DIVISION VI—SOIL AND WATER MANAGEMENT AND CONSERVATION

Runoff and Erosion Losses from Mexico Silt Loam in Relation to Fertilization and Other Management Practices[1]

F. D. Whitaker, V. C. Jamison, and J. F. Thornton[2]

ABSTRACT

Results from the runoff-erosion plots on claypan soils at McCredie, Missouri, are summarized. With improvement due to fertilization and sod rotations, the performance of these soils approaches that of the better soils of Missouri. Where adequate fertility is supplied the chief advantage of growing corn in a sod-based rotation over continuous corn is the reduction in the time the soil is without protective cover. The critical period found for erosion losses from corn was from the time of seedbed preparation until the growing crop provided an adequate canopy. Erosion losses for rotation corn were about 60% as high as for continuous corn from intense rain storms that occurred during this period. Average soil and water losses from adequately fertilized soil were less for corn in rotation than for continuous corn during the corn growing season. Seedbed preparation by subtillage so as to leave shredded cornstalks on or near the surface reduced erosion losses.

The urgent need for improved methods of farming the large areas of claypan soils of the Midwest became evident during a period of low farm incomes (1930-36). Soil surveys at this time[3] showed that about 7 inches, or about one-half the original topsoil, had been lost from the sloping claypan soil areas in about 70 years. In an effort to increase cash incomes, increasing areas of this land had been plowed from pasture or meadow and planted to small grains and intertilled crops, without fertilizer and usually without regard to slope. Production was low and decreased further with the removal of nutrients by crops and with losses in runoff and erosion. With the increased expense and low yields for this type of farming the returns were often less than production costs.

A basic study of management problems was planned and runoff plots were established at the Midwest Claypan Experiment Farm near McCredie, Missouri, in 1939-40. The soil at this location is representative of those claypan soils of the Midwest that are characterized by gently rolling topography, a gray leached surface, a low level of fertility, and a clay subsoil layer of low permeability.

Emphasis was first given to the effect of crop sequence on runoff and erosion. Three tons of lime and 200 pounds of 0-20-20 fertilizer per acre at the time small grain was seeded still gave low yields, crops of poor quality and high rates of runoff and erosion. In 1947-48, fertilization by soil test was adopted and the management of crop residues was included in the study.

In 1954 studies were initiated to determine the effect of soil fertility on runoff and erosion. A wide range of fertility treatments for continuous corn and for crop rotation with 2 years of meadow in each cycle, and a corn-oats rotation without fertilizer treatment were included. To determine the effect of leaving crop residues on the soil surface, seedbed preparation for corn by subtillage was compared with plowing. Since 1955 runoff and erosion losses have also been measured from continuous corn grown with adequate fertilizer and farmed on the contour. In 1958 irrigated and adequately fertilized plots were added to study the effect of maintaining adequate soil moisture on runoff and erosion as well as on crop production.

DESCRIPTION OF PLOTS AND TREATMENTS

There are 32 small (0.0217 acre) and 2 one-acre plots in the present study. The small plots are 10.5 by 90 feet and are farmed lengthwise with the slope. The 1-acre continuous corn plots have a slope length of 420 feet and are farmed on the contour. All the plots are equipped to measure runoff and soil losses.

The rotations with fertilizer and seedbed preparation treatments are shown in table 1. All the rotations and treatments are on duplicate plots except the corn-oats rotation without fertilizer. For the latter, corn and oats alternate on two plots so that both crops are grown each year. For the corn-wheat-meadow-meadow rotations the different crops and treatments occur in cycle on two plots each year.

The "full fertility" treatment entailed the application of lime, phosphate and potash according to soil tests (1) since 1954. Adjustments according to test requirements have been made each year before planting corn. In addition ammonium nitrate has been applied at 200 pounds per acre before plowing or tilling for corn and starter fertilizer (3-12-12) applied at 300 pounds per acre with seeding of corn. Corn was sidedressed with ammonium nitrate at 200 pounds per acre. Ammonium nitrate was applied to wheat at 200 pounds per acre before tillage and starter fertilizer (0-20-20) applied at 200 pounds per acre at seeding. In addition, for the full fertility treatment, the first and second-year meadow received three 100-pound applications of ammonium nitrate or 100 pounds of N per acre per year (about March 1 and after first and second cuttings).

The "starter fertility" treatment involved the application of 3-12-12 at 300 pounds per acre at seeding for corn, and ammonium nitrate at 120 pounds and 0-20-20 at 200 pounds per acre at seeding of wheat.

Table 1—Treatments in study started in 1954 and modified by irrigation test in 1958.

Rotation	Fertility treatment	Seedbed preparation	Plot size*	Number of plots
Corn-Oats	None	plow (for corn)	0.0217	1†
Cont. Corn	Full	subtill	0.0217	2
Cont. Corn	Full	plow	0.0217	2
Cont. Corn	Starter	plow	0.0217	2
Cont. Corn	Full	plow	1.0	2
C-W-M-M	Full	plow (for corn)	0.0217	8
C-W-M-M	Starter	plow (for corn)	0.0217	8
		Irrigation plots started in 1958		
Cont. Corn (irr.)	Full	subtill	0.0217	2
Cont. Corn (irr.)	Full	plow	0.0217	2
Cont. Corn (not irr.)	Full	subtill	0.0217	2
Cont. Corn (not irr.)	Full	plow	0.0217	2

* All small (0.0217-acre) plots have a slope length of 90 feet and are farmed up and down slope. The 1-acre plots have a slope length of 420 feet and are farmed on the contour.
† Two plots alternating for corn and oats so that both are grown each year.

[1]Contribution from Soil and Water Conservation Research Division, ARS, USDA, and the Missouri Agr. Exp. Sta., Columbia, as Jour. Series No. 2148. Presented before Div. VI, Soil Science Society of America, Dec. 7, 1961, at Chicago, Ill. Received Nov. 19, 1960. Approved Feb. 14, 1961.

[2]Engineering Aide, Soil Scientist, and Agricultural Engineer, respectively, USDA, Columbia, Mo.

[3]Personal communication from H. E. Grogger, State Soil Scientist, SCS, Columbia, Mo.

The effect of leaving shredded cornstalks on or near the surface is part of the present study. To leave the cornstalks on or near the surface, the seedbed is prepared by the use of a field tiller. The results are compared with those obtained by the conventional method of plowing and disking for corn.

RESULTS

During the 7-year period 1947-1954, when nearly adequate fertility treatments were used, yields were higher, the quality of meadow was improved (table 2), and runoff and erosion were much lower than during an earlier period of inadequate fertilization. According to Smith (2), soil loss from corn following 4 years of meadow was 41% greater than from corn following 1 year of meadow during this earlier period when only 200 pounds of 0-20-20 per acre was used on small grain in the rotation. The fourth year of meadow was largely weeds and annual lespedeza. During the following 3 years (1947-50) when nearly adequate rates of N, P and K were used on all crops, vigorous growth of grass was maintained throughout the meadow period. The soil loss under corn following 4 years of meadow was 21% less than under corn following 1 year of meadow. Rainfall intensities during the period (1947-50) were generally lower than during the earlier period.

The effects of the different fertility treatments and cropping systems on runoff and erosion during the recent period of the study (1954-59) are shown in figure 1. The average annual rainfall for this period was 32.23 inches or about 6 inches less than the average for the 68-year period (1891-1958). The erosion index (5) for the corn-growing season was 72% of the average for the 21-year period (1938-59). The rainfall during the corn-growing season was 18.43 inches for the 6-year period, or 0.57 inch more than the average for the longer 68-year period.

The results (figure 1) show that the greatest value of adequate fertility in reducing runoff and especially soil losses is during the periods when small grain or meadow is grown. Soil conditioning due to adequate fertility and meadow in a rotation is effective in controlling soil and water losses from moderate storms during the corn-production period. However, the soil conditioning did not provide full protection for large rains of high intensities occurring soon after planting. The results for a series of storms with a total precipitation of 4.23 inches in 10 hours occurring June 29-30, 1957, are shown in figure 2. Soil and water losses from the corn plots on these 2 days were between two and three times the annual (1954-59) average amounts for the corn-growing season (Apr. 20 to Oct. 1). Since most of the high intensity storms occur during the time interval of seedbed preparation, planting and cultivation, soil loss from corn may occasionally exceed an annual allowable amount above which productivity will decline. Smith and Whitt (4) concluded losses from sloping claypan soils should not exceed 3 tons per acre per year.

The critical time interval for soil and water loss for corn production is from the time of seedbed preparation until the crop provides sufficient cover for protection. Soil conditioning, whether residual from meadow or from shredded cornstalks, will reduce runoff and erosion during this period. Leaving the cornstalks on the surface by subtillage for seedbed preparation will further reduce losses (figures 1 and 2). However, the soil conditioning effect of meadow on soil loss was 1.64 times more effective than leaving cornstalks on the surface for the series of high intensity storms of June 29-30, 1957.

A heavy soil cover of shredded cornstalks from adequately fertilized continuous corn seems to afford about the same degree of protection as newly seeded small grain and meadow during the time interval from corn harvest to seedbed preparation time the next spring (figure 1).

The period following seedbed preparation and seeding of wheat is an additional period in the rotation cycle when high soil losses may be expected. Soil loss may be reduced by leaving most of the cornstalks on the soil surface when preparing the seedbed for wheat. This critical period for wheat is usually during the month of October. For a series

Table 2—The improvement in yields and protein content of forage due to fertilization.

Fertilizer treatment	First-year meadow	Second-year meadow	Annual average
	Yield of dry matter in tons/acre (1954-59)		
Full	3.33	3.43	3.38
Starter	2.41	2.68	2.54
Increase	0.92	0.75	0.84
Probability level*	0.01	0.01	0.01
	Pounds of protein per ton forage (1954-57)		
Full	312	300	306
Starter	275	293	284
Increase	37	7	22
Probability level*	0.01	0.50	0.09

* A probability level of 0.01 is considered "highly significant".

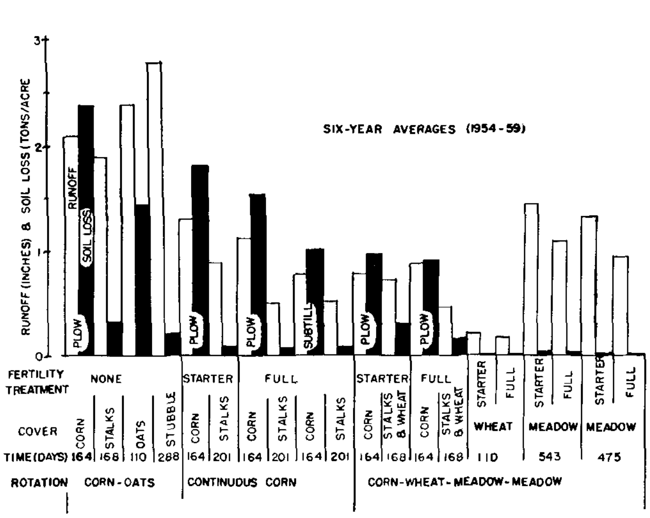

Figure 1—Average runoff and erosion losses during a 6-year period (1954-59) for different cropping systems and fertility treatments.

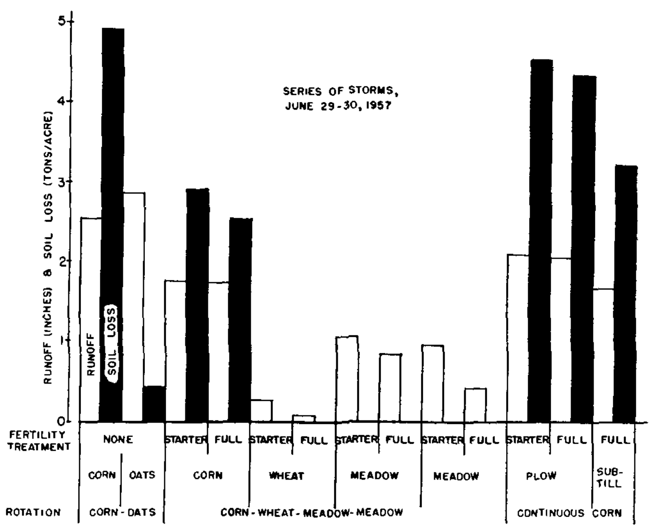

Figure 2—Runoff and erosion losses for a series of high intensity storms that occurred June 29-30, 1957.

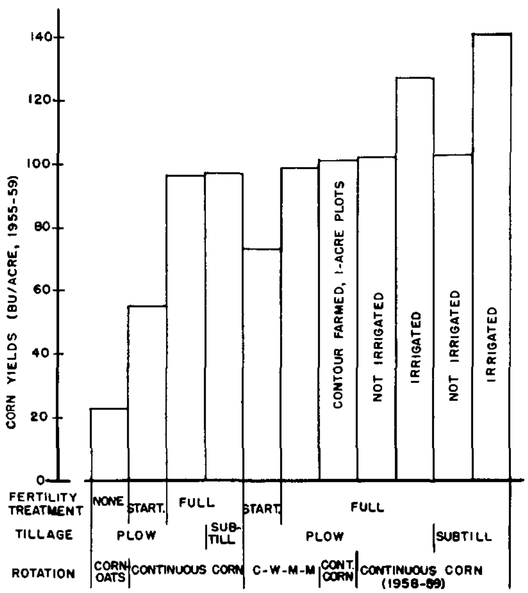

Figure 3—Average corn yields for different cropping systems and fertility treatments.

of storms occurring October 2 to 10, during which time there was a total of 5.75 inches of rain, wheat land with the starter-fertility treatment lost 1.08 tons per acre or about 90% of the annual loss for 1959. The corresponding loss for the full-fertility treatment was 0.48 ton per acre or all of the annual loss for 1959. More rapid growth and establishment of the newly seeded crop with full fertility account for the difference.

The effect of low fertility on runoff and erosion is shown by the corn-oats rotation without fertility treatments (figure 1). Average runoff (1954-59) for the time corn and cornstalks were on the land (4/8 to 3/18 the following year) was 3.94 inches with a soil loss of 2.66 tons per acre. For the oat period (3/19 to 4/7 the following year) the average runoff was 5.09 inches with a soil loss of 1.58 tons per acre. Runoff for the unfertilized corn-oats rotation was 2.77 times and the soil loss 1.33 times that from continuous corn fully fertilized.

The average annual runoff (1955-59) was 2.71 inches from adequately fertilized continuous corn grown on the contour on plots with a slope length of 420 feet. The corresponding soil loss was 2.98 tons per acre. The ratio of soil loss from this slope length to that of the small plots (farmed with the slope and with the same crop and treatment) has varied from 0.36 in 1959, a year of low rainfall intensities throughout the corn growing season, to 2.34 in 1957 when contour furrows were broken by a series of heavy rains of high intensities that occurred a few weeks after corn planting. The average soil loss per acre from the long-slope contour plots was 1.61 times greater than for the small plots. Thus growing corn on the contour may conserve water and save soil for most seasons. However, the hazard of damage from high intensity storms that occasionally occur during the critical period for corn production is increased by the practice. Methods of reducing slope length hazard such as by terracing or strip cropping, are necessary to cultivate rolling land safely.

Runoff from the irrigated continuous corn plots during 1959 was 3.73 inches in comparison to 1.55 inches from nonirrigated continuous corn plots and soil loss was only 0.52 ton per acre or an increase of 0.18 ton per acre for irrigation. Most of the runoff occurred when the growing corn or cornstalks provided good protective cover. More data are needed to determine the effect of irrigation on soil and water losses from corn. This study has been in operation only 2 years. No irrigation was needed in 1958. Six irrigations (a total of 11.5 inches) were applied from July 26 to August 10 in 1959. Rainfall sufficient to cause runoff from any plots was not received until October.

The effect of the treatments on corn yields for 1955-59 are shown in figure 3. Because of the crop failure due to drought the results for 1954 are not included.

DISCUSSION

The average corn yield has been increased by adequate fertility to a level about 4 times that receiving no fertilizer. A more developed and deeper root system has increased the efficiency of corn in the use of soil moisture. Although adequate fertilization affords a good protective cover of growing plants or cornstalks during most of the year when corn is grown, soil losses may be high during the interval of seedbed preparation, planting and cultivation of the young crop. The soil conditioning given by well-fertilized meadow in the rotation before corn provides protection except for occasional storms of high intensity during critical periods. One advantage of growing corn in a rotation as compared to continuous corn would be to reduce the average frequency of expected losses from such storms occurring when the soil is without adequate cover. On an average, in a corn-wheat-meadow-meadow rotation, severe losses from such storms would occur less frequently than for continuous corn.

This experiment was revised in 1954 primarily to test the effectiveness of a high level of fertility on erosion control. From an economic viewpoint, high rates of fertilization cannot be justified unless facilities for supplemental irrigation at a relatively low cost are available. The cost/return ratio for the extra fertilizer or the full fertility over the starter treatment on the rotation was estimated as 1:1.30. The increased return would probably be insufficient to cover the additional labor and machinery costs of applying the extra fertilizer and harvesting the increased crops. The highest cost/return ratio for additional fertilizer was 1:2.16 for corn in rotation in 1958 when the moisture supply was adequate during the entire growing season.

Adequate fertilization has provided conditions of considerable value in reducing runoff and erosion from sloping claypan soils. Growth of crops on these soils has been greatly stimulated by fertilization. Soil treatments, crop rotations including grasses and legumes, have produced marked improvement in productivity and resistance to erosion (2). With this improvement the performance of these soils is approaching that of the better soils of Missouri. More rapid development of crops on these soils reduces the time when soil is directly exposed to the kinetic energy of falling raindrops. Improved root systems, with increased crop residues returned to the soil, condition the soil so as to further increase resistance to erosion. Winter-killing of wheat has been greatly reduced by adequate fertility. The more rapid development of wheat is of utmost importance to both production and soil protection, especially during years when seeding is delayed by corn harvest or wet weather.

LITERATURE CITED

1. Graham, E. R. Testing Missouri soils. Missouri Agr. Exp. Sta. Circ. 345. 1950.
2. Smith, D. D. Soil and water losses reduced by improved fertility. USDA Soil Conserv. 15(11):254-257. 1950.
3. ———. Fertility increases efficiency of soil moisture. Better Crops with Plant Food 38 (6):11-12, 39. 1954.
4. ———, and Whitt, D. M. Evaluating soil losses from field areas. Agr. Eng. 29:394-396, 398. 1948.
5. Wischmeier, W. H. A rainfall erosion index for a universal soil-loss equation. Soil Sci. Soc. Am. Proc. 23:246-249. 1959.