of various amounts and intensities of rainfall\* and number of rains at the station that exceeded expected intensities during short periods, 1936-45.

| 5-minute period    |                   |                    |  |                |
|--------------------|-------------------|--------------------|--|----------------|
| FREQUENCY PERIOD** | EXPECTED RAINFALL | EXPECTED INTENSITY | NO. OF RAINS EXCEEDING EXPECTED INTENSITY*** |                |
| <i>years</i>       | <i>inches</i>     | <i>in./hr.</i>     | <i>Gage #5</i>                               | <i>Gage #7</i> |
| 2                  | .40               | 4.80               | 3  | 8              |
| 5                  | .46               | 5.52               | 1  | 5              |
| 10                 | .51               | 6.12               | 0  | 2              |
| 25                 | .57               | 6.84               | 0  | 1              |
| 50                 | .60               | 7.20               | 0  | 1              |
| 100                | .66               | 7.92               | 0  | 0              |
| 15-minute period   |                   |                    |  |                |
| FREQUENCY PERIOD** | EXPECTED RAINFALL | EXPECTED INTENSITY | NO. OF RAINS EXCEEDING EXPECTED INTENSITY*** |                |
| <i>years</i>       | <i>inches</i>     | <i>in./hr.</i>     | <i>Gage #5</i>                               | <i>Gage #7</i> |
| 2                  | .77               | 3.08               | 2  | 3              |
| 5                  | .95               | 3.80               | 0  | 2              |
| 10                 | 1.12              | 4.48               | 0  | 1              |
| 25                 | 1.25              | 5.00               | 0  | 0              |
| 50                 | 1.49              | 5.96               | 0  | 0              |
| 100                | 1.56              | 6.24               | 0  | 0              |
| 30-minute period   |                   |                    |  |                |
| FREQUENCY PERIOD** | EXPECTED RAINFALL | EXPECTED INTENSITY | NO. OF RAINS EXCEEDING EXPECTED INTENSITY*** |                |
| <i>years</i>       | <i>inches</i>     | <i>in./hr.</i>     | <i>Gage #5</i>                               | <i>Gage #7</i> |
| 2                  | 1.02              | 2.04               | 2  | 2              |
| 5                  | 1.30              | 2.60               | 0  | 1              |
| 10                 | 1.60              | 3.20               | 0  | 0              |
| 25                 | 1.87              | 3.74               | 0  | 0              |
| 50                 | 2.12              | 4.24               | 0  | 0              |
| 100                | 2.30              | 4.60               | 0  | 0              |

\* Data compiled from Yarnells Rainfall Intensity-Frequency Data, U.S.D.A. Misc. Pub. No. 204.

\*\* The frequency period represents the time during which a rain is expected to occur once.

\*\*\* Gage #5 was located at the station and gage #7 was located one mile east of the station

Figure 3 shows the trend of rainfall intensity from month to month. Intensity increases steadily until June, and a decrease which occurs during July is followed by a sharp rise during August. The remaining months of the year show progressively fewer rains with high intensities.

Figure 4 shows the effect of high intensity rains on soil and water losses. Water losses are more or less uniform throughout the year, but most of the soil losses occur during two or three rains of high intensity.

### CONTROL PLOT STUDIES

Table 3 gives the lay-out and treatment of the 14 control plots, and figure 5 summarizes the average annual soil and water losses from these plots.

*Length of Slope Studies.*—Control plots 1, 2, and 4 were used in studying the effects of length of slope on soil and water losses. All were 6 feet wide and plot 1 was 36.3 feet long, plot 2 was 72.6 feet, and plot 4 was 145.2 feet long. The areas were thus one-two hundredth, one-hundredth, and one-fiftieth acre respectively. A 4-year rotation (corn, oats, wheat, hay) was used on them all.

Table 4 gives the annual soil and water losses from these plots. While the losses were not consistent from year to year, the general trend was an increase in soil loss and decrease in water loss as the slope length increased. It would appear that rainfall intensity and permeability of the soil are more important than soil cover. This is evident in comparing data for 1937 and 1941. Wheat was grown in both of these years; and there was 9.72 inches more rain in 1937

Table 3.—Control plot lay-out and cropping system,  
Soil Conservation Experiment Station, 1936-41

| Plot No.* | LENGTH      | SLOPE           | SOIL TREATMENT        | CROPPING SYSTEM                          |
|-----------|-------------|-----------------|-----------------------|--|
|           | <i>feet</i> | <i>per cent</i> |                       |  |
| 1         | 36.3        | 15.2            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 2         | 72.6        | 13.5            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 3         | 72.6        | 13.5            | Fertilizer            | Permanent bluegrass—white clover sod     |
| 4         | 145.2       | 12.8            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 5         | 145.2       | 12.8            | Fertilizer            | Permanent bluegrass—white clover sod     |
| 6         | 72.6        | 13.6            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 7         | 72.6        | 13.6            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 8         | 72.6        | 13.4            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 9         | 72.6        | 13.2            | Fertilizer and manure | 4-year rotation (corn, oats, wheat, hay) |
| 10        | 72.6        | 13.4            | No treatment          | Bare fallow                              |
| 11        | 72.6        | 13.5            | No treatment          | Fallow, weeds allowed to grow            |
| 12        | 72.6        | 13.3            | Fertilizer            | Permanent alfalfa                        |
| 13        | 72.6        | 13.1            | No treatment          | Top soil removed, continuous corn        |
| 14        | 72.6        | 13.0            | Fertilizer and manure | Top soil removed, continuous corn        |

\* Plot 1 was 1/200-acre, plots 4 and 5 were 1/50-acres and all other plots were 1/100-acre. Plots 3 and 5 were in permanent bluegrass-white clover sod.



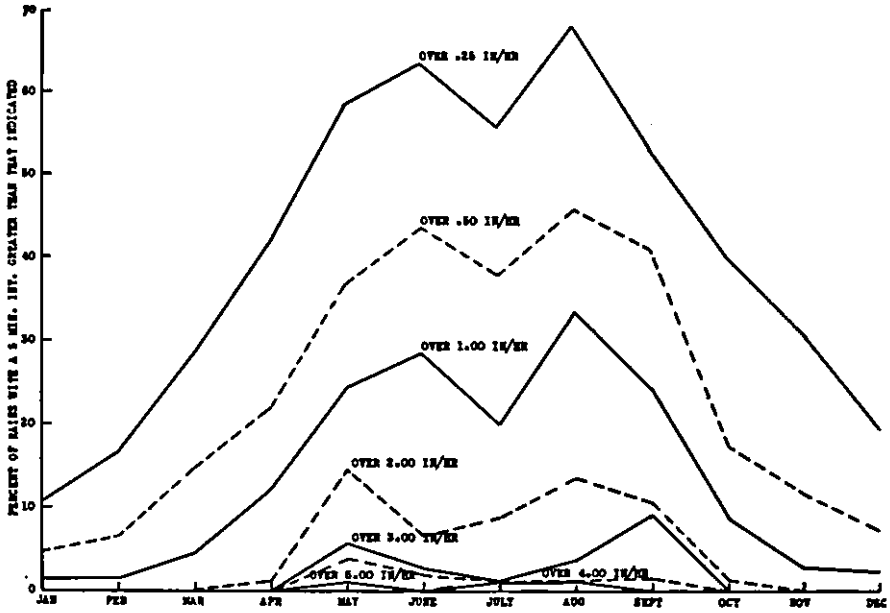


Fig. 3.—Percentages of total monthly precipitation, 1936-45, falling at rates equal to or greater than selected intensities.

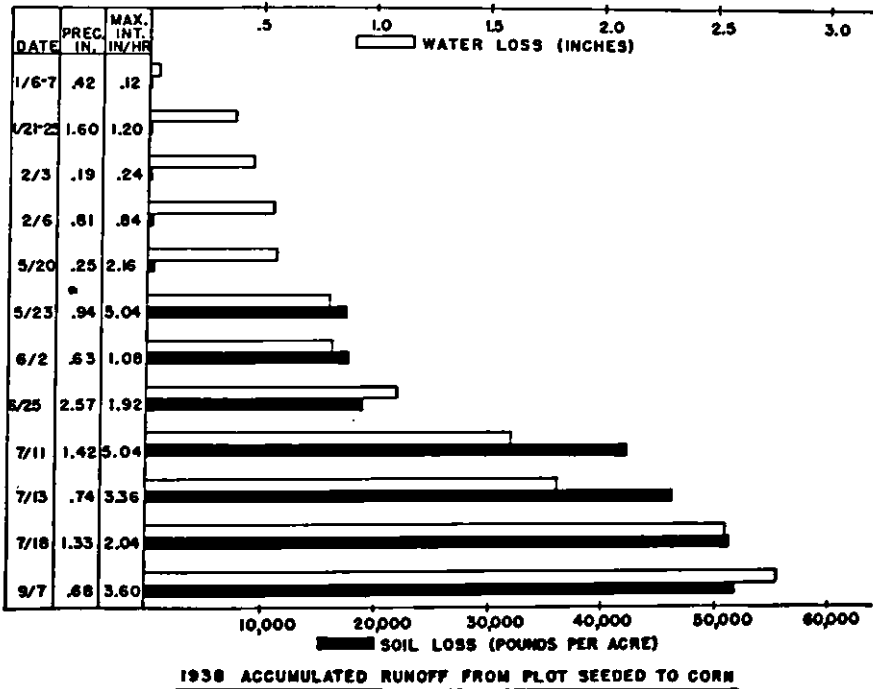


Fig. 4.—Effect of high intensity rains on soil and water losses from a plot seeded to corn.

Table 4.—Annual soil and water losses from plots of different lengths, 1936-41

| YEAR    | CROP  | RAINFALL      | PLOT 1, SHORT   |              | PLOT 2, STANDARD† |              | PLOT 4, LONG‡   |              |
|---------|-------|---------------|-----------------|--------------|-------------------|--------------|-----------------|--------------|
|         |       |               | RUNOFF          | SOIL LOSS    | RUNOFF            | SOIL LOSS    | RUNOFF          | SOIL LOSS    |
|         |       | <i>inches</i> | <i>per cent</i> | <i>lb./A</i> | <i>per cent</i>   | <i>lb./A</i> | <i>per cent</i> | <i>lb./A</i> |
| 1936    | Oats  | 43.85         | 4.36            | 10,750       | 5.52              | 21,440       | 3.42            | 15,435       |
| 1937    | Wheat | 39.87         | 2.18            | 784          | 1.43              | 211          | 0.73            | 97           |
| 1938    | Hay   | 31.30         | 1.47            | 0            | 0.61              | 0            | 0.26            | 0            |
| 1939    | Corn  | 34.52         | 4.61            | 34,182       | 4.92              | 38,876       | 4.03            | 35,749       |
| 1940    | Oats  | 36.27         | 10.20           | 5,454        | 5.21              | 4,599        | 6.45            | 6,990        |
| 1941    | Wheat | 30.15         | 4.88            | 1,396        | 4.31              | 2,076        | 4.91            | 2,435        |
| Average |       | 35.99         | 4.64            | 8,761        | 3.72              | 11,200       | 3.28            | 10,118       |

\* Length 36.3 feet    † Length 72.6 feet    ‡ Length 145.2 feet

than in 1941, but both soil and water losses were much less on all plots in 1937. This condition must be attributed to higher amounts of rainfall and greater intensities during the summer season in 1941.

The decrease in runoff on the longer plots probably was due to the fact that in moving over a longer distance the flowing water had a greater opportunity to infiltrate into the soil, while on the shorter plot water ran off the plot before it could be absorbed by the soil. The increase in soil loss on the longer plots may have been due to the increased scouring action of the water as it moved down the slope.

From a practical standpoint, the above data and information show the need for such conservation practices as strip-cropping, terracing, and the use of sod crops. If these plots are regarded as 6-foot segments from actual field strips, the data form the basis for the development of soil and water conserving practices under actual field conditions.

*Effects of Permanent Sod.*—Control plots 3 and 5 were seeded to a permanent mixture consisting of Kentucky bluegrass, red top, timothy, red clover, alsike clover, and white clover. After the second year the stand was predominately bluegrass and white clover. Plot 12 was seeded to alfalfa in 1935.

Figure 5 indicates that there were moderate soil and water losses from the grass plots; but over 99 per cent of the soil loss occurred in 1936, the year in which the plots were seeded. The spring seeding was a failure due to dry weather and intense rains during the summer, and the plots were reseeded in the fall. While water losses were highest in 1936, there was a fairly high runoff in succeeding years. Nearly all of this runoff occurred during the late winter and early spring when the snow cover melted. At this time the soil was still frozen and the grass prevented infiltration because of the "shingling" effect.

The alfalfa plot lost very little soil or water and, again, most of the soil was lost in 1936 and 1937 when the stand was becoming

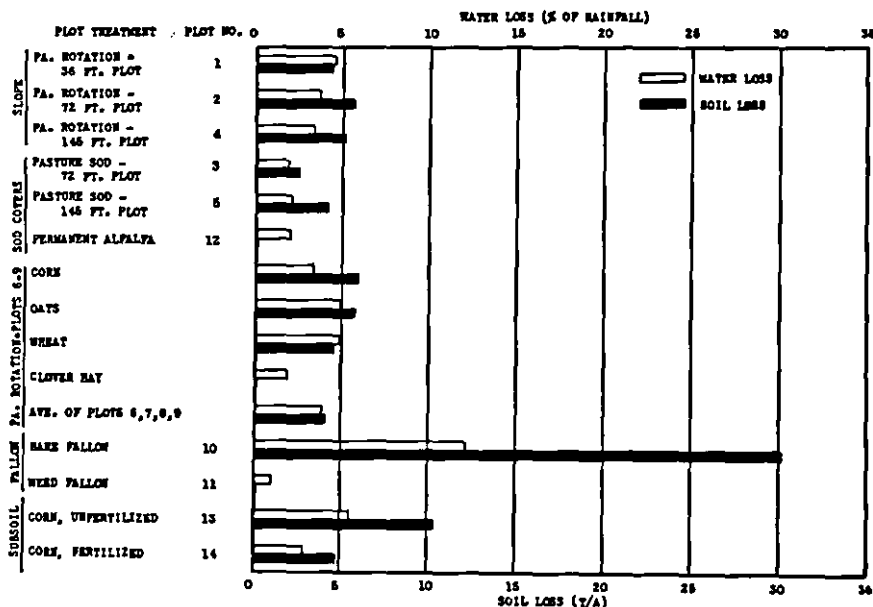


Fig. 5.—Average annual soil and water losses from control plots, 1936-41.

established. Water losses were highest during the late winter and early spring months due to melting snow and ice.

The above information shows that, when sod crops are grown, dangers of erosion are greatest during the time the seed-bed is prepared and the sod is becoming established. This is especially true when the land has been thoroughly worked; therefore, consideration should be given to seeding on a partially fitted seed-bed.

*Crop Rotation Studies.*—Control plots 6 to 9 were used in the study of a 4-year rotation (corn, oats, wheat, and clover hay). By using four plots, each crop of the rotation was represented each year thus eliminating differences due to varying amounts of rainfall and intensities from year to year and month to month.

Table 5 gives the average rainfall and soil and water losses for the periods during which each crop occupied the soil. On the average, corn was on the land from May to the following April, oats from May through September, wheat from October through the following June, and hay from July through the remainder of the four years.

If only the time which an individual crop occupies the soil is considered, oats is the most erosive crop of the rotation. However, oats is sown, completes its growth, and is harvested during the season

Table 5.—Average rainfall, soil and water losses from different crops in a 4-year rotation, May 1936 to April 1942

| CROP  | MONTHS | AVERAGE<br>RAINFALL FOR<br>PERIOD | PERCENTAGE<br>OF TOTAL<br>RAINFALL | SOIL LOSS |                        | WATER LOSS |                        |
|-------|--------|-----------------------------------|------------------------------------|-----------|------------------------|------------|------------------------|
|       |        |                                   |                                    | Tons/A    | Percentage<br>of Total | Inches     | Percentage<br>of Total |
|       |        | <i>inches</i>                     |                                    |           |                        |            |                        |
| Corn  | 12     | 35.29                             | 24.82                              | 6.40      | 39.98                  | 1.45       | 2.80                   |
| Oats  | 5      | 15.83                             | 11.13                              | 5.02      | 31.35                  | 1.01       | 17.97                  |
| Wheat | 9      | 26.38                             | 18.55                              | 3.49      | 21.80                  | 1.13       | 20.11                  |
| Hay   | 22     | 64.69                             | 45.50                              | 1.10      | 6.87                   | 2.03       | 36.12                  |
| TOTAL | 48     | 142.19                            | 100.00                             | 16.01     | 100.00                 | 5.62       | 100.00                 |

of greatest runoff producing rains. A more accurate picture of the erosiveness of individual crops can be obtained by determining the percentage of total soil and water losses which each crop produces. Thus, corn is on the land during one-fourth of the rotation, receives about one-fourth of the rainfall, and causes about 40 per cent of the soil loss and 26 per cent of the water loss. Oats is on the land only 10 per cent of the time, receives 11 per cent of the rainfall, and causes 31 per cent of the soil loss and 18 per cent of the water loss. On the other hand, hay receives almost half the rainfall during the rotation but accounts for only 17 per cent of the total soil loss. The water loss from hay is about 36 per cent of the total, most of this occurring as late winter and early spring runoff.

Figure 6 shows the soil and water losses from month to month during the 4-year rotation. It will be noted that the critical period for soil loss for corn was during August and September after the corn had completed its growth and cultivation had ceased. This indicates the need of adequate cover crops. With oats the greatest amount of soil was lost during the first month of growth, decreasing as the cover became heavier.

Water losses are quite high during midsummer when corn, oats, and wheat are grown; but the greatest peak is reached in March of every year. This peak is caused largely by melting snow and ice in late winter and early spring.

These data demonstrate the need for maximum use of sod crops in rotations. In short rotations, grass crops should occupy the land at more frequent intervals, and in longer rotations should be grown two or more years. Furthermore, these studies show that in strip-cropping, two or more erosive spring-planted crops such as corn, oats, tobacco, potatoes, and tomatoes should be alternated with less erosive crops such as fall-sown grains or sod.

*Fallowing.*—Control plots 10 and 11 were established as fallow plots for comparison with cropped plots and for studies of rainfall

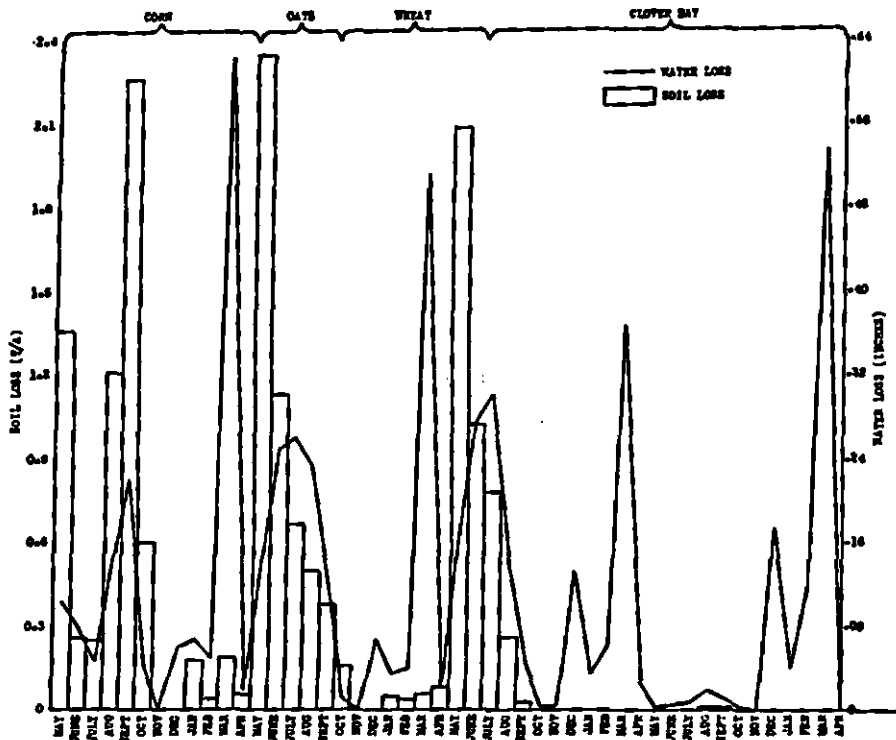


Fig. 6.—Average monthly soil and water losses from a 4-year rotation, May 1936 to April 1942.

characteristics. Plot 10 was kept bare by scraping the weeds off at the ground surface with a hoe, and plot 11 was left undisturbed after the plot was installed. After the first year, plot 11 had a heavy cover of weeds and volunteer grass. It will be seen from figure 5 that this plot lost less soil and water than any of the cropped plots.

Figure 7 shows the average monthly rainfall and soil and water losses from the bare fallow plot. Rainfall was fairly evenly distributed throughout the year, but most of the soil and water losses were confined to the months of March through September, the period of high intensity rains. The high runoff in March was due partly to prolonged rains but mostly to melting snow and ice.

Tables 6 and 7 and figure 8 summarize the data from 49 rains during the period 1936-41 which produced over a half ton of soil loss per acre. This "erosive" rain data shows the characteristics of rainfall from month to month and its effect on unprotected soil. These figures show, again, that the critical period for soil and water losses are the months of May through August. Rainfall is not only at a maximum

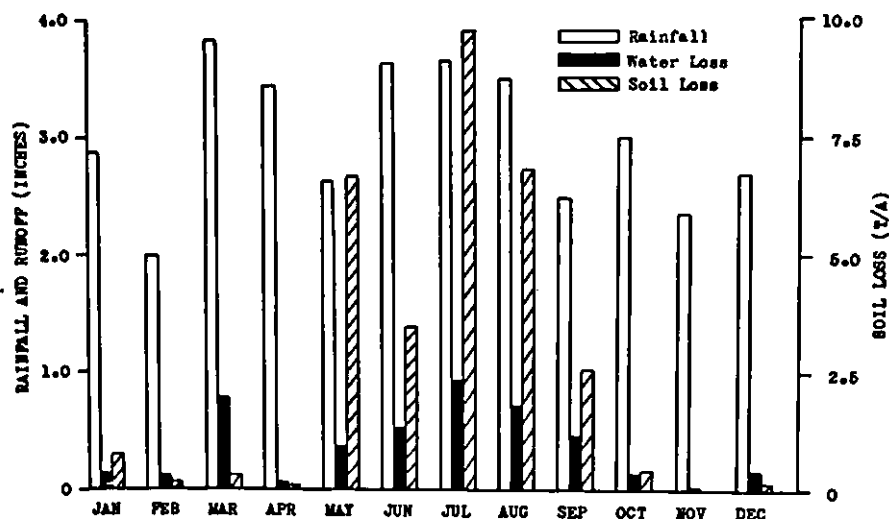


Fig. 7.—Average monthly distribution of rainfall, runoff, and soil loss from bare fallow plot for the 6-year period, 1936-41.

during this period, but there are more erosive rains and intensities are higher.

Of the 49 erosive rains, those having a maximum intensity of 2 to 3 inches per hour produced the greatest percentage of soil and water losses. This class also had the highest number of erosive rains. All but one of these rains occurred during the months of May through August and approximately half occurred in July. Again it should be pointed out that, when cultivated crops are grown, the most destructive rains occur when the soil is least protected.

*Soil Rebuilding Studies.*—In order to determine the effects of manure and fertilizer upon an eroded soil, the surface soil was removed from control plots 13 and 14 at the beginning of the experiment. Both plots were seeded to corn each year, and plot 13 received no fertilizer treatments while plot 14 received an annual application of 300 pounds of superphosphate and 14 tons of manure per acre. It is recognized that continuous corn cropping is not advisable even on an uneroded soil, but the figures given in table 8 show that good fertilizer treatments will materially reduce soil and water losses and increase yields on a soil that has lost all or most of its top soil. Increased organic matter not only assists in improving yields but builds up the soil organic matter content, thus improving the permeability.

Table 6.— Monthly distribution of 49 erosive rains and soil and water losses from bare fallow plot, 1936-41

| MONTH OR ITEM                                      | RAINS CLASSIFIED ACCORDING TO SOIL LOSS |                   |                   |                   |                   |                     |               |                           | RAINFALL        |                     |                                       |                              |       |   |        |
|--|---|-------------------|-------------------|-------------------|-------------------|---------------------|---------------|---------------------------|-----------------|---------------------|---------------------------------------|------------------------------|-------|---|--------|
|  | 0.50 to<br>0.99 T                       | 1.00 to<br>2.49 T | 2.50 to<br>4.99 T | 5.00 to<br>7.49 T | 7.50 to<br>9.99 T | 10.00 to<br>14.99 T | Over<br>15.00 | Total<br>Erosive<br>Rains | Average Amount  |                     | Av. 5-min max int<br>of erosive rains | Runoff from<br>erosive rains |       | Soil loss<br>and annual erosion<br>from erosive rains |        |
|  | No                                      | No                | No                | No                | No                | No                  | No            | No                        | All rains<br>in | Erosive rains<br>in |                                       | in/br                        | in    | per cent  | T/A    |
| January  | 0                                       | 0                 | 1                 | 0                 | 0                 | 0                   | 0             | 1                         | 2.88            | 0.27                | 1.20                                  | 0.09                         | 32.96 | 0.76  | 2.66   |
| February   | 1                                       | 0                 | 0                 | 0                 | 0                 | 0                   | 0             | 1                         | 2.01            | 0.13                | 0.84                                  | 0.02                         | 15.38 | 0.15  | 0.52   |
| March  | 1                                       | 1                 | 0                 | 0                 | 0                 | 0                   | 0             | 2                         | 3.83            | 1.28                | 0.54                                  | 0.54                         | 42.34 | 0.29  | 1.01   |
| April  | 0                                       | 0                 | 0                 | 0                 | 0                 | 0                   | 0             | 0                         | 3.44            | 0                   | 0                                     | 0                            | 0     | 0   | 0      |
| May  | 0                                       | 1                 | 1                 | 1                 | 0                 | 1                   | 1             | 5                         | 2.62            | 0.98                | 3.65                                  | 0.36                         | 36.84 | 6.58  | 22.89  |
| June   | 2                                       | 1                 | 1                 | 1                 | 0                 | 0                   | 0             | 5                         | 3.62            | 0.94                | 2.24                                  | 0.32                         | 34.15 | 2.13  | 7.43   |
| July   | 5                                       | 2                 | 3                 | 3                 | 1                 | 1                   | 0             | 15                        | 3.64            | 2.22                | 2.64                                  | 0.84                         | 37.79 | 9.50  | 33.07  |
| August   | 6                                       | 2                 | 2                 | 0                 | 1                 | 0                   | 1             | 12                        | 3.48            | 1.76                | 2.10                                  | 0.62                         | 34.94 | 6.55  | 22.80  |
| September  | 2                                       | 1                 | 3                 | 0                 | 0                 | 0                   | 0             | 6                         | 2.48            | 1.00                | 3.66                                  | 0.40                         | 40.40 | 2.42  | 8.42   |
| October  | 1                                       | 1                 | 0                 | 0                 | 0                 | 0                   | 0             | 2                         | 2.98            | 0.26                | 1.80                                  | 0.08                         | 32.31 | 0.35  | 1.20   |
| November   | 0                                       | 0                 | 0                 | 0                 | 0                 | 0                   | 0             | 0                         | 2.34            | 0                   | 0                                     | 0                            | 0     | 0   | 0      |
| December   | 0                                       | 0                 | 0                 | 0                 | 0                 | 0                   | 0             | 0                         | 2.68            | 0                   | 0                                     | 0                            | 0     | 0   | 0      |
| TOTAL  | 18                                      | 9                 | 11                | 5                 | 2                 | 2                   | 2             | 49                        | 36.01           | 8.84                | —                                     | 3.28                         | 37.05 | 28.74   | 100.00 |
| Total erosive rainfall in<br>each class (per cent) | 37.85                                   | 16.21             | 21.53             | 10.61             | 2.66              | 6.82                | 4.32          |                           |                 |                     |                                       |                              |       |   |        |
| Average maximum in-<br>tensity for each class      | 1.79                                    | 2.06              | 2.87              | 2.95              | 2.82              | 4.68                | 5.40          |                           |                 |                     |                                       |                              |       |   |        |
| Runoff for each<br>class (per cent)                | 19.10                                   | 26.17             | 23.58             | 12.72             | 4.49              | 8.45                | 5.49          |                           |                 |                     |                                       |                              |       |   |        |
| Soil loss caused by<br>each class (per cent)       | 7.18                                    | 7.90              | 23.22             | 17.71             | 10.27             | 15.57               | 18.15         |                           |                 |                     |                                       |                              |       |   |        |
| Average rainfall per<br>rain (inches)              | 1.12                                    | 0.96              | 1.04              | 1.13              | 0.70              | 1.81                | 1.14          |                           |                 |                     |                                       |                              |       |   |        |
| Average soil loss<br>per rain (T/A)                | 0.69                                    | 1.51              | 3.64              | 6.11              | 8.85              | 13.42               | 15.65         |                           |                 |                     |                                       |                              |       |   |        |
| Average runoff per<br>rain (inches)                | 0.21                                    | 0.57              | 0.42              | 0.50              | 0.44              | 0.83                | 0.54          |                           |                 |                     |                                       |                              |       |   |        |

Table 7.—Monthly distributon of 49 erosive rains and average soil and water loss from bare fallow plot, 1936-41

| RAINS CLASSIFIED ACCORDING TO 5-MINUTE AVERAGE MAXIMUM INTENSITY (in./hr.) |           |           |           |           |           |           |           | AVERAGE MONTHLY RAINFALL IN THE 49 RAINS |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--|
| MONTH OR ITEM  | 0.00-0.99 | 1.00-1.99 | 2.00-2.99 | 3.00-3.99 | 4.00-4.99 | Over 5.00 | Total     |  |
|  | <i>No</i> | <i>No</i> | <i>No</i> | <i>No</i> | <i>No</i> | <i>No</i> | <i>No</i> | <i>inches</i>                            |
| January  | 0         | 1         | 0         | 0         | 0         | 0         | 1         | 0.27                                     |
| February   | 1         | 0         | 0         | 0         | 0         | 0         | 1         | 0.13                                     |
| March  | 2         | 0         | 0         | 0         | 0         | 0         | 2         | 1.28                                     |
| April  | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0  |
| May  | 0         | 0         | 2         | 1         | 1         | 1         | 5         | 0.98                                     |
| June   | 0         | 3         | 1         | 0         | 1         | 0         | 5         | 0.94                                     |
| July   | 0         | 4         | 6         | 4         | 0         | 1         | 15        | 2.22                                     |
| August   | 4         | 3         | 3         | 1         | 0         | 1         | 12        | 1.76                                     |
| September  | 0         | 0         | 0         | 5         | 1         | 0         | 6         | 1.00                                     |
| October  | 1         | 0         | 1         | 0         | 0         | 0         | 2         | 0.26                                     |
| November   | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0  |
| December   | 0         | 0         | 0         | 0         | 0         | 0         | 0         | 0  |
| TOTAL  | 8         | 11        | 13        | 11        | 3         | 3         | 49        | —  |
| Average annual rainfall in each class (inches)                             | 2.06      | 1.47      | 2.43      | 1.46      | 0.81      | 0.61      |           | 8.84                                     |
| Rainfall in each class (per cent)  | 23.32     | 16.59     | 27.46     | 16.53     | 9.14      | 6.96      |           |  |
| Soil loss caused by each class (per cent)                                  | 3.53      | 10.55     | 29.29     | 17.05     | 13.08     | 26.50     |           |  |
| Runoff caused by each class (per cent)                                     | 22.04     | 15.84     | 25.45     | 17.00     | 10.32     | 9.36      |           |  |
| Average rainfall per rain (inches)   | 1.55      | 0.80      | 1.12      | 0.80      | 1.62      | 1.23      |           | 1.08                                     |
| Average soil loss per rain (T/A)   | 0.76      | 1.65      | 3.88      | 2.67      | 7.52      | 15.23     |           | 3.52                                     |
| Average runoff per rain (inches)   | 0.54      | 0.28      | 0.38      | 0.30      | 0.68      | 0.61      |           | 0.40                                     |

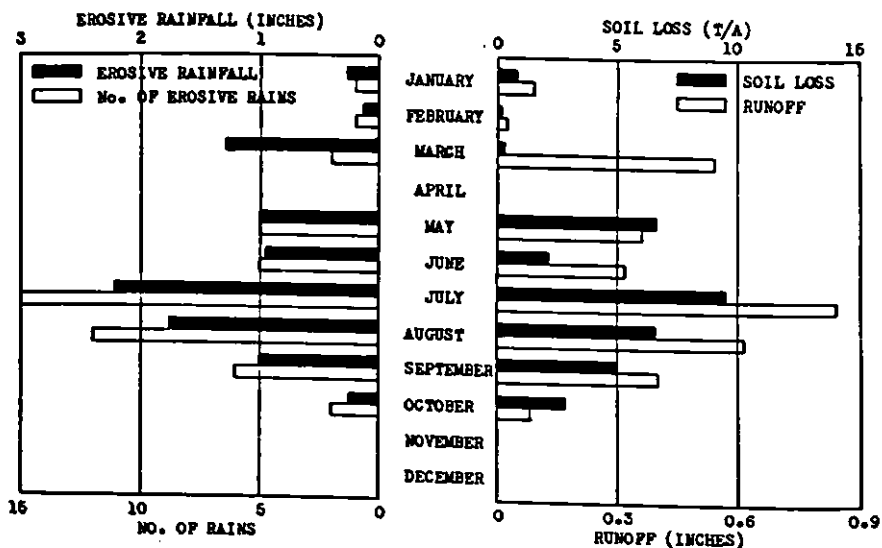


Fig. 8.—Soil and water losses caused by 49 erosive rains on bare fallow plot, 1936-41.



Table 8.— Average annual soil and water losses and yields from desurfaced plots, 1936-41

| PLOT NUMBER | TREATMENT   | SOIL LOSS           | WATER LOSS            | CORN YIELD         |
|-------------|---|---------------------|-----------------------|--------------------|
| 13          | Surface soil removed,<br>continuous corn                            | <i>T/A</i><br>10.29 | <i>inches</i><br>1.99 | <i>T/A</i><br>0.24 |
| 14          | Surface soil removed,<br>continuous corn,<br>manured and fertilized | 4.70                | 0.99                  | 0.77               |

## STRIP CROPPING STUDIES

Breaking up a sloping field into alternate strips of cultivated and noncultivated crops is one of the primary soil and water conserving practices. If these strips are established along the contour, additional protection is afforded. The proper width of such strips is dependent on many factors, among which are degree of slope, crop rotation, soil type, and the farming system.

The strip cropping experiment reported here does not attempt to determine the proper strip width under all circumstances, but it

Table 9.— Soil and water losses from strip cropping plots, 1936-38

| PLOT NUMBER* | STRIP WIDTH | CROP ROTATION**  | YEAR    | RAINFALL      | SOIL LOSS  | WATER LOSS    |                 |
|--------------|-------------|--|---------|---------------|------------|---------------|-----------------|
|              |             |  |         | <i>inches</i> | <i>T/A</i> | <i>inches</i> | <i>per cent</i> |
| 1            | 100         | Corn, hay, wheat<br>Wheat, corn, hay<br>Hay, wheat, corn | 1936    | 43.86         | 2,883      | 0.40          | 0.91            |
|              |             |  | 1937    | 39.51         | 44         | 2.19          | 5.54            |
|              |             |  | 1938    | 31.08         | 128        | 0.65          | 2.09            |
|              |             |  | Average | 38.15         | 1,018      | 1.08          | 2.83            |
|              |             |  |         |               |            |               |                 |
| 2            | 100         | Corn, hay, oats<br>Oats, corn, hay<br>Hay, oats, corn    | 1936    | 43.86         | 8,126      | 0.59          | 1.35            |
|              |             |  | 1937    | 39.51         | 410        | 2.45          | 6.20            |
|              |             |  | 1938    | 31.08         | 801        | 1.09          | 3.51            |
|              |             |  | Average | 38.15         | 3,112      | 1.38          | 3.62            |
|              |             |  |         |               |            |               |                 |
| 3            | 50          | Corn, hay, wheat<br>Wheat, corn, hay<br>Hay, wheat, corn | 1936    | 43.86         | 6,920      | 3.25          | 7.41            |
|              |             |  | 1937    | 39.51         | 71         | 2.05          | 5.19            |
|              |             |  | 1938    | 31.08         | 305        | 0.55          | 1.77            |
|              |             |  | Average | 38.15         | 2,432      | 1.95          | 5.11            |
|              |             |  |         |               |            |               |                 |
| 4            | 50          | Corn, hay, oats<br>Oats, corn, hay<br>Hay, oats, corn    | 1936    | 43.86         | 8,416      | 1.39          | 3.17            |
|              |             |  | 1937    | 39.51         | 1,016      | 2.51          | 6.35            |
|              |             |  | 1938    | 31.08         | 3,907      | 2.10          | 6.76            |
|              |             |  | Average | 38.15         | 4,446      | 2.00          | 5.24            |
|              |             |  |         |               |            |               |                 |
| 5            | 300         | Wheat<br>Hay<br>Corn                                     | 1936    | 43.86         | 20,926     | 5.61          | 12.79           |
|              |             |  | 1937    | 39.51         | 180        | 2.99          | 7.57            |
|              |             |  | 1938    | 31.08         | 51,758     | 2.78          | 8.94            |
|              |             |  | Average | 38.15         | 24,288     | 3.79          | 9.93            |
|              |             |  |         |               |            |               |                 |
| 6            | 300         | Oats<br>Hay<br>Corn                                      | 1936    | 43.86         | 31,320     | 4.26          | 9.71            |
|              |             |  | 1937    | 39.51         | 773        | 3.87          | 9.79            |
|              |             |  | 1938    | 31.08         | 57,991     | 3.43          | 11.04           |
|              |             |  | Average | 38.15         | 30,028     | 3.85          | 10.09           |
|              |             |  |         |               |            |               |                 |

\* All plots were 21 feet wide and 300 feet long, average slope 9.5 percent

\*\* First named crop was at the bottom of the slope

does indicate the value of strip cropping as compared with non-strip cropping.

Table 9 gives runoff data from six plots during the period 1936-38. It will be noted that soil and water losses from the stripped plots were influenced by the particular crop at the foot of the slope nearest the collecting tanks. When corn was in this position the losses were much greater than when grain or hay crops were grown. Consequently, the average runoff for the rotation is a more important consideration than the runoff for a single year.

The figures shown in table 9 indicate that the 50-foot strips were too narrow. It was apparent that, on this slope, the noncultivated strips were not wide enough to retard and spread water flow until it could be taken up by the soil. Observations during individual storms showed that runoff from corn strips passed completely through the adjacent hay or grain strips and thus increased the runoff on the next lower cultivated strips. This was especially evident on plot 4.

#### TILLAGE STUDIES

In order to determine the effects of direction of tillage on soil and water losses, six one-tenth-acre plots were established on a slope averaging 9.4 per cent. These plots were 21 feet wide and 207.5 feet long. All plots were planted to corn (check-rowed) each year and received 300 pounds of superphosphate and 14 tons of manure per acre. The directions of the various tillage operations are shown in figure 9. At the beginning of the experiment plots 5 and 6 were subsoiled to a depth of 16 inches and at intervals of 10 feet in the directions indicated. Subsoiling was accomplished with difficulty due to the shallowness of the soil and frequent limestone outcrops.

Figure 9 indicates that the direction of cultivation is more important than the other two operations. Plowing was done in the spring of each year and the plots were immediately prepared for seeding. Consequently there were no differences in the surface condition of the plots over a period long enough to produce differences in runoff. This is shown in the plot which was plowed across the slope and cultivated up and down the slope. This plot lost more soil than any of the other plots.

After the first year the subsoiled plots showed no evidences of the subsoiling operation and differences in soil and water losses were not significant.

This experiment clearly indicates the value of contour cultivation. In every case, those plots which were cultivated on the contour lost much less soil and water than those which were cultivated up and down the slope.

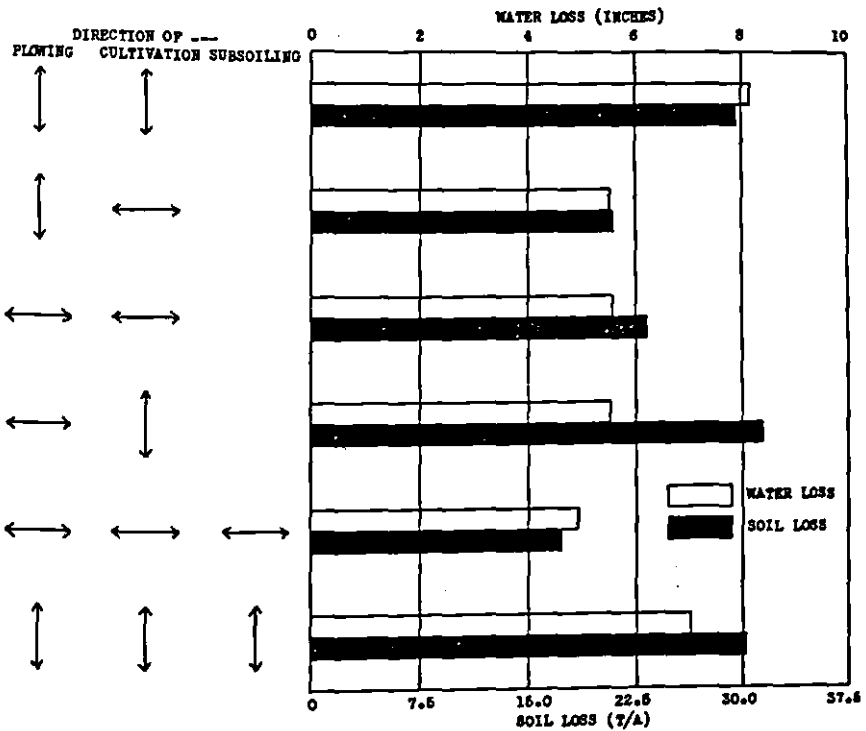


Fig. 9.—Average annual soil and water losses from tillage plots, 1936-38.