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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
College Station, Brazos County, Texas

BULLETIN NO. 411 MARCH, 1930

DIVISION OF AGRONOMY

FACTORS INFLUENCING RUNOFF AND SOIL EROSION

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†As of March 1, 1930.
**In cooperation with U. S. Department of Agriculture.
***In cooperation with the School of Agriculture.

This Bulletin reports results so far available from three years' work at Substation No. 7, located near Spur, Dickens County, in a study of factors influencing runoff and soil erosion and the effects of conservation on the increase in crop yields. The results are directly applicable to an area of about 14 million acres in which Miles and Abilene soils predominate and indirectly applicable to all of Texas. The equipment used is fully described. The available rainfall data show that 85 per cent of the average annual rainfall of 22 inches, comes in this region during the summer months. Two well defined peaks, one in May and one in September, with a period of depression of rainfall in July, emphasizes the necessity of conserving water from the spring rains to carry crops through the normally dry period in July. The possibilities of conservation are shown by the fact that approximately 20 per cent of the total rainfall is ordinarily lost in this region as runoff. The results indicate that the intensity of the rainfall is a factor in losses of water and soil, but that other factors such as soil-moisture content are operative to a considerable degree. The runoff losses have not been found to be in direct proportion to the steepness of the grade. The soil losses seem to be more nearly in proportion to the steepness of the grade than is the case with water losses. Tremendous quantities of water and soil have been lost from lands with even a gentle slope. Grass has been found to be a very effetive vegetative cover in conserving water. Milo was more effective than cotton, and cotton more effective than no crop at all. The efficiency of a crop in preventing runoff seems to be due partially to its coverage and partially to its removal of water, which in turn affects the absorption by the soil. Tillage has been found effective in the storage of water. Contoured rows, terraces, and dikes have been found effective in saving water and in increasing crop yields. The results indicate that in this region, it is possible by the use of contoured rows and closed terraces to conserve all the water and entirely prevent runoff. By means of diversion terraces, as much as two to four inches of water have been applied to other areas, but such applications of water have not thus far been fully satisfactory because of the difficulty of spreading and retaining the water on the land.

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FACTORS INFLUENCING RUNOFF AND SOIL EROSION

A. B. CONNER
R. E. DICKSON
D. SCOATES*

Throughout Texas and the Southwest, water is the chief limiting factor in crop production. Soil fertility is also a limiting factor in some regions. In sections where erosion has been accelerated by methods of utilizing land, soil fertility has been depleted.

Climatic conditions in Texas are such that in nearly every part of the State crops are subject to periods of deficient soil moisture caused by either a shortage of total rainfall or a lack of proper distribution. Shortages of rainfall can be partially overcome by the storage of water in the soil, thus carrying over the largest amount of soil moisture possible for use of the crop. Unfavorable seasonal distribution of rainfall and the losses of soil and soil fertility can also be partially remedied by the same measures; hence, control of rainfall water and its storage in the soil is an important problem confronting the agriculture of Texas. Undoubtedly in certain seasons of low total rainfall no measure of precaution will fully compensate for the shortage, but in seasons of fair rainfall, attended by poor distribution, it seems probable that by the application of effective methods concerned in the storage of water in the soil, favorable growing conditions can be greatly extended and the probability of good production increased.

Intensity and distribution of the rainfall are important factors to be considered. The slope of the land, the crop grown on the land, and tillage operations practiced are other important considerations, as they materially affect storage of water in the soil. These same factors apply to losses of soil and soil fertility, inasmuch as water is the vehicle which carried away soil and soil fertility. Any means of retarding the off-flow of water also retards the carrying away of soil and soil fertility.

The purpose of this Bulletin is to present the results so far available of experimental work conducted at the Spur Experiment Station in the study of some of the principal factors concerned in losses of water by runoff and of soil by erosion, and the effect of these losses on the yield of crops.

SCOPE OF WORK

In the plan of work originally outlined, two phases of the problem were to be considered: (1) a study of factors contributing to runoff losses under subhumid conditions as influenced by (a) rapidity of rainfall, (b) slope of the land, (c) physical condition of the land, (d) use

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of terraces and other obstructions; and (2) a study of the effects of preventing runoff losses on crop production.

At the inception of this work, soil erosion was not thought to be an important consideration in the section involved (Figure 5), and hence no definite mention was made in the project of the soil-erosion problem. It was realized, however, that the set-up and equipment necessary for the measurement of water losses would suffice for measuring soil losses. In the first crop season, the soil losses were so astoundingly large that

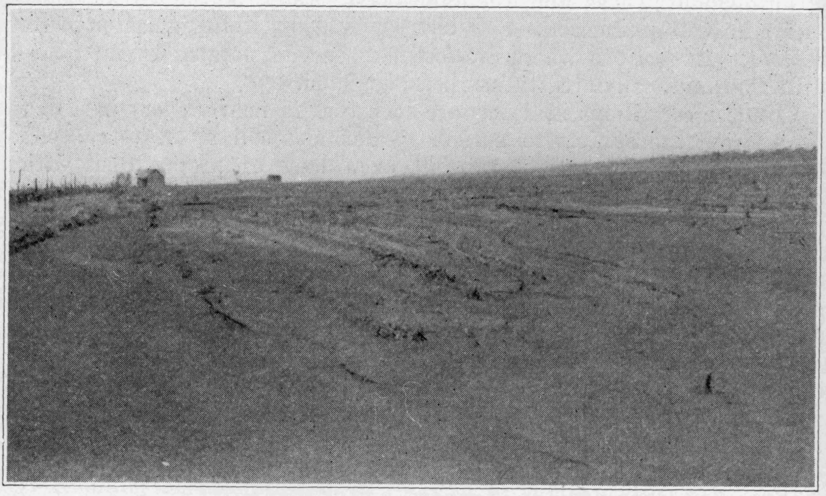

Fig. 1. Sheet erosion in a cotton field.

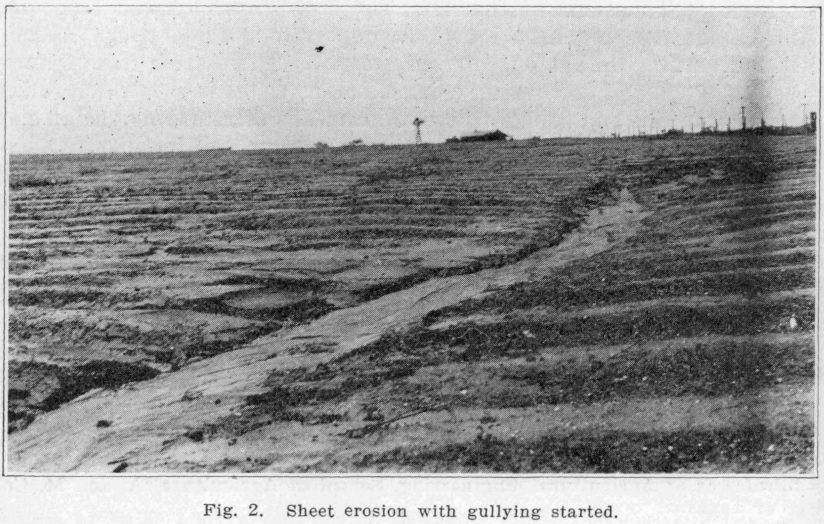

Fig. 2. Sheet erosion with gullying started.

this phase of the work assumed an unexpected importance in connection with the study, and measurements of soil losses have been obtained throughout in an endeavor to correlate these soil losses, as well as the water losses, with the factors under consideration.

The general method of procedure in formulating a plan of operation has been to make use of the available meteorological data and other experimental data available relating to the subject. This plan has involved establishing a set of control plats with equipment for obtaining

Fig. 3. An example of gullying.

Fig. 4. Effectiveness of a terrace in checking the movement of water on rolling land.

accurate measure of losses of water and soil under the following conditions: during periods of rainfall varying in size and intensity; from plats with different grades; from plats planted to different crops; and from plats fallowed. These data obtainable from the control plats have been further supplemented by the installation of a series of field areas ranging from 5.5 to 11 acres in size, and variously equipped, from which, by means of weirs and water-stage recorders, an accurate measure of water loss was recorded, thus supplementing the small control plats by field areas approaching closely field conditions as they exist in this region.

It is realized that, in this set-up, variations in the field areas, particularly, will necessarily affect the records obtained, and that a period of years and a duplication of some of the field areas will be required to obtain conclusive results. It is believed, however, that the use of the control plats in connection with the field areas will tend to enable verification of accuracy in the field results.

The areas on which these tests are being conducted were put into cultivation in 1909, 1910, and 1911, and were in experimental-plat work until 1924. During 1924, 1925, and 1926, there were 90 acres of cotton grown on the 100 acres in the field areas and the remaining 10 acres were used for growing feed crops. The land has a gradient ranging from one-half of 1 per cent to 3 per cent.

HISTORICAL

The use of runoff water in irrigation is an old and accepted practice. For centuries, water has been impounded by man and diverted onto fields and vineyards to supplement the normal rainfall. The American Indians of the subhumid regions were efficient in diverting water onto their fields during rainy periods.

These early experiences in the use of water have, perhaps, been an incentive to the more intensive and systematic studies relating to the use of water which comes as rainfall. In the development of the subhumid region in the Western and Southwestern States, intensive studies have been made by research workers in dry-farming problems having to do primarily with storing and retaining moisture in the soil through cultural practices. Much work has been done relating to the percolation of water and on the relation of water to plants. Numerous studies have been made on the duty of water in irrigation and the discharge of water through river courses as it relates to rainfall, flood control, and silting problems.

The Missouri Experiment Station initiated experiments in 1917 on soil erosion and surface runoff, and has contributed information on the subject of erosion. The Bureau of Public Roads, United States Department of Agriculture, has conducted, in co-operation with the North Carolina Experiment Station, experiments on soil erosion. The Bureau of Chemistry and Soils, United States Department of Agriculture, has contributed to our general knowledge of soil-erosion problems as they occur in different parts of the United States and elsewhere. The Forest Service, United States Department of Agriculture, has contributed to the knowledge of off-flow of rain water in relation to losses on grazing and forest areas. Agricultural Experiment Stations in various States have also contributed basic information relating to the problem.

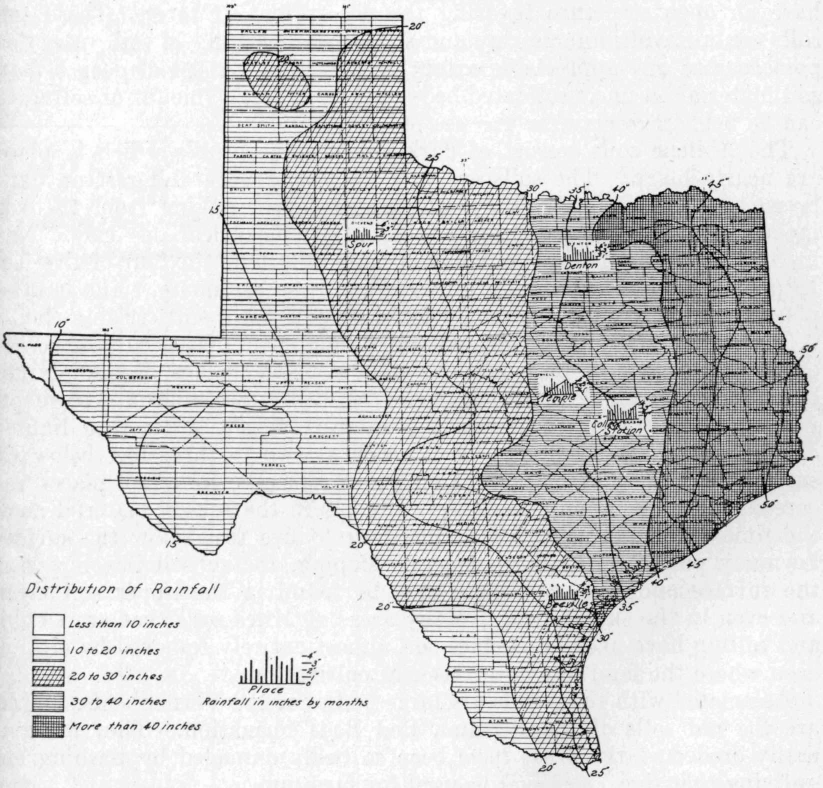

Fig. 5. Rainfall map of Texas, showing monthly distribution at five points.

DESCRIPTION OF AREA

The area to which this work applies occupies all or parts of 44 counties and covers approximately 20,000,000 acres. Of this, about 14,000,000 acres are predominately Abilene and Miles soils, with some other soils that are closely related to them. The soils on the Station belong to the Abilene and Miles series.

The Rolling Plains are generally undulating, with some rather good-sized bodies of land that are nearly flat or gently sloping. The Abilene soils, and the closely related dark soils, occupy the larger areas of nearly flat lands. The clay loam types prevail in the dark group of soils. The Miles soils are in general more rolling in many places, and the sandy types are the most extensive in this series.

All of the soils of this region have a natural granular and open structure, which allows the ready cultivation of the land into a friable condition. This allows water to enter the soil and pass through it freely. It also permits easy washing and eroding of the surface where it is at all sloping. The subsoils, though as a rule heavier than the top soils, have an open structure favoring the absorption of water. These subsoils contain considerable clay and subsurface leaching of soil water does not occur to any appreciable extent, and as they consist of deep beds of soil material on unconsolidated beds of clays, a large amount of soil water can be held in reserve for the use of crops.

The Abilene soils consist of dark-brown surface soils which in places are nearly black. The soils are 4 to 10 inches deep and rest on dark-brown or chocolate-brown clay, which at a depth ranging from 18 to 24 inches merges below into lighter-colored friable calcareous clay. Normally a layer of soft lime carbonate occurs at a depth of four or five feet. In places this is a bed of soft, almost pure, lime carbonate, while in other places it is mixed with salmon-colored or yellowish, soft, friable clay.

The Miles soils, where normal soil development has occurred, consist of reddish-brown or brownish-red soils 4 to 12 inches deep underlain by subsoils of friable clay of a red or reddish-brown color. At a depth ranging from 18 to 24 inches the subsoils merge below into lighter-colored chocolate-red friable clay, which at two to three feet below the surface is somewhat calcareous in many places. In other places calcareous material is found only very slightly in the subsoil material above the lime carbonate zone, which lies four to five feet below the surface. In many places where the surface is sloping, the subsoil lies very near the surface and lime carbonate may be found in the upper soil layers and even in the surface soil. Many areas of Miles soils that are sloping and rolling have had the surface soil almost entirely removed by erosion, even where the land has never been in cultivation.

Associated with these soils are large bodies of the Vernon soils. These are the red soils of the Permian Red Beds formation. They are very easily eroded; large areas have been so badly damaged by washing and gullying that they can never be used for farming.

EQUIPMENT

Meteorological

The meteorological instruments are adjacent to the control plats (Figures 6 and 8). They consist of maximum and minimum thermometers, relative atmospheric humidity thermometers, anemometer, evaporation tank, an automatic gauge for weighing and recording rain and snow, and a standard government rain and snow gauge. The automatic gauge (Figure 9) is particularly useful in that it records the rate of rainfall. In addition to these instruments, there are two other rain gauges placed at points on the field areas in order to check on variations in rainfall.

Control Plats

The control plats (Figure 6) are located on Miles clay loam and consist of eight plats 6 feet wide and 96.8 feet long, or 1/75 of an acre in size. The number of the plat, the grade, the cropping, and the treatment are given in Table 1.

These plats are located on land that had been in cultivation for thirteen years prior to the inception of this study. They are located adja-

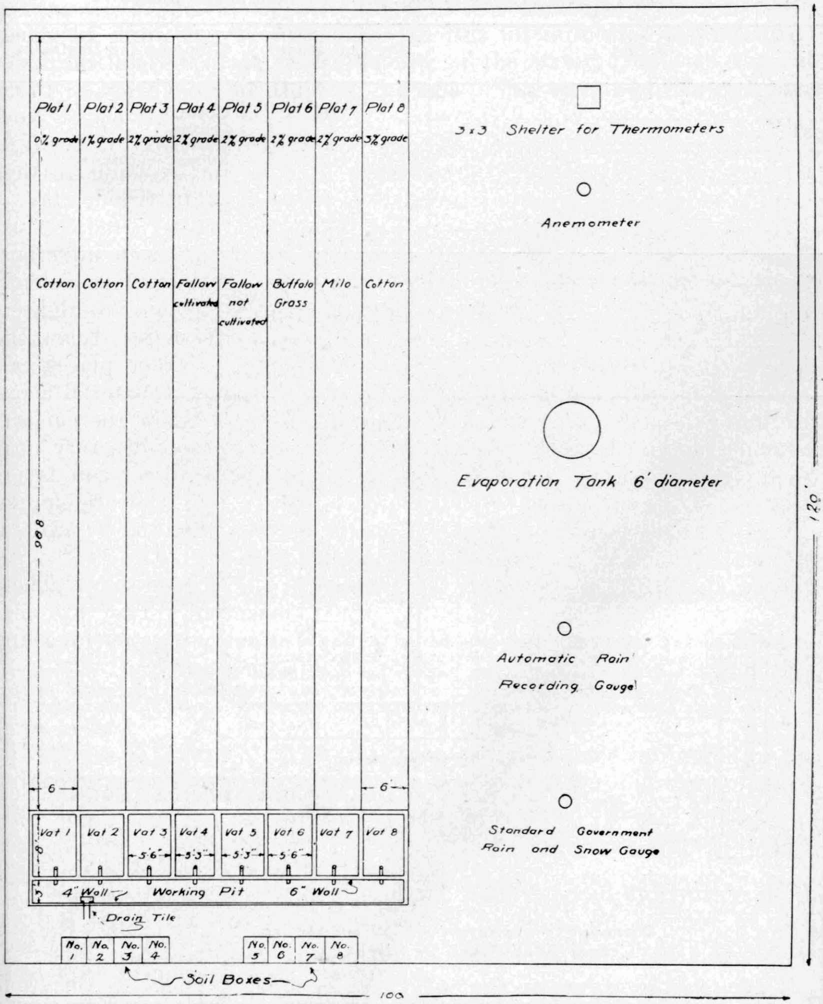

Fig. 6. Diagram showing arrangement, size, grade, and treatment of control plats, together with location of vats, working pit, and meteorological instruments.

cent to the field areas as shown in Figure 10. There was a natural 2 per cent slope, which furnished as nearly ideal conditions as could be obtained. It was necessary to excavate in order to form grades of less than 2 per cent on two of the plats, and to make a fill on a third plat in order to establish a grade of 3 per cent. These excavations and fills have undoubtedly affected the results on these three plats, more especially during the first year.

Table 1.—Control plats, number, grade, cropping, and treatment

Plat	Per cent grade*	Cropping and treatment
1	0	Cotton
2	1	Cotton
3	2	Cotton
4	2	Fallow, cultivated
5	2	Fallow, not cultivated
6	2	Buffalo grass
7	2	Milo
8	3	Cotton

*Number of feet fall per 100 feet.

The plats are bordered with No. 20-gauge galvanized iron, 15 inches wide and sunk 12 inches beneath the surface of the soil. This border is

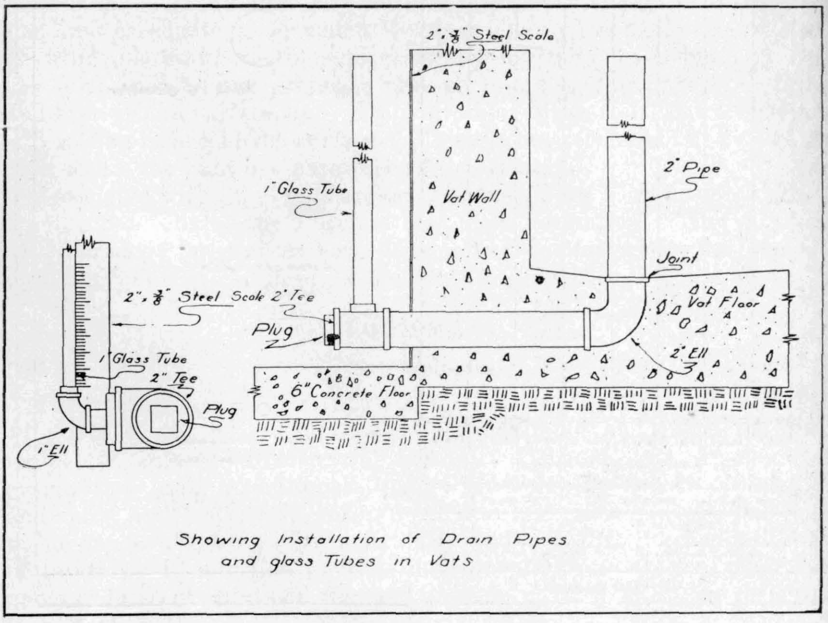

Fig. 7. Equipment for measuring water losses from control plats. The vats are calibrated and a direct-reading scale provided for the glass tubes in the working pit.

held in place by being riveted to inch angle-iron posts 36 inches long and set in concrete four feet apart.

The soil of the plats, with the exception of plats 5 and 6, is annually spaded with a garden fork to a depth of four inches. The crop residue on each plat is spaded under at the time of the preparation of the plat soil.

At the lower end of each of the control plats is a calibrated concrete vat four feet deep, five and one-half feet wide, and eight feet long. The water inlets to these vats are on a soil level with the lower end of the plat. At the side of the vats opposite the plats is a working pit three feet wide, four feet deep, and 48 feet long. In this pit is located the equipment for quick and accurate measurements of the water caught in the vats, as well as provision for draining the vats. The details of this equipment

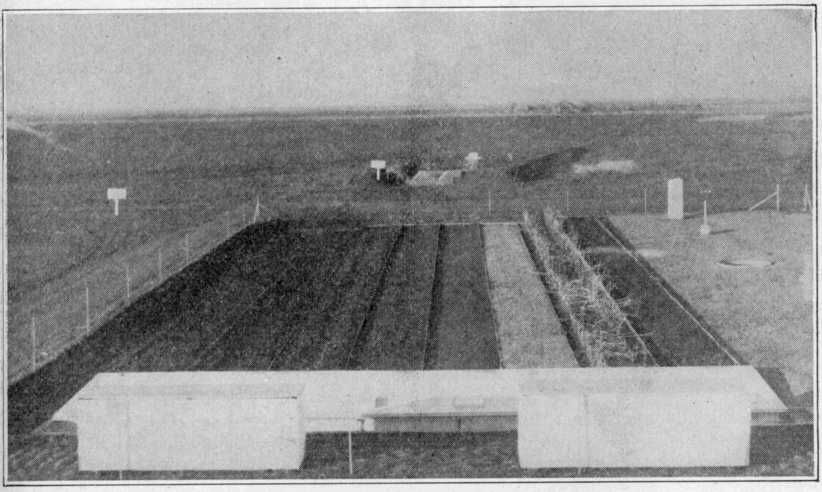

Fig. 8. The eight control plats 1/75 of an acre in size. The plats are numbered 1 to 8 from left to right. The meteorological instruments are at the extreme right. In the foreground are soil boxes containing the eroded soil. Between the soil boxes and the control plats, and under cover, are the concrete vats for catching the water and soil. In the background is shown equipment for measuring water losses from field areas.

are shown in Figure 7. The glass tube and steel scale calibrated to read direct in gallons provides a ready method of determining the amount of water in the tank. The plug in the pipe that supports the glass tube is for drainage. The vats are covered with a waterproof metal roof with a man-hole entrance to each vat.

The preparation of the land and the planting and cultivation of the control plats are necessarily performed by hand on account of their small size. This handwork is made to approximate as nearly as possible field work performed with machinery.

The cotton and milo plats are planted as near the first of May as possible. The rows are 36 inches wide and are 18 inches from the plat

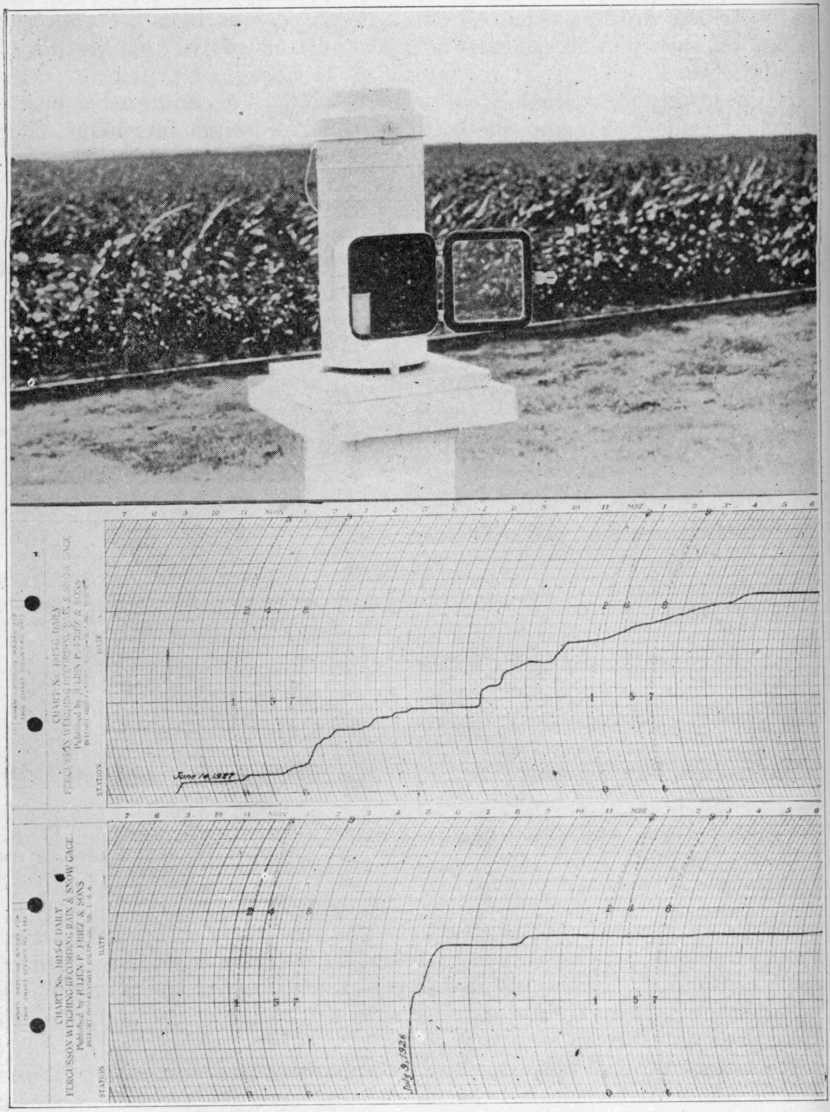

Fig. 9. Recording rain gauge and charts on which records are made. The upper chart represents a characteristic slow rain; the lower one, a rainfall of great intensity for periods.

borders. Cotton plants are spaced 12 inches in the row, and milo plants 18 inches.

The buffalo grass on plat 6 was transplanted in sods six inches square from nearby pasture lands on June 15, 1926, but it was late fall before the plat was perfectly sodded. The grass is clipped with a lawn mower, so as to maintain as nearly as possible the conditions of grass land pastured with cattle.

Plat 5, "fallow, not cultivated," has all vegetation removed with a weeding hoe, care being exercised not to disturb unnecessarily the surface of the soil.

The suspended matter in the water reaching the tanks is allowed to settle, the water drawn off, and representative samples of water and soil taken. The residue left in the vats is removed and weighed; samples are dried in a soils oven and the soil losses determined on a water-free basis.

Representative water and soil samples are taken following each rain and the remaining eroded soil is stored in soil boxes shown in the foreground of Figure 8.

Field Areas

There are ten field areas, each having a different treatment, located on Miles clay loam. They vary in size from 5.5 to over 11 acres. The size, arrangement, topography, and location of terraces are shown in Figure 10. Two of these areas, 5 and 6, were laid out and terraces constructed in the spring of 1926. The other eight were established in the spring of 1927. The field areas, with their acreages and treatments, are as follows:

Area 1—Contoured rows, cropped to cotton, 11.530 acres.
Area 2—Rows following the natural slope (up and down hill), cropped to cotton, 9.386 acres.
Area 3—One-foot fall* between level terraces,† cropped to cotton, 10.711 acres.
Area 4—Three-foot fall between level terraces, cropped to cotton, 10.259 acres.
Area 5—Two-foot fall between terraces having a fall of three inches per 100 feet along the terrace, cropped to cotton, 5.532 acres.
Area 6—Two-foot fall between level terraces, cropped to cotton, 6.044 acres.
Area 7—Level terraces with borders diked to hold all of the water that falls on the area, cropped to cotton, 6.329 acres.
Area 8—Level terraces with borders diked to hold all of the water that falls on the area, cropped to alfalfa, 7.825 acres.
Area 9—Level terraces with borders diked to hold all of the water that falls on the area and the runoff water from Areas 2 and 3, planted to cotton, 9.292 acres.
Area 10—Level terraces with borders diked to hold all of the water that falls on the area and the runoff water from Areas 5 and 6, cropped to alfalfa, 8.131 acres.

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*"Fall" means a difference of elevation. One-foot fall between terraces indicates a difference of one foot elevation between terraces.

†Level terrace is a terrace that is run on a contour or is level from one end to the other.

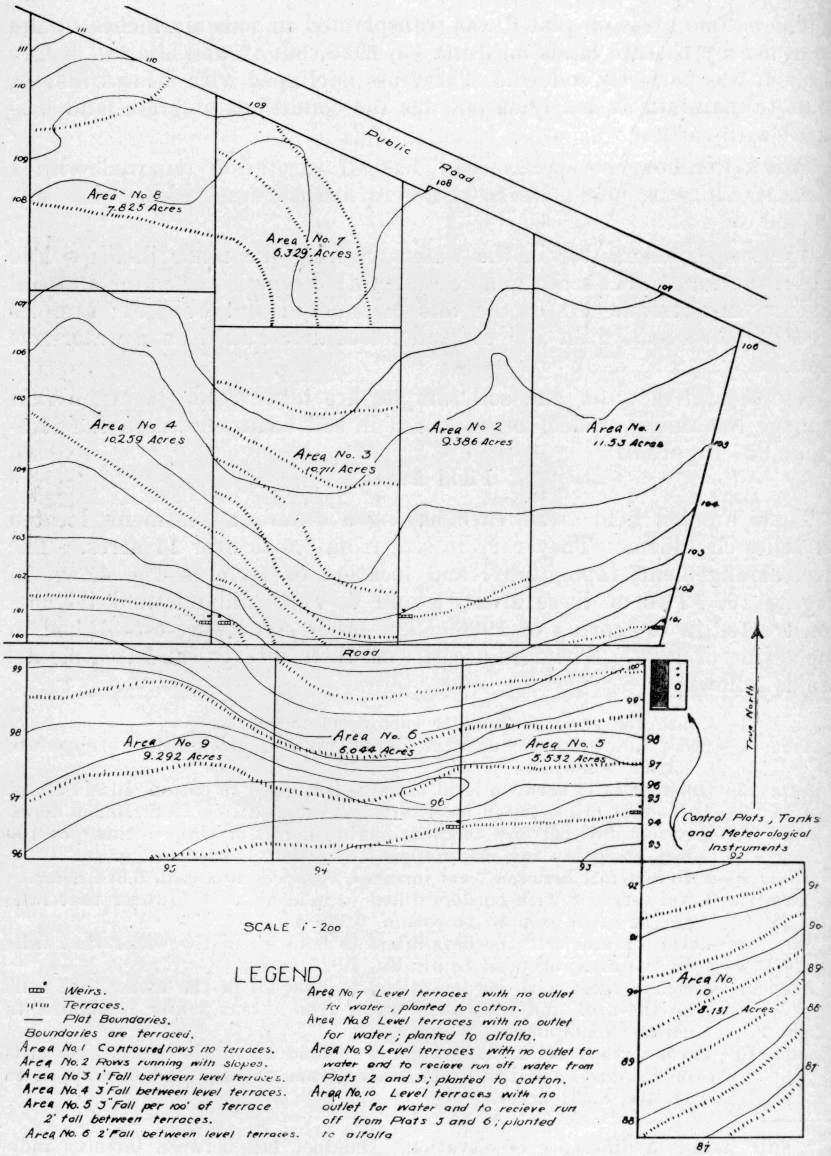

Fig. 10. Plan of field areas showing arrangement, sizes, contours, terraces, and the location of the control plats with reference to the field areas.

Areas 1 to 6, inclusive, are equipped with water-measuring devices. Typical equipment is shown in Figure 11.

Each of these units is equipped with a weir and an automatic time-recorder. The weir unit is built of reinforced concrete and is four feet high, 18 feet long, and six inches thick. In each unit there are two 90-degree notches with a depth of 18 inches. This design of weir is used in order to measure a very small flow as well as a large one. It records a discharge as low as .1836 cubic foot over 10-minute periods, and one as high as 8160 cubic feet in the same length of time.

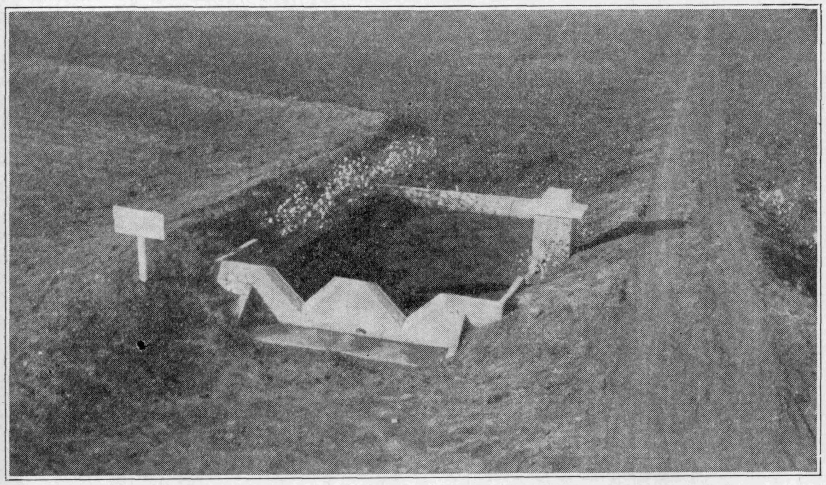

Fig. 11. One of the six concrete weirs with two 90-degree notches, still pond, and water-stage recorder used in measuring runoff from the field areas.

The still-ponds are twenty feet wide and forty feet long, with a depth of eighteen inches below the level of the notch. The purpose of the pond is to bring the water to a state of rest before passing over the weir.

A concrete still-well two feet six inches square and eight feet high is placed at the edge of each still-pond. This still-well is a support for the water-stage recorder and houses the water-float, clock-weights, and counter-weights.

ANALYSIS OF RAINFALL DATA

Rainfall

The rainfall data at Spur for a period of seventeen years show that the average annual rainfall is 22.01 inches, and that in this period violent fluctuations in annual rainfall have occurred ranging from 11.09 inches in 1924 to 38.08 inches in 1926. Table 2 shows in detail the monthly and annual rainfall for the seventeen years, and Figure 12 shows a graphic representation of the rainfall by months for the three years in which this work has been conducted, 1926, 1927, and 1928, as

Table 2.—Monthly and annual rainfall, inches, 1912 to 1928, inclusive, at Spur.

Months	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	Total	Average
January	.00	.04	.09	.40	.00	.22	.00	.28	1.31	.30	.31	.05	.00	.34	.67	1.10	.24	5.35	.314
February	1.15	.41	.19	2.10	.00	.51	.64	.21	.00	1.08	.00	.85	.09	.16	.04	.26	.96	8.65	.508
March	1.02	1.23	.33	3.20	.43	.00	.30	3.56	.16	.66	.76	1.01	1.88	.19	1.62	1.06	.36	17.77	1.045
April	1.05	.77	1.99	7.64	2.35	1.27	.62	3.78	.99	.00	5.57	3.89	.81	4.77	4.18	.40	.20	40.28	2.369
May	1.99	.44	10.58	2.31	1.31	1.71	2.44	4.37	6.91	.91	5.18	1.14	1.98	2.75	3.17	.66	4.33	52.18	3.069
June	3.14	4.35	1.28	4.08	2.36	.14	1.97	2.03	3.36	4.45	1.77	4.95	.65	1.74	2.14	4.56	1.60	44.57	2.621
July	.53	.70	4.70	.78	.56	2.17	.44	2.60	.75	.00	.25	.26	2.01	3.43	7.37	1.47	5.15	33.17	1.951
August	1.66	.07	5.89	1.48	4.01	1.58	1.42	2.44	8.34	.09	1.60	1.40	.87	7.37	7.04	.78	3.97	50.01	2.941
September	2.04	5.72	1.41	7.65	1.12	4.12	.92	4.26	2.20	4.08	1.00	1.57	2.00	3.66	3.50	4.22	.05	49.52	2.912
October	1.87	2.94	5.23	5.17	2.63	.12	2.60	7.48	2.49	.00	1.06	6.58	.80	.73	5.13	1.19	1.37	47.39	2.787
November	.00	3.64	.87	.00	.82	.07	.20	.80	1.11	.00	1.80	2.36	.00	.22	.52	.00	1.43	13.84	.814
December	.60	1.89	1.57	1.05	.00	.00	1.37	.00	.38	.05	.03	.87	.00	.24	2.70	.42	.33	11.50	.676
Annual	15.05	22.20	34.13	35.86	15.59	11.91	12.92	31.81	28.00	11.62	19.33	24.93	11.09	25.60	38.08	16.12	19.99	374.23	22.007

Rainfall 7 months in summer, April to October, inclusive, 18.65 inches or 84.75 per cent.
Rainfall 5 months in winter, November to March, inclusive, 3.357 inches or 15.25 per cent.

Table 3.—Average monthly and annual rainfall at Spur compared with that at four other points in the State.

Number years' record	Station	Inches												
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
32	Beeville	1.11	1.63	2.19	2.53	3.92	3.21	2.08	2.12	3.89	2.89	2.17	2.31	30.05
15	Denton	2.17	1.66	1.93	4.37	3.90	3.21	2.20	3.30	2.35	3.61	2.25	2.54	33.49
15	Temple	2.52	2.25	2.26	4.80	3.57	2.65	1.53	2.67	4.19	3.59	3.04	3.03	36.10
31	College Station	3.01	2.72	2.61	4.12	4.51	3.39	2.45	2.45	2.67	3.14	3.16	3.79	38.02
	Average	2.20	2.06	2.25	3.96	3.97	3.11	2.07	2.63	3.28	3.31	2.66	2.92	34.42
17	Spur	.31	.51	1.04	2.37	3.07	2.62	1.95	2.94	2.91	2.79	.81	.68	22.00

compared with the average monthly rainfall for seventeen years. Table 2 shows that most of the rainfall in this region occurs during the crop-growing season, with little or no rainfall during the winter months. The average rainfall for a period of seven months, April to October, inclusive, is 85 per cent of the total annual rainfall.

Seasonal Distribution

Seasonal rainfall is a better measure of the supply of water available to crops than total rainfall, as evidenced by the fact that localities with

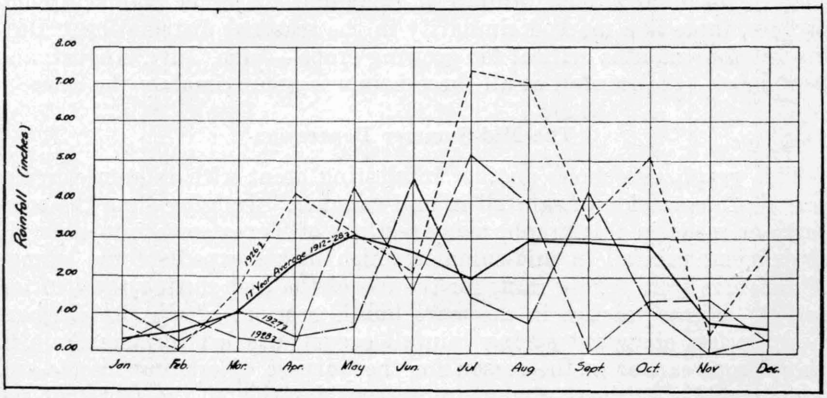

Fig. 12. Rainfall by months during the three years of this work, compared with the average for 17 years.

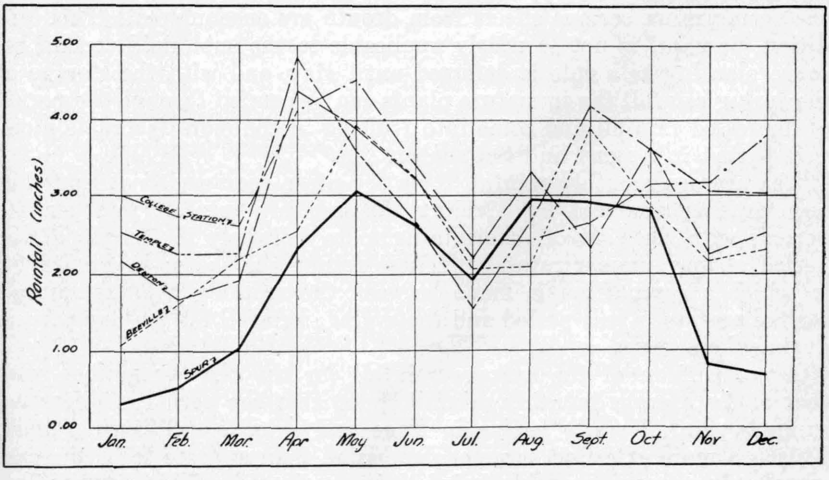

Fig. 13. Monthly rainfall at Substation No. 7 (Spur) compared with that at four other Stations.

Average of four Stations, June to September, inclusive, 11.09 inches.

Average of Spur Station, June to September, inclusive, 10.42 inches.

an annual rainfall of as much as 40 inches are frequently subject to periods when the crop suffers for lack of moisture. Only a certain amount of rain is needed to produce maximum crop yields, and when an excess occurs it may introduce many complications, such as erosion, insect depredations, deterioration of crops in the field, extra labor and costs, and numerous other harmful results.

Figure 13 illustrates the characteristic seasonal distribution of rainfall at Spur and at four other points in Texas, namely, Beeville, Denton, Temple, and College Station, where the total annual rainfall varies from 30 to 38 inches. It is noteworthy that although there is a wide difference in the total annual rainfall at Spur and the other points in comparison, there is a marked similarity in the seasonal distribution. During the four months critical for growing crops—June, July, August, and September—the rainfall at all these points is approximately the same.

The Mid-Summer Depression

This graph also shows another interesting point with reference to the period of depression of rainfall in mid-summer. Judging from the comparisons made in this graph, many sections of Texas come into a period of deficient rainfall in mid-summer which makes expedient the storage of moisture from spring rains for the use of the crop during the fruiting period. Farm practice in the more humid sections of the State, where more or less abundant spring rainfall occurs, has led farmers there to plant crops earlier in the season for the purpose of evading insects and other troubles, without giving proper consideration to the fact that the crop would normally come into fruiting during the summer depression of rainfall. Accordingly, unless water has been stored in the soil from the spring rains, serious effects from drouth are encountered. This condition, perhaps, is not so nearly applicable to the subhumid section because planting as a rule is deferred until May, and with the storage of the spring rainfall the immature plants can be carried through the period of depressed rainfall and come into fruiting in the more favorable moisture period in August and September.

The average monthly rainfall for a seventeen-year period at Spur has been further analyzed by dividing the monthly rainfall into ten-day periods with the view of determining more definitely the length of the period of low summer rainfall. These results are shown in Figure 14, in which a comparison is made between the monthly average rainfall for the seventeen-year period and the average rainfall for ten-day periods during these years.

A comparison of the average rainfall for the ten-day periods with that of the average monthly rainfall shows that the period of depressed summer rainfall really begins in June and extends well into August. This is a more extended summer depression than appears to be the case when only average monthly rainfall is considered. This further emphasizes the necessity for conserving the rather large amounts of rainfall which occur as torrential rains in the spring and which are needed to bring the plants through the period of summer depression in a healthy condition for setting a crop under favorable conditions which normally occur in August and September.

Table 4.—Rainfall at Spur in inches, by 10-day periods, 1912-1928, inclusive

Period		Monthly total, 17 years	Monthly average, 17 years	10-day total for 17 years	10-day average for 17 years calculated to 30-day period
January	1–10			2.13	.37
	11–20			1.77	.31
	21–31	5.35	.314	1.45	.23
February	1–10			1.44	.25
	11–20			3.92	.69
	21–28	8.65	.508	3.29	.72
March	1–10			4.52	.79
	11.20			4.81	.84
	21–31	17.77	1.045	8.44	1.35
April	1–10			10.84	1.91
	11–20			8.21	1.44
	21–30	40.28	2.369	21.23	3.74
May	1–10			18.26	3.22
	11–20			16.30	2.87
	21–31	52.18	3.069	17.62	2.82
June	1–10			23.82	4.20
	11–20			12.47	2.20
	21–30	44.57	2.621	8.28	1.46
July	1–10			9.33	1.64
	11–20			5.85	1.03
	21–31	33.17	1.951	17.99	2.86
August	1–10			14.89	2.62
	11–20			13.87	2.44
	21–31	50.01	2.941	21.25	3.40
September	1–10			12.93	2.28
	11–20			19.60	3.45
	21–30	49.52	2.912	16.99	2.99
October	1–10			17.03	3.00
	11–20			18.22	3.21
	21–31	47.39	2.787	12.14	1.94
November	1–10			5.26	.92
	11–20			3.52	.62
	21–30	13.84	.814	5.06	.89
December	1–10			5.59	.98
	11–20			3.32	.58
	21–31	11.50	.676	2.59	.41

It is important to adjust the seeding date to fit the supplies of moisture which exist in this region. The planting of crops on the early supplies of spring moisture is likely to result in taking the crop into the period of depressed rainfall in an advanced stage, so that it suffers more heavily and fails to produce the maximum yield. On the other hand, planting can be delayed too long or until the last peak of the spring rainfall has occurred, when the germinating seeds are subjected to drying winds and low humidity, resulting in poor stands. The optimum planting time is in May, at which time there is abundant moisture for germinating the seed and establishing vigorous young plants able to withstand the subsequent dry period and utilize the rainfall at the second peak for setting fruit and maturing a crop. Perhaps the same general principles may be applied to some extent in the humid region, but it is realized that insect depredations and other factors of such character may upset the practical utility of such a practice in a humid region.

Rains Classified as to Size

A classification of the 861 rains during the seventeen-year period according to size is given in Table 5. The total rainfall for this period was 374.23 inches, with 170.44 inches occurring in rains of less than one inch, 203.79 inches in rains greater than one inch, and 104.40 inches in rains greater than two inches. The heavier rains occurred during the growing season. Of the 35 rains of over two inches, eight occurred in June, and seven in August, with only three in July. Over 50 per cent of the rainfall during June and August occurs in rains of over two inches. Figure 15 shows the percentage of the total water losses from runoff by months with over one-third of the total occurring in August.

All the rain periods of over two inches for seventeen years, 1912 to 1928, are shown in Table 6. During this time there were three years, 1917, 1918, and 1924, that did not have a rain period of over two inches; there were four years that had only one rain period over two inches. There have been only four rain periods in the seventeen years with a total rainfall over five inches. Heavy rain periods (two inches and more) do not occur frequently, there being an average of two and one-half such rain periods a year.

Relation of Character of Rainfall to Runoff

The normal seventeen-year rainfall for July and August combined is 4.89 inches. In 1926 and 1928 the rainfall for this period was 14.41 and 9.12 inches, respectively, or 2.4 times normal. Forty-four per cent of the total runoff for the three years occurred in July and August, 1926,

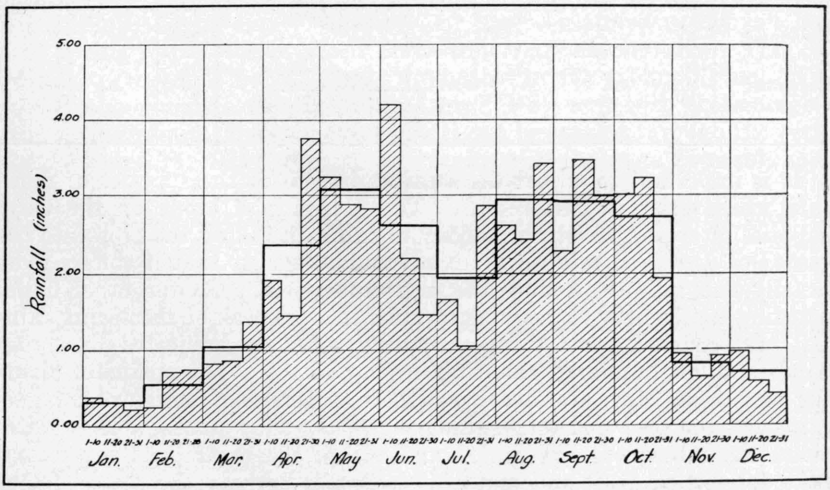

Fig. 14. The rainfall by 10-day periods showing two rain peaks in the spring, with a rather long dry period from the last of June through July and the first part of August. The depressed rainfall during the growing season emphasizes the need of storage of water in the soil at the time of spring rains, as a reserve supply for crop use in midsummer.

Table 5.—Rain periods at Spur classified according to size, 1912-1928, inclusive.

Months	Total rainfall, inches	Number of rains	Average rain, inches	Rainfall of less than 1 inch			Rainfall of over 1 inch			Rainfall of over 2 inches		
				No.	Total	Per cent	No.	Total	Per cent	No.	Total	Per cent
January	5.35	25	.214	25	5.35	100.00	0	.00	.00	0	.00	.00
February	8.65	41	.210	40	7.43	85.89	1	1.22	14.10	0	.00	.00
March	17.77	52	.341	49	13.98	78.67	3	3.79	21.32	0	.00	.00
April	40.28	82	.491	72	24.26	60.22	10	16.02	39.77	2	5.26	13.05
May	52.18	114	.457	100	24.08	46.14	14	28.10	53.85	6	17.28	33.11
June	44.57	101	.441	85	10.07	22.59	16	34.50	77.42	8	23.56	52.86
July	33.17	76	.436	68	14.79	44.58	8	18.38	55.41	3	10.85	32.17
August	50.01	98	.510	82	12.60	25.19	16	37.41	74.80	7	25.11	50.20
September	49.52	100	.495	84	21.60	43.61	16	27.92	56.38	5	11.44	23.10
October	47.39	86	.551	67	16.68	35.19	19	30.71	64.80	4	10.96	23.12
November	13.84	42	.329	40	10.99	79.40	2	2.85	20.59	0	.00	.00
December	11.50	44	.261	42	8.61	74.86	2	2.89	25.13	0	.00	.00
Total	374.23	861	....	754	170.44	....	107	203.79	....	35	104.46	....

and 16 per cent in July and August, 1928, or a total of 60 per cent for the three years has occurred in the four months—July and August, 1926, and July and August, 1928. The character of the rainfall (Tables 10, 11, and 12) was not more torrential during this period than for other periods, but the large amount of rain saturated the soil and the runoff was undoubtedly due more to the water content of the soil than it was to the character of the rains.

Table 6.—Rain periods at Spur of over two inches, 1912-1928, inclusive

1912	June 17-18	2.60	1920	May 15	2.30
1913	June 30	2.63		May 23	3.17
	September 2	2.18		August 16-23	4.62
	September 25	3.48	1921	June 2-7	3.35
	October 1-3	2.47		September 21	2.10
1914	May 29-31	7.11	1922	May 1-3	2.14
	July 3	3.65	1923	June 8-9	3.30
	August 24-30	5.13		October 13-15	4.30
	October 21-25	3.54	1924	....	....
1915	March 9-11	2.33	1925	April 24-27	4.04
	Apıil 15-18	2.07		July 28-31	3.35
	June 5-7	3.19		August 7-9	5.01
	September 21-25	5.39		September 14	2.04
	October 12-17	4.97	1926	April 20-27	3.04
1916	October 13-15	2.57		July 7-10	2.55
1917	....	....		July 25-30	4.68
1918	....	....		August 16-18	2.38
1919	March 22-24	2.35		August 28-31	2.68
	April 25-28	2.54		September 26-30	2.99
	May 7-11	2.88		October 15-16	2.22
	July 20	2.30	1927	September 25-28	2.24
	September 14-20	2.98	1928	May 13-21	3.70
	October 5-9	4.78		July 21-31	4.16
				Total	141.50

Total for 17 years, 374.23. Per cent of rainfall coming in rain period of over 2 inches, 37.81.

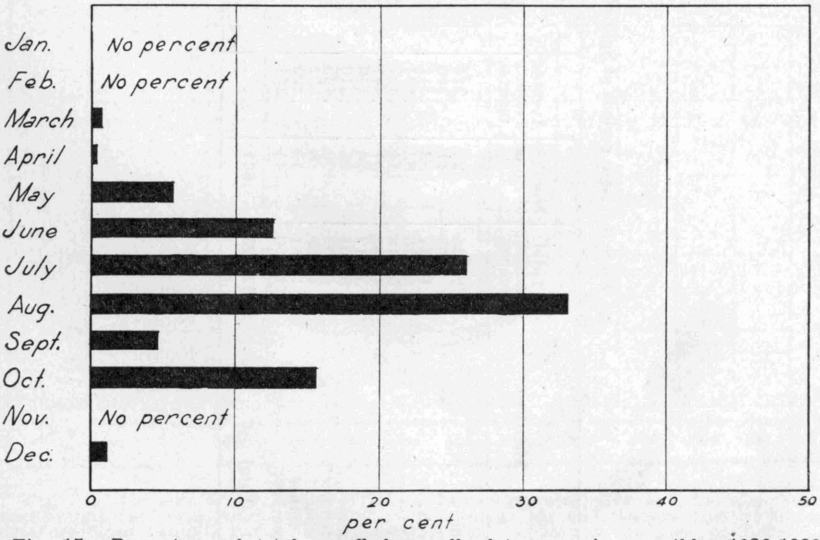

Fig. 15. Percentage of total runoff from all plats occurring monthly, 1926-1928. Over one-third of the total water losses for the year occurred during the month of August, which is the normal month for crop fruiting, and the time when the demand for water is the greatest.

The heavy rainfall in July and August of these years is unusual. The only other rain period in the seventeen years (Table 2) that approaches the heavy rains of 1926 was in May, 1914. Runoff losses occurring in July and August, 1926 and 1928, although accounting for 60 per cent of the runoff for the three-year period, did not reflect so much in crop yields as other smaller losses have when water was more of a limiting factor. The relative small losses occurring with the torrential rains of May 18 and June 11, 1928, occurring at a time when moisture was badly needed, reflected on crop yields more than the heavier losses occurring in July and August. The loss of 77 per cent of the torrential rain on July 9, 1926, would have been disastrous to the crop yield of that year had it not been for the abundant rainfall that followed.

The data have furnished evidence in abundance that runoff is influenced by the water content of the soil. On the other hand, it is a common observation of soil physicists that extremely dry soil will not absorb water so readily as soil containing a fair percentage of moisture. This law cannot be verified from data during the three years of this study, nor can specific cases be given in this period, because the water content of the soil was sufficiently large at all times to allow rapid absorption. There are, however, a number of interesting cases in other years that may be cited. In 1920 torrential rains of 1.30 inches and 2.74 inches fell on April 24 and April 27, respectively. There had been less than two inches of rainfall for the seven-month period preceding these rains. The seed bed had been prepared for spring planting, but the soil was very dry. Following these successive rains, totaling 4.04 inches, there was insufficient moisture to germinate cotton, grain sorghum, or cow peas, on plowed land and the moisture did not meet under the beds of listed land. Identically the same thing happened with a rain of 1.77 inches on June 9, 1916. Observations such as these have led to the substituting of a clod mulch for the dust mulch and for abandoning the drag harrow as a farm implement in subhumid regions, as this implement places the soil surface in a condition which is conducive to increasing runoff.

Table 7.—Influence of July and August rainfall on runoff.

Year	Total annual rainfall, inches	July and August Rainfall, Inches					Average annual runoff from eight plats
		Total	Total producing runoff	Total torrential producing runoff	Number of rains producing runoff	Average runoff from eight plats	
1926	38.08	14.41	13.91	6.44	7	4.58	6.95
1927	16.12	2.25	.92	.55	1	.03	.91
1928	19.99	9.12	6.84	4.64	8	1.64	2.59

Average rainfall July and August, 17 years, 4.89.
60.42 per cent of runoff occurring July and August, 1926 and 1928.
43.83 per cent occurred July and August, 1926.

EXPERIMENTAL DATA FROM CONTROL PLATS

Effectiveness of Rainfall

Rainfall may be classified as effective and ineffective. Effective rainfall is that which is stored in the soil and subsequently used by plants. Ineffective rainfall is that which has no value in so far as plant growth is concerned. Rainfall may be ineffective by occurring as small infrequent showers, which are lost quickly through evaporation. Other rains may be rendered largely ineffective through runoff. Rainfall may occur out-of-season for the crop grown and be partially lost through evaporation, percolation, or transpiration in weed growth before the crop has an opportunity to use it.

An attempt has been made to determine the moisture absorbed by the soil during the three years in which these studies have been in progress (Table 8). The rainfall for the three years averages 21.36 inches, of which 4.85 inches fell as small showers, and 3.63 inches were lost by runoff from cotton land with a 2 per cent gradient, leaving a balance available for plant growth of 12.88 inches. It is assumed that some part of this remainder was lost by percolation and evaporation and, accordingly, the total amount of rainfall actually used by crops was probably less than 10 inches annually. The rainfall for 1927 was six inches below normal and the ineffective light showers were numerous, so the runoff was very small. In 1926 the runoff was heavy and the ineffective showers were few. These two factors seem to have a tendency to balance each other, and it is probable that the amount of soil moisture available for plant use does not vary as widely from year to year as does the rainfall.

Table 8.—Effectiveness of annual rainfall.

Year	Rainfall, inches	Ineffective small showers inches	Lost as runoff from 2 per cent grade planted to cotton	**Effective rainfall, inches
1926*	27.99	2.50	7.13	18.36
1927	16.12	6.59	.57	8.96
1928	19.99	5.47	3.19	11.33
Average	21.36	4.85	3.63	12.88

*From June 18 to December 31, 1926.
**The amount lost through evaporation and percolation is not accounted for in these figures.

Seasonal Runoff

Attention has been called to the seasonal distribution of rainfall and its importance to crop production. The total monthly loss in water by runoff from each of the eight control plats for each of the three years in which this work has been in progress, together with the average monthly loss, is shown in Table 9. Figure 15 is a graphic representation of these losses expressed in percentages, and indicates the seasonal periods in which losses occur. It is significant that July and August

Table 9.—Runoff from control plats, in inches per month, 1926-1928.

		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Plat 1—Level.													
Cotton	1926	0	0	.00	.00	.00	.08	.07	.47	.03	.35	0	.03
Cotton	1927	0	0	.00	.00	.00	.21	.00	.00	.00	.00	0	.00
Cotton	1928	0	0	.00	.00	.12	.11	.12	.23	.00	.00	0	.00
Average	......	0	0	.00	.00	.04	.13	.06	.23	.01	.12	0	.01
Plat 2—1 per cent grade.													
Cotton	1926	0	0	.00	.00	.00	.52	2.04	2.90	.22	1.11	0	.11
Cotton	1927	0	0	.00	.00	.00	.37	.00	.00	.00	.00	0	.00
Cotton	1928	0	0	.00	.00	.50	.45	.95	.71	.00	.00	0	.00
Average	......	0	0	.00	.00	.17	.45	1.00	1.20	.07	.37	0	.04
Plat 3—2 per cent grade.													
Cotton	1926	0	0	.00	.00	.00	.57	1.89	3.22	.23	1.20	0	.02
Cotton	1927	0	0	.00	.00	.00	.57	.00	.00	.00	.00	0	.00
Cotton	1928	0	0	.00	.00	.58	.46	1.27	.87	.00	.00	0	.00
Average	......	0	0	.00	.00	.19	.53	1.05	1.36	.08	.40	0	.01
Plat 4—2 per cent grade.													
Fallow cultivated	1926	0	0	.00	.00	.00	.32	2.78	4.76	.94	3.03	0	.48
Fallow cultivated	1927	0	0	.00	.00	.00	.79	.00	.00	.68	.37	0	.00
Fallow cultivated	1928	0	0	.00	.00	.93	.56	1.63	.93	.00	.00	0	.00
Average	......	0	0	.00	.00	.31	.56	1.47	1.90	.54	1.13	0	.16
Plat 5—2 per cent grade.													
Fallow not cultivated	1926	0	0	.00	.00	.00	.46	2.65	4.74	.60	3.23	0	.40
Fallow not cultivated	1927	0	0	.38	.14	.00	1.55	.25	.00	.90	.36	0	.00
Fallow not cultivated	1928	0	0	.05	.00	1.51	.87	2.45	1.49	.00	.08	0	.00
Average	......	0	0	.14	.05	.50	.96	1.78	2.08	.50	1.22	0	.13
Plat 6—2 per cent grade.													
Buffalo grass	1926	0	0	.00	.00	.00	.47	1.66	1.77	.04	.52	0	.00
Buffalo grass	1927	0	0	.00	.00	.00	.00	.00	.00	.00	.00	0	.00
Buffalo grass	1928	0	0	.00	.00	.00	.00	.11	.09	.00	.00	0	.00
Average	......	0	0	.00	.00	.00	.16	.59	.62	.01	.17	0	.00

Table 9.—Runoff from control plats, in inches per month, 1926-1928— Continued.

		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Plat 7—2 per cent grade.													
Milo	1926	0	0	.00	.00	.00	.48	1.37	2.08	.07	1.60	0	.01
Milo	1927	0	0	.00	.00	.00	.18	.00	.00	.00	.00	0	.00
Milo	1928	0	0	.00	.00	.17	.19	.06	.42	.00	.00	0	.00
Average		0	0	.00	.00	.06	.28	.48	.83	.02	.53	0	.00
Plat 8—3 per cent grade.													
Cotton	1926	0	0	.00	.00	.00	.38	1.62	2.64	.15	.87	0	.02
Cotton	1927	0	0	.00	.00	.00	.56	.00	.00	.00	.00	0	.00
Cotton	1928	0	0	.00	.00	.53	.46	1.07	.70	.00	.00	0	.00
Average		0	0	.00	.00	.18	.47	.90	1.11	.05	.29	0	.01
Percentage of average annual runoff occurring monthly		0	0	.50	.14	5.16	12.69	26.59	33.83	4.51	15.38	0	1.16

are the two months in which the heaviest losses occur. The losses during these two months amount to 60.42 per cent of the total losses for the year. During the month of August 33.83 per cent of the total water loss occurred.

The fact that these heavy losses occur during the period when the growing crop is making its heaviest demands for moisture probably explains the marked increases that have been secured in crop yields through checking the runoff. It is rather surprising that the month of July, which is the period of low rainfall between the early June and late August peaks, should show such a heavy loss. This may be due in part to the abnormally heavy rainfall in July in 1926, and it is probable that when records for a longer period are available the average losses for July will not be so large. It is realized that a three-year average is a short period from which to draw conclusions, but the presentation of the data for this short period of time will at least indicate the trend of seasonal loss in this region.

Rapidity of Precipitation in Relation to Runoff

An attempt has been made to study runoff as influenced by the intensity of the rainfall. The self-recording rain gauge has made it possible to measure the rainfall occurring at any given period, so that the fall can be classified as to intensity. On the other hand, the runoff occurring was obtained only for the total rainfall periods, and cannot be classified for the different periods of intensity. Nevertheless, a classification of the rainfall as to its intensity has been made as follows:

(1) Torrential rainfall, including all rainfall which occurs at a rate greater than .75 inches per hour;

(2) Medium rainfall, including all rainfall which occurs at a rate between .40 and .75 inches per hour;

(3) Slow rainfall, including all rainfall which occurs at a rate of less than .40 inches per hour.

The classification of rainfall for each of the rain periods producing runoff during the three years, together with the percentage of runoff for the period for each of the plats, is shown in Tables, 10, 11, and 12.

Inasmuch as the intensity of the rain as it varied in any rain period can only be considered in connection with the total runoff for the period, it is well to point out some individual rains that may indicate the relationship between intensity of the rain and runoff. The rainfall on July 9, 1926, shown in Table 10, totaling 1.63 inches, 94 per cent of which has been classified as torrential, had an average loss from the eight plats of 77.07 per cent. This period was largely a period of torrential rainfall and with a heavy runoff. On the other hand, it is significant that this rainfall followed the day after a rainfall of .92 inches, which probably left the soil fairly well supplied with moisture and contributed to the runoff.

Table 10.—Rapidity of rainfall in relation to runoff water from control plats, 1926

Date of rain	Character of rain						Total rain-fall, inches	Per cent of water lost as runoff								Water fell on 8 plats, gals.	Water lost from 8 plats, gals.	Per cent water lost from 8 plats
	Torrential		Medium		Slow			Plat 1 0 per cent cotton	Plat 2 1 per cent cotton	Plat 3 2 per cent cotton	Plat 4 2 per cent fallow culti.	Plat 5 2 per cent fallow not culti.	Plat 6 2 per cent buffalo grass	Plat 7 2 per cent milo	Plat 8 3 per cent cotton			
	Inches	Per cent	Inches	Per cent	Inches	Per cent												
June 18	.00	0	1.20	89	.14	11	1.34	5.98	39.16	42.46	24.32	34.42	35.04	36.07	25.24	3881	1192	30.71
July 8	.00	0	.67	73	.25	27	.92	.00	.00	.00	22.52	19.51	3.75	T	T	2665	152.5	5.72
July 9	1.53	94	.00	0	.10	6	1.63	*	95.74	84.72	91.50	94.04	81.76	83.03	85.74	4721	3638.5	77.07
July 26	1.10	63	.65	37	.00	0	1.75	3.95	27.62	29.20	31.87	53.66	16.89	1.10	12.94	5039	1313	25.90
Aug. 2	.73	25	2.20	75	.00	0	2.93	4.24	19.32	18.85	22.15	21.21	15.55	11.78	19.79	8487	1410	16.61
Aug. 16	1.38	58	.90	38	.10	4	2.38	7.54	23.79	36.56	59.19	58.02	11.02	16.83	18.57	6894	1995	28.94
Aug. 24	.60	37	.00	0	1.02	63	1.62	8.52	33.25	45.18	62.23	58.82	11.08	20.46	34.95	4692	1610	34.31
Aug. 31	1.10	41	.63	23	.95	36	2.68	1.03	45.86	39.68	63.38	66.47	32.46	37.62	39.16	7762	3160	40.71
Sept. 3	.29	100	.00	0	.00	0	.29	4.76	33.33	42.86	76.19	76.19	14.29	19.05	28.57	840	310	36.90
Sept. 29	.10	4	.72	24	2.14	72	2.96	.47	4.20	3.73	24.26	13.06	.00	.47	2.33	8574	200	2.33
Oct. 4	1.15	62	.00	0	.70	38	1.85	8.96	22.39	25.38	65.69	67.93	13.44	38.82	17.17	5358	1740	32.47
Oct. 11	.80	75	.00	0	.26	25	1.06	7.81	26.06	32.57	62.53	70.35	20.84	53.42	15.63	3070	1110	36.15
Oct. 16	.00	0	.00	0	2.22	100	2.22	4.98	18.91	17.42	52.25	55.36	2.49	14.31	17.42	6430	1472	22.89
Dec. 6	.00	0	.00	0	1.67	100	1.67	1.65	6.61	1.16	28.94	23.98	.00	.83	1.32	4837	390	8.06
Total	8.78	......	6.97	......	9.55	......	25.30	....	....	....	....	....	....	....	....	73280	19693	....
Average per cent	34.70	......	27.54	......	37.74	......	....	4.08	27.31	28.20	48.74	47.78	17.65	22.24	22.47	....	....	26.87

*Plat overflowed.

Table 11.—Rapidity of rainfall in relation to runoff water from control plats, 1927

Date of rain	Character of rain						Total rain-fall, inches	Per cent of water lost as runoff								Water fell on 8 plats, gals.	Water lost from 8 plats, gals.	Per cent water lost from 8 plats
	Torrential		Medium		Slow			Plat 1 0 per cent cotton	Plat 2 1 per cent cotton	Plat 3 2 per cent cotton	Plat 4 2 per cent fallow culti.	Plat 5 2 per cent fallow not culti.	Plat 6 2 per cent buffalo	Plat 7 2 per cent milo	Plat 8 3 per cent cotton			
	Inches	Per cent	Inches	Per cent	Inches	Per cent												
Mar. 31	.83	89	.00	0	.10	11	.93	.00	.00	.00	.00	40.84	0	.00	.00	2694	137.5	5.10
April 12	.35	100	.00	0	.00	0	.35	.00	.00	.00	.00	39.46	0	.00	.00	1014	50	4.93
June 1	1.25	88	.00	0	.16	12	1.41	13.71	22.53	24.00	30.85	39.18	0	12.73	27.91	4084	872.5	21.36
June 14	.35	17	.25	13	1.41	70	2.01	T	1.37	6.18	9.62	37.10	0	.00	4.81	5822	430	7.38
June 23	.00	0	.00	0	.38	100	.38	.00	.00	.00	.00	50.88	0	.00	.00	1101	70	6.36
June 30	.48	100	.00	0	.00	0	.48	2.88	5.75	23.02	34.52	11.51	0	.00	14.39	1390	160	11.51
July 24	.55	59	.37	41	.00	0	.92	.00	.00	.00	.00	27.02	0	.00	.00	2665	90	3.37
Sept. 6	.60	46	.00	0	.72	54	1.32	.00	.00	.00	.00	18.83	0	.00	.00	3823	90	2.35
Sept. 29	1.39	62	.25	11	.60	26	2.24	.00	.00	.00	30.21	28.98	0	.00	.00	6488	480	7.39
Oct. 10	.00	0	.58	66	.30	34	.88	.00	.00	.00	12.37	40.80	0	.00	.00	2549	265	10.39
Total	5.80	......	1.45	......	3.67	......	10.92	....	....	....	....	....	....	....	....	31630	2645	....
Average per cent	53.11	......	13.27	......	33.60	......	....	1.89	3.41	5.25	16.88	32.69	0	1.64	5.12	....	....	8.36

Table 12.—Rapidity of rainfall in relation to runoff water from control plats, 1928

Date of rain	Character of rain: Torrential		Medium		Slow		Total rain-fall, inches	Per cent of water lost as runoff: Plat 1 0 per cent cotton	Plat 2 1 per cent cotton	Plat 3 2 per cent cotton	Plat 4 2 per cent fallow culti.	Plat 5 2 per cent fallow not culti.	Plat 6 2 per cent buffalo	Plat 7 2 per cent milo	Plat 8 3 per cent cotton	Water fell on 8 plats, gals	Water lost from 8 plats, gals.	Per cent water lost from 8 plats
	In-ches	Per cent	In-ches	Per cent	In-ches	Per cent												
Mar. 15	.36	100					.36	.00	.00	.00	.00	15.34	.00	.00	.00	1042.72	20	1.91
May 11			.24	100			.24	.00	.00	.00	.00	T	.00	.00	.00	695.12	0	T
May 13			.58	37.41	.97	62.58	1.55	.00	.00	.00	.00	17.81	.00	.00	.00	4489.44	100	2.22
May 15	.27	100					.27	.00	.00	3.06	12.27	32.73	.00	.00	.00	782.00	47	6.01
May 18	.98	100					.98	10.99	27.90	23.11	43.96	57.21	.00	5.63	24.80	2838.48	687	24.20
May 20	.36	45	.44	55.00			.80	1.72	25.34	43.15	58.69	74.22	.00	15.53	36.25	2317.12	750	32.36
June 4	.40	100					.40	.00	.00	.00	.00	6.90	.00	.00	.00	1158.56	10	8.63
June 11	.93	100					.93	11.87	49.00	50.48	60.88	91.32	.00	20.78	50.48	2693.68	1127.5	41.85
July 17	.78	100					.78	.00	17.70	23.01	34.52	46.03	.00	.00	15.93	2259.20	387.5	17.15
July 23	1.22	73.93	.43	26.06			1.65	3.34	22.50	32.64	46.03	79.51	.00	.00	27.62	4779.12	1265	26.46
July 24			.32	100			.32	.00	.00	.00	4.31	12.94	.00	.00	.00	926.80	20	2.15
July 30	.83	100					.83	8.31	39.93	49.91	54.90	73.20	1.66	8.31	44.92	2404.00	845	35.14
July 31	.32	100					.32	.00	34.52	43.15	43.15	43.15	.00	.00	38.84	926.80	235	25.35
Aug. 4	1.21	100					1.21	19.40	59.34	71.90	75.32	91.30	7.98	35.38	58.20	3504.64	1835	52.35
Aug. 10	.38	45.78			.45	54.21	.83	.00	.00	.00	.00	38.26	.00	.00	.00	2404.00	115	4.78
Aug. 18			.70	100			.70	.00	.00	.00	3.94	9.86	.00	.00	.00	2027.52	35	1.72
Oct. 3	.43	100					.43	.00	.00	.00	.00	19.26	.00	.00	.00	1245.44	30	2.40
Total	8.47		2.71		1.42		12.60									36,493.84	7509	
Average per cent	67.22		21.50		11.27			4.69	20.91	25.31	32.34	51.45	.87	6.90	22.99			20.57

On September 29, 1927, shown in Table 11, a rainfall period of 2.24 inches occurred, of which 62 per cent was classified as torrential rain. This rain came following a dry period of some days, the previous rain occurring on September 6. This rather heavy rain period, with more than half the rain classified as torrential, showed an average runoff loss of only 7.39 per cent for all the plats, and here again it is obvious that the moisture condition of the soil was an influencing factor. This same condition seems to have obtained for the rain period of September 6, 1927, 46 per cent of which was classified as torrential, and with a loss from only one of the eight plats. Still another rain period, June 1, 1927, totaling 1.41 inches, 88 per cent of which was classified as torrential rain, lost an average of 21.36 per cent. This relatively small loss, from a rain period essentially torrential in character, followed a period during the month of May when there was practically no effective rainfall, indicating again that the water content of the soil is a material factor in the amount of runoff resulting from torrential rains.

On August 4, 1928, a rainfall of 1.21 inches occurred, all of which was classified as torrential, and with an average runoff loss of 52.85 per cent from the eight plats. This rainfall occurred four days after a rain period and the heavy losses can be credited in part at least to the fact that the soil was fairly well filled with moisture. Torrential rains occurred on May 18, May 20, June 11, June 17, July 23, July 30, and August 4 in the year 1928, and, in all these cases, rather heavy runoff losses were recorded. It is significant that during this period there were frequent effective rains.

Table 13.—Relation of percentage of runoff to days elapsed since preceding effective rain.

Rank, according to lowest per cent runoff	Treatment	Per cent runoff		
		0-10 days between rains	11-20 days between rains	21-54 days between rains
Plat 1	Level—cotton	4.6	1.5	4.6
Plat 6	2 per cent grade—buffalo grass	11.4	7.2	0.0
Plat 7	2 per cent grade—milo	18.1	4.5	4.0
Plat 8	3 per cent grade—cotton	23.7	7.0	8.6
Plat 2	1 per cent grade—cotton	25.2	10.5	8.9
Plat 3	2 per cent grade—cotton	27.9	11.9	7.4
Plat 4	2 per cent grade—fallow, cultivated	44.8	22.8	19.1
Plat 5	2 per cent grade—fallow, not cultivated	53.1	28.2	30.6

Since the moisture condition of the soil has obviously affected the runoff, the different rains from which runoff occurred during the three-year period have been classified as to the number of days which had elapsed since the previous effective rain. On the basis of these classifications, the runoff in gallons for each of the eight control plats has been recorded, and the runoff expressed in percentages with results shown in Table 13. The results are graphically shown in Figure 16. It is obvious that in all of the plats the moisture condition of the soil as indicated by the number of days since the preceding effective rain has been a material factor in the losses. The graph also shows that the crop on the land, as it has undoubtedly influenced the moisture content of the soil, has been an influencing factor. This emphasizes the fact that the moisture content of the soil is an important factor in determining the runoff from any given rain or rain period, and it further emphasizes the necessity of measuring the inflow of water for a given rainy period in order to have comparable data as to the influence of intensity of the rainfall on runoff.

Rapidity of Precipitation in Relation to Soil Erosion

In the study of intensity of rainfall in relation to soil erosion, the same difficulties arise as apply to a study of intensity of rainfall in relation to runoff. The records classifying the rainfall in given periods as to intensity and a lack of a corresponding period classification of erosion taking place under these different intensities of rainfall, make it impossible to arrive at any definite conclusion.

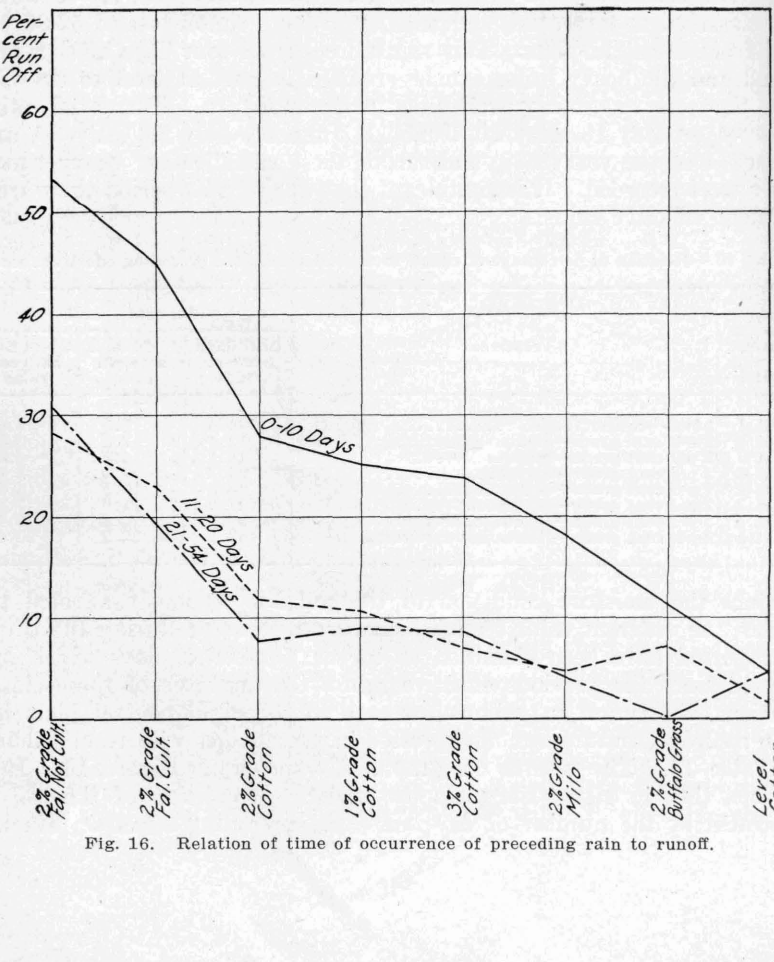

Fig. 16. Relation of time of occurrence of preceding rain to runoff.

However, by comparing the data presented in Table 14 for each of the three years, and assuming that the erosiveness was equally great for all the other rainfall as for torrential, it can be estimated that in 1926 approximately 14,000 pounds of soil per acre were lost from 8.78 inches of torrential rain; whereas in 1928 approximately the same amount of torrential rain, 8.47 inches, resulted in a loss of approximately 8,000 pounds to the acre; whereas in 1927, when the torrential rain represented about one-third of the total rainfall, a loss of only 1,000 pounds to the acre is chargeable to torrential rainfall.

The fact that, in general, 20 per cent of the total rainfall comes in ineffective showers and causes no runoff, makes actually much wider differences than these estimated differences, and altogether the results indicate that the losses from torrential rains vary widely in different seasons and perhaps are influenced to a large degree by other factors than the intensity of the fall.

Table 14.—Effect of torrential rains on erosion

Year	Total rainfall, inches	Torrential rainfall		Erosion from Plat 3, cotton on 2 per cent grade, pounds of soil per acre
		Inches	Per cent	
1926	38.08	8.78	23.06	55,896
1927	16.12	5.80	35.98	3,185
1928	19.99	8.47	42.37	17,105

Effect of Slope of Land on Runoff

Four plats are included in the series of control plats having grades of 0, 1, 2, and 3 per cent. The data secured are shown in Table 15, in which the runoff is expressed in inches per plat and in percentage.

In general, the plats with 1, 2, and 3 per cent grades have lost from five to six times more water than the level plat. The 2 per cent grade lost slightly more water than the 1 per cent grade, but the difference is not comparable to the difference between the runoff from the 1 per cent grade and that from the level plat. The 3 per cent grade in every case lost less water than the 2 per cent grade. This is probably due to the filling in of soil to establish the grade, which process left this plat in condition to absorb more water than a natural 3 per cent grade would have absorbed. Some slight filling was necessary to establish the 2 per cent grade and this may account for no greater difference in loss between the 2 per cent grade and the 1 per cent grade. Considering the fact that the soil on these grades has been in place for three years and apparently has been well settled by the repeated frequent and heavy falls of rain, it is surprising that the losses are not more nearly in proportion to the grade—in fact, these results indicate that the losses are not in direct proportion to the steepness of the grade, and that large water losses occur on areas with very little slope.

Table 15.—Influence of slope of land on runoff from plats planted to cotton, 1926-1928.

Slope	Runoff in inches*				Runoff in percentage			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Plat 1, Level	1.03	.21	.59	.61	4.08	1.89	4.69	3.55
Plat 2, 1 per cent grade	6.91	.37	2.63	3.30	27.31	3.41	20.91	17.21
Plat 3, 2 per cent grade	7.13	.57	3.19	3.63	28.20	5.25	25.31	19.58
Plat 8, 3 per cent grade	5.68	.56	2.78	3.01	22.47	5.12	22.09	16.56

*The total amount of rainfall from which runoff occurred in 1926, 1927, and 1928 was 25.30, 10.92, and 12.60 inches, respectively, with an annual average of 16.27 inches.

Table 16.—Influence of slope of land on soil erosion from plats planted to cotton, 1926-1928.

Slope	Loss per acre (pounds)				Surface soil eroded (Inches)			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Plat 1, Level	22,449	1,760	1,541	8,583	.077	.006	.005	.029
Plat 2, 1 per cent grade	41,303	3,234	11,336	18,624	.142	.011	.039	.064
Plat 3, 2 per cent grade	55,896	3,185	17,105	25,395	.190	.010	.058	.086
Plat 8, 3 per cent grade	57,342	4,588	14,788	25,572	.197	.015	.050	.087

Effect of Slope of Land on Soil Erosion

A record of the soil losses obtained from each of the control plats, established on different control gradients and all of which was cropped to cotton, is presented in Table 16. It is observed that from the average of the three years, the soil loss is twice as great from the plat with 1 per cent grade as it is from the level plat, and approximately three times as great from the plat with 3 per cent as from the plat with level grade.

There is an indication that the losses of soil are more directly in proportion to the steepness of the grade than are the water losses. These results show rather conclusively that cultivated lands with as little slope as 1 per cent are in danger of being impoverished by losses of soil and soil fertility much more rapidly than level land.

Relation of Crops to Runoff

It has long been recognized that vegetative cover is effective in retarding the off-flow of water from the land. Vegetative cover in the form of forests, grass lands, and even cultivated crops forms a natural obstruction to the movement of water. Not only is the live vegetative cover effective, but the little cover from plants further safeguards against the rapid movement of water and gives it more time to penetrate the soil.

Four of the control plats, each with a 2 per cent grade, one planted to cotton, one milo, one buffalo grass, and one fallowed, furnish some data as to the effectiveness of crops over fallowing. The results obtained for the three years in water losses from these plats are shown in Table 17.

The fallowed plat shows an average annual loss of 6.08 inches, the cotton plat an average loss of 3.63 inches, the milo plat a loss of 2.22 inches, and the grass plat a loss of 1.53 inches. The heaviest loss from both the grass plat and the milo plat occurred during the first year, the losses from these two plats being relatively small in the two succeeding years. The grass plat lost most heavily during the first year before the surface had become completely sodded. It is obvious that grass is very effective in preventing runoff.

The relatively low water loss from the milo plat is attributed to the fact that milo is a heavy user of water, and also produced a large plant growth and crop residue that retards the fall and surface movement of water. The leaf sheaths of milo form a receptacle for water and retain a portion of the rainfall which is evaporated before it reaches the soil. Milo also draws heavily upon the water supply at the time of year when the greatest amount of runoff ordinarily occurs.

Table 17.—Influence of crops on runoff from plats with 2 per cent grade, 1926-1928.

Crop	Runoff in inches*				Runoff in percentage			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Plat 3, Cotton	7.13	.57	3.19	3.63	28.20	5.25	25.31	19.58
Plat 4, Fallow	12.33	1.84	4.07	6.08	48.74	16.88	32.34	32.65
Plat 6, Buffalo Grass	4.47	0.00	.11	1.53	17.65	0.00	.87	6.17
Plat 7, Milo	5.63	.18	.87	2.22	22.24	1.64	6.90	10.26

*The total amount of rainfall from which runoff occurred in 1926, 1927, and 1928 was 25.30, 10.92, and 12.60 inches, respectively, with an annual average of 16.27 inches.

Table 18.—Influence of crops on erosion from plats with 2 per cent grade, 1926-1928.

Crop	Loss per acre (pounds)				Surface soil eroded (Inches)			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Plat 6, Buffalo Grass	22,640	0	171	7,603	.077	.000	.005	.026
Plat 7, Milo	31,733	887	1,872	11,497	.109	.003	.006	.039
Plat 3, Cotton	55,986	3,185	17,105	25,395	.190	.010	.058	.086
Plat 4, Fallow (cultivated)	81,459	6,922	23,437	37,272	.280	023	.080	.127

It is interesting to note in Table 9 the effect the condition of the growing crop has on runoff. In August, 1926, the runoff from the milo plat was 2.08 inches, and from the corresponding cotton plat, 3.22 inches. During this period the milo plant was making its greatest demand on the soil moisture. The milo plant matured and became dormant in September, while the cotton plant continued vigorous growth into October. The runoff from the milo plat in October was 1.60 inches, and the cotton, 1.20 inches.

Buffalo grass has been very effective as a cover and has practically eliminated the loss through runoff during the years 1927 and 1928. It emphasizes the importance of maintaining on grazing lands a good grass cover and indicates that heavy losses can occur on grazing lands when these are overstocked and the grass cover partially destroyed.

The fallow plat furnishes a splendid example of what is taking place on orchard lands. The cultivation and covering on orchard land, with the exception of the tree cover, is very much the same as on the fallow plat. It is obvious that the terracing of orchard lands will facilitate the absorption of water and greatly increase the chances of profitable production in farm orchards in this section.

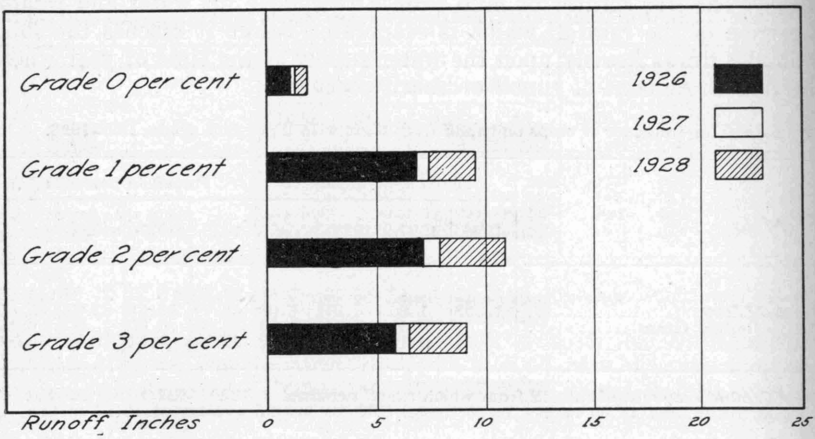

Fig. 17. Influence of slope on runoff from land planted to cotton.

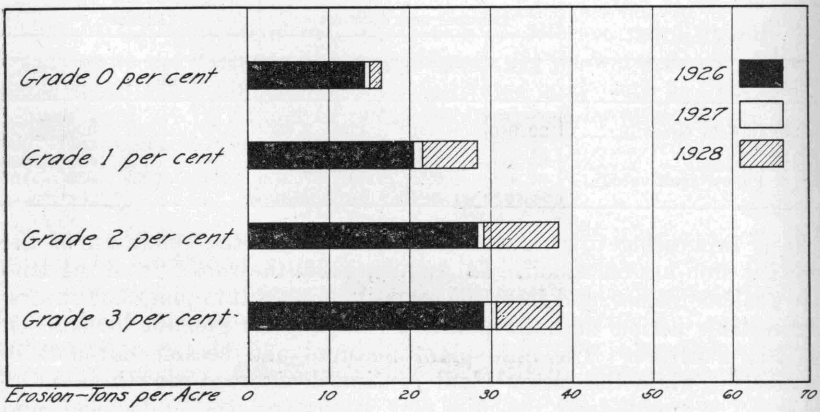

Fig. 18. Influence of slope on soil erosion from land planted to cotton.

Relation of Crops to Soil Erosion

Vegetation is a contributing factor in controlling erosion. The grass, when a solid turf has been established on the plat, has been very effective in preventing soil wastage. The plat planted to milo was second in effectiveness. It should be stated here that only the heads were harvested from the milo plat, the stalks, leaves, and roots being left to be incorporated in the soil.

The average of the three years (Table 18 and Figure 20) probably does not show the relative effectiveness of crops in checking erosion so well as the average of the last two years, since the plats during the first year were lacking in plant residues and the grass plat was not completely sodded. The average soil loss in tons per acre during 1927 and 1928

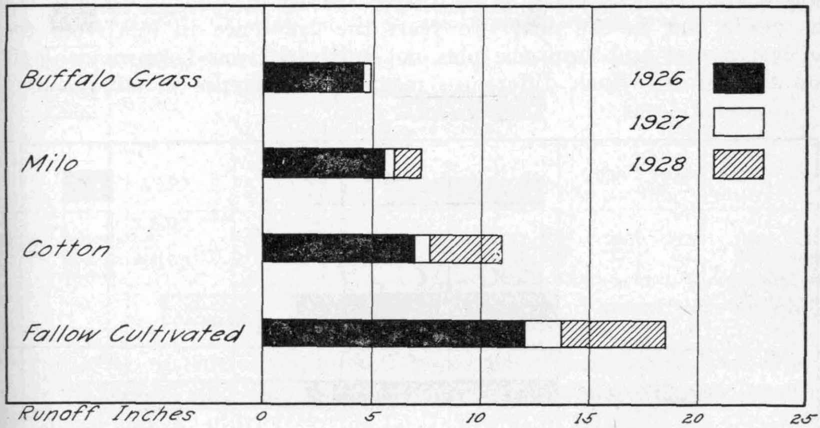

Fig. 19. Influence of crop on runoff from land with a 2 per cent grade.

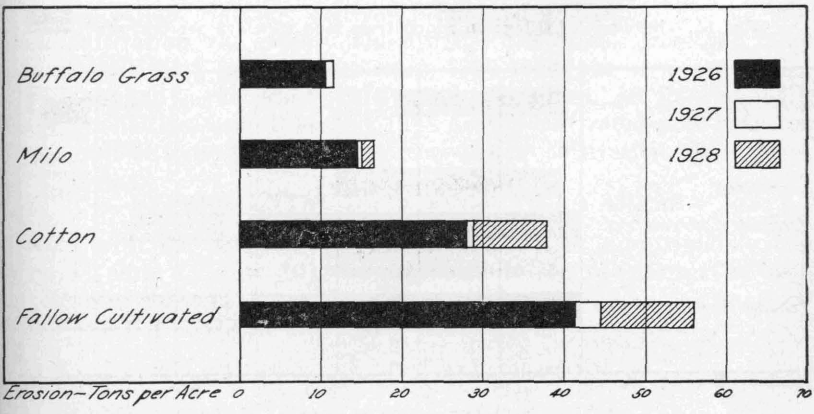

Fig. 20. Influence of crop on soil erosion from land with a 2 per cent grade.

was: Grass plat, .04; milo, .69; cotton, 5.07; and fallow, 7.59. These data are in agreement with the general opinion that constant cropping to cotton is hard on the land and indicate that the ill effects are due largely to erosional losses as well as to plant food removed with the harvested crop.

Influence of Tillage on Runoff

Two control plats, both with a 2 per cent grade, were fallowed, one cultivated and one not cultivated. Both plats, however, were kept free from weeds. The soil of the cultivated plat was spaded when the other plats in the series were prepared. Subsequently cultivation was given from time to time in the same manner as the plats on which crops were grown. The water losses recorded from each of these plats are shown in Table 19. During the first year there was little difference in the runoff from the two plats, as both were spaded in June in establishing the grade, but in the next two years the difference in loss from the cultivated plat and from the plat not cultivated was between one-half and two-thirds. Such differences mean the difference in storage of a

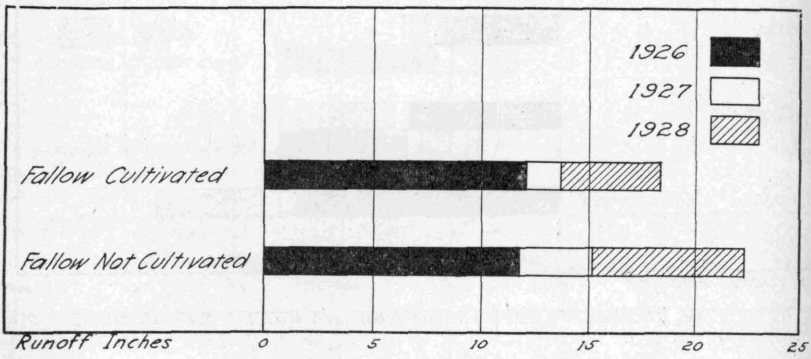

Fig. 21. Influence of tillage on runoff from land with a 2 per cent grade.

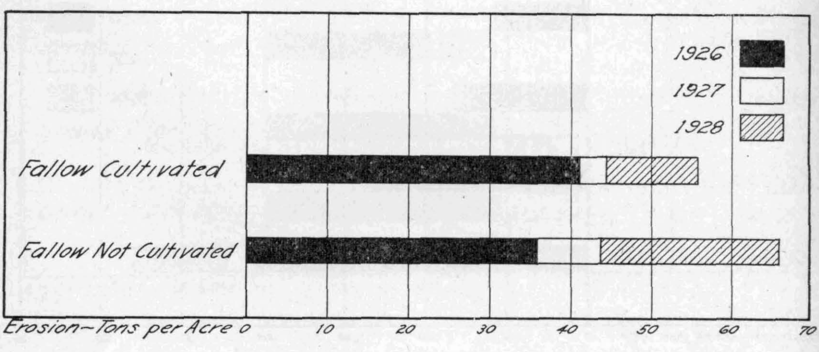

Fig. 22. Influence of tillage on soil erosion from land with a 2 per cent grade.

considerable amount of water and indicate the importance of preparing land and thus putting it in the best condition to absorb rainfall.

Figure 21 shows graphically the results secured in each of the three years in runoff from the two plats.

Table 19.—Influence of tillage on runoff from plats with 2 per cent grade, 1926-1928.

Treatment	Runoff in inches*				Runoff in percentage			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Fallow, Cultivated	12.33	1.84	4.07	6.08	48.74	16.88	32.34	32.65
Fallow, not cultivated	12.09	3.57	6.48	7.38	47.78	32.69	51.45	43.90

*The total amount of rainfall from which runoff occurred in 1926, 1927, and 1928 was 25.30, 10.92, and 12.60 inches, respectively, with an annual average of 16.27 inches.

Table 20.—Influence of tillage on erosion from plats with 2 per cent grade, 1926-1928.

Treatment	Loss per acre (pounds)				Surface soil eroded (Inches)			
	1926	1927	1928	Av.	1926	1927	1928	Av.
Fallow, cultivated	81,459	6,922	23,437	37,272	.280	.023	.080	.127
Fallow, not cultivated	77,301	13,664	39,743	40,269	.256	.047	.136	.146

Influence of Tillage on Soil Erosion

The effect of cultivation on soil losses, as determined on two fallow plats (Table 20 and Figure 22), one being spaded in the spring and cultivated and the other receiving no treatment at all, with the exception of having weeds pulled up or clipped with a hoe, is not in accord with general opinion or findings in other erosion studies. The soil losses from the fallow plat not cultivated have been greater than on plats where cultivation was given. The average loss of soil from the fallow plat not cultivated for the three years, 1926-1928, has been over 20 tons of soil annually, and where cultivation was given, 18 tons annually. The erosional losses in 1927 and 1928 on the cultivated plat have been 57 per cent of those from the plat receiving no cultivation.

EXPERIMENTAL DATA FROM FIELD AREAS

Work with the field areas, which varied in size approximately from 5½ to 11 acres (Figure 10), was included to secure information as to the effect of preventing runoff on crop yields.

The study is classified under four headings:

1. Effect of field obstructions on runoff and crop yields;
2. Relation of terrace spacings to runoff and crop yields;
3. Relation of grade of terrace to runoff and crop yields;
4. Maximum utilization of rainfall as affecting crop yields.

Effect of Field Obstructions on Runoff and Crop Yields

The influence of obstructions on runoff is shown by comparing the results from Area 2, which had rows running with the slope; Area 1, which had contour rows; Area 6, which had two-foot fall between level terraces; and Area 7, which was diked so that no water could run off.

The results secured in measuring the water losses from these areas are shown in Table 21. The water losses in 1927 were low on all areas, and the crop yields as shown in Table 22 are in accord with these losses, though the differences are not very great.

The relative losses in 1928, however, are not consistent either with our knowledge of the effectiveness of obstructions in retarding water, or with the crop yields for 1928 shown in Table 22. This inconsistency, which occurs particularly in comparing Areas 1 and 2, can be explained by the fact that the long rows running with the slope on Area 2 permitted the concentration of water on the lower part of the area. This movement of water left the land at the upper end of the area in a smooth condition and with a large proportion of sand particles on the surface, a condition favorable to destructive wind effects. On June 9, a sand storm occurred, resulting in heavy damage to the young cotton plants on the upper part of this area, not correspondingly heavy on other areas. The diked border at the lower end of Area 2 held much of the water that fell on this area, resulting in an exceedingly good crop on that part of the area to balance the damaged crop on the upper part of the area and introducing a source of error which affects these results. This same condition did not occur on Area 1, where the rows were contoured and where the water was evenly distributed.

Table 21.—Runoff in inches and percentages from field areas, as influenced by obstructions, 1927-1928.

Area	Treatment	Runoff, percentage			Runoff, acre-inches		
		1927	1928	Average	1927	1928	Average
2	Rows running with slope...	6.75	38.22	22.48	.3822	2.882	1.632
1	Contoured rows...........	2.59	49.74	26.17	.1469	3.727	1.936
6	2-ft. fall between level terraces..............	1.99	11.47	6.73	.1128	.860	.486
7	Diked.....................	0.00	00.00	0.00	.0000	.000	.000

Table 22.—Influence of obstructions to runoff on crop yields from field areas, 1927-1928.

Area	Treatment	Yield, pounds of seed cotton		
		1927	1928	Average
2	Rows running with slope........................	646	156	401
1	Contoured rows.................................	648	300	474
6	2-ft. fall between level terraces..................	611	466	538.5
7	Diked..	753	586	669.5

The acre yields from the different areas shown in Table 22 indicate in a general way the relative values of the different kinds of obstructions. The yield of 156 pounds of seed cotton in 1928 on Area 2 is low, due to the damage resulting from the sand storm.

The trend of these results indicates the effectiveness of obstructions in preventing runoff and the resultant increase in crop yield due to the saving of water.

Two other areas, each containing 4.58 acres, one level-terraced and with contoured rows and the other without terraces and with rows running with the slope, showed an average acre yield of 952 pounds and 669 pounds of seed cotton, respectively. These areas, however, were not equipped with measuring devices, and it was impossible to secure a record of the water lost.

Area 7, which was diked to hold all water, has been exceptionally interesting. The months of June and July, 1927, and May, July, and August, 1928, had abnormal rainfall. The soil on this area absorbed the water from these heavy-rain periods without apparent damage to the growing crop. Soils and subsoils having an open structure, such as these soils have, allow a rapid infiltration and can store large amounts of water for subsequent use by plants.

Relation of Terrace Spacings to Runoff and Crop Yields

Field Areas 3, 6, and 4, containing approximately 11, 6, and 10 acres, respectively, were all terraced; the terraces were run on contour lines but were given a fall of one, two, and three feet, respectively, between the terraces. The results for the two-year period are shown in Table 23. The cotton yields from these same plats are shown in Table 24. These results are directly contrary to what would be expected, and the yields secured from each of the three areas seem to conform closely to the amount of water saved.

Table 23.—Runoff in inches and percentages from field areas, as influenced by terrace spacing, 1927-1928.

Area	Treatment	Runoff, percentage			Runoff, acre-inches		
		1927	1928	Average	1927	1928	Average
3	1-ft. fall between level terraces	6.49	35.90	21.19	.3675	2.692	1.529
6	2-ft. fall between level terraces	1.99	11.47	6.73	.1128	.860	.486
4	3-ft. fall between level terraces	0.00	19.60	9.80	.0000	1.432	.716

These three areas are not uniform with reference to the natural slope of the land and soil. By referring to the map of the field areas (Figure 10), it is noted that Areas 3 and 6 are on the crest of the field and that Area 4 is much better adapted with reference to soil and topography.

Accordingly, observations of the movement of water over these areas during the two years lead to the conclusion that the areas are not comparable. The experiment will have to be revised to eliminate these sources of error. It is contemplated to duplicate these areas in another part of the field and to add a number of other areas for the purpose of checking the reliability of the results accruing from the series involved.

Table 24.—Influence of terrace spacing on crop yields from field areas, 1927-1928.

Area	Treatment	Yield, pounds of seed cotton		
		1927	1928	Average
3	1-ft. fall between level terraces..................	590	297	443.5
6	2-ft. fall between level terraces..................	611	466	538.5
4	3-ft. fall between level terraces..................	602	356	479

Relation of Grade of Terrace to Runoff and Crop Yields

Areas 6 and 5 furnish a comparison of terraces that have a slope of three inches in 100 feet with terraces built on a level. These two areas are each approximately six acres in size and are located on an almost ideal slope for such comparative work. Table 25 shows the amounts of water lost from each of these areas for each of the two years. It is observed that approximately four times more water was lost on the terraces that had a fall than on the terraces that were constructed on the level. The average runoff from Area 6 in 1927 and 1928 was .486 inches and from Area 5, 1.815 inches; that is, the level terraces held 1.329 inches more rain water than did the terraces with a slope. The differences in cotton yields are significantly in favor of the level terraces (Table 26).

Table 25.—Runoff water in inches and percentages from field areas, as influenced by terraces with and without fall, 1927-1928.

Area	Treatment	Runoff, percentage			Runoff, acre-inches		
		1927	1928	Average	1927	1928	Average
6	2-ft. fall between level terraces.............	1.99	11.47	6.73	.1128	.860	.486
5	2-ft. fall between terraces with 3-in. fall.........	9.90	40.94	25.42	.5602	3.070	1.815

The terraces were built on Areas 5 and 6 in 1926, but the equipment for measuring runoff was not installed until 1927. The acre yield of seed cotton in 1926 on Area 6, having level terraces, was 683 pounds; and Area 5, having a slope of three inches in 100 feet along the terrace, produced 609 pounds of seed cotton to the acre. The increased yield from the area having level terraces over the area having terraces with a slope of three inches in 100 feet on the terrace, in 1926, 1927, and 1928, was 74 pounds, 79 pounds, and 173 pounds of seed cotton per acre, respectively, with an average for the three years of 109 pounds of seed cotton per acre in favor of the level terraces. This average yield is not surprising in view of the additional water saved. It is commonly known that a small rain at the critical time often materially increases the yield.

Table 26.—Influence of terraces with and without fall on crop yields from field areas, 1927-1928.

Area	Treatment	Yield, pounds of seed cotton			
		1926	1927	1928	Average
6	2-ft. fall between level terraces.......	683	611	466	587
5	2-ft. fall between terraces with 3-in. fall..........................	609	532	293	478

Maximum Utilization of Rainfall as Affecting Crop Yields

Since the conservation of rainfall is desirable in this region, it seemed well to include some field areas on which all of the rainfall was retained for comparison with some other field areas which received not only the rainfall but had definite amounts of water diverted from other areas to supplement the rainfall.

Accordingly, a group of four field areas was established. These included Field Areas 7 and 8, planted to cotton and alfalfa, respectively, both equipped with closed terraces on contours, and Field Areas 9 and 10, planted to cotton and alfalfa, respectively, both equipped with borders and a system of diversion terraces designed to save not only the rainfall but to take care of additional measured water diverted into these areas (Figure 10).

It was realized that such a practice might require considerable alterations in these diversion terraces and obstructions before these areas could be expected to handle most efficiently the rainfall and additional measured water diverted onto them. However, both of the crops used, cotton and alfalfa, are heavy users of water. This is especially true of alfalfa, which is an ideal crop to utilize water diverted from other areas, not only because it uses water practically throughout the year, but because alfalfa is usually planted on areas where runoff water is available.

The four field areas, 7, 8, 9, and 10, were established in 1927, 7 and 9 put into operation in 1927, and 8 and 10 in 1928. Records were secured as to the effectiveness of closed terraces built on contours from Areas 7 and 8 in both 1927 and 1928, with the result that no losses of water from rainfall occurred on either of these areas, either in 1927 or 1928, showing that under such conditions as obtained in those years the use of contoured terraces on such slopes can be made effective in preserving all the rainfall. Records of crop yields for 1927 and 1928 were secured from Area 7 planted to cotton with yields amounting to 753.04 and 586.66 pounds of seed cotton to the acre, for the two years, respectively.

The effectiveness of closed terraces built on contours in terms of crop yields is shown by the fact that in 1927 the yield of cotton from Area 7, so equipped, was 169 pounds of seed cotton per acre greater than the average yield of cotton on the four field areas equipped with open terraces, and 233 pounds greater than the average of the four same field areas for 1928. Field Area 9, planted to cotton and equipped with borders and a system of diversion terraces, was designed to prevent any water loss from runoff and during the year 1928 received a measured amount of 4.99 acre-inches of water per acre from other areas. This amount of water was sufficient to cause breakage in the borders and terraces, and a loss of part of the diverted water during 1928. This breakage caused inaccuracies in both the rainfall saved and the additional water supplied. This area produced a yield of 441 pounds of seed cotton to the acre in 1928, or 88 pounds more than the average yield of the four plats equipped with open terraces. Such differences as these indicate the possibility of the use of closed terraces built on contour lines in subhumid regions.

Field Areas 8 and 10 were planted to alfalfa in September, 1928, but notes on yields were not secured although there was an observable difference in the crops on the two areas in favor of Area 10, which received 2.73 acre-inches per acre diverted runoff from other areas. This area produced four cuttings as against three cuttings from Area 8, which received only the rainfall, and there was a marked difference in the

Fig. 23. A broad-base terrace under construction. This terrace is 24 feet wide at the base and is two feet high. Crops can be grown on top of this terrace and it can be planted and cultivated with two-row implements.

growth on the two areas for each of the cuttings, again indicating the feasibility of using diversion water in growing alfalfa.

Field Area 10, like the corresponding area, 9, planted to cotton, developed some breaks in the border terraces, and lost a considerable amount of water, nullifying the records as to the amounts of water actually retained on the land. The system of diversion terraces on both Areas 9 and 10 is imperfect in the retention of rainfall and equal distribution of water brought in, and accordingly, the perfection of these diversion terraces is one of the problems to be studied and improved through experience. Observations made thus far on these areas, both as to the amount of water retained and the resultant increased crop growth, indicate the importance of developing this series in order to get definite and reliable information as to the feasibility and profitableness of impounding runoff for use in crop growth.

Fig. 24. A broad-base terrace in a cotton field. This terrace was constructed in March, 1928, and the picture was taken in December. The best cotton in the field was made on top of the terrace and on the rows just above the terrace.

The solution of the problem lies in devising some system to bring the water onto the land with reduced velocity, and even distribution of this water over the area, thus allowing the maximum absorption and reducing the chance of breakage in the diked borders and the consequent loss of water. The construction thus far has been inadequate to accomplish these ends, and it is felt that such a system can be worked out only by means of the trial-and-error method preparatory to studies of the effect of application of such additional water on crop yields.

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SUMMARY

Since water is the chief limiting factor in crop production in the subhumid region of Texas, the study of the rainfall, its character, seasonal distribution, and means of increasing the amount absorbed by the land, and measuring the effects of such moisture conservation on crop yields, is of the greatest practical importance to the region.

The plan of the work reported in this publication relates to the study of factors contributing to losses of rainfall water and soil and the effects of conservation of rainfall water and soil on crop production.

The results reported were obtained at Substation No. 7, near Spur, Dickens County, Texas, located in the Rolling Plains region of Northwest Texas. The soil on which this work was done is Miles clay loam and the results are considered as directly applicable to parts of 44 counties and approximately 14,000,000 acres of land of the Miles and Abilene and related series and indirectly applicable to all of the subhumid portion of Texas.

The equipment used in this work consists of a complete set of meteorological instruments, a series of control plats equipped with tanks to catch the runoff water and eroded soil, and a series of field areas 5 to 11 acres in size, six of which are equipped with still ponds, weirs, and water-stage recorders for measuring the losses of water.

The average rainfall at Spur for a period of 17 years shows that 85 per cent of the total rainfall comes during the growing season for summer crops. The monthly distribution of rainfall shows two rain peaks, one in May and one in September, with a period of depression in July.

A comparison of the distribution of the rainfall at Spur and at four other stations in Texas shows a similarity in rain peaks and in the summer period of depressed rainfall.

A study of the distribution of the rainfall at Spur by 10-day periods

shows that the period of depressed rainfall begins in June and extends to August.

A classification of the rains for 17 years as to size shows that 45 per cent of the total rainfall occurred in rains less than one inch in size and that the remaining 55 per cent was approximately equally divided between rains of one to two inches and rains of over two inches.

Approximately 20 per cent of the total rainfall has been ineffective because it has occurred in small showers, another 20 per cent was lost as runoff, leaving approximately 60 per cent of the total rainfall to be absorbed by the soil.

Measurements of the water lost from the eight control plats for the three-year period show that 60 per cent of the total water losses occurred during the months of July and August and in August alone 33 per cent of the losses occurred.

Studies of the influence of the intensity of rainfall on runoff indicate that other factors such as moisture content of the soil at the time of rainfall exert considerable influence on the losses, requiring additional refinements in methods and procedure for conclusive results.

The intensity of the rainfall seems to have the same relation to erosion that it has to the losses of water by runoff and requires the same methods for further study.

The results indicate that runoff losses are not in direct proportion to the steepness of the grade, but that tremendous water losses occur on areas with very little slope.

The results indicate that losses of soil by erosion are more directly in proportion to the steepness of the grade than is the case with water losses and that slopes with as little as 1 per cent grade are in danger of being impoverished rapidly by soil erosion.

Grass was found to be an effective vegetative cover in retarding the off-flow of water. Milo is more effective than cotton and cotton more effective than fallow. The efficiency of a crop is partially due to its coverage and partially due to its removal of water from the soil, which in turn affects the absorption of water.

The results indicate that vegetative cover is a contributing factor in controlling erosion, the losses of soil being in proportion to the effectiveness of the crops as a vegetative cover and its use of water. The soil losses were in direct proportion to the water losses.

Tillage of land as compared with untilled fallow land in conserving water shows that the losses from the tilled plats were from one-half to two-thirds as much as from the plats not cultivated and that the soil losses as influenced by tillage were approximately in the same proportion.

Results from field areas as to the effectiveness of obstructions in preventing runoff and in increasing crop yields were not consistent, but in general indicate that considerable amounts of water can be saved by the use of contoured rows, level closed terraces, and dikes, and that the crop yield is in proportion to the amount of water saved.

Results as to the influence of spacing between terraces on runoff and crop yields are inconclusive.

The results where level terraces were compared with terraces built with a fall of three inches in 100 feet have consistently shown that level terraces are much more effective in saving water and the level-terraced area has shown an average annual yield of 109 pounds of seed cotton to the acre more than where the terrace had a fall of three inches in 100 feet.

Studies relating to utilization of rainfall and its effects on crop yields indicate that under the conditions in this region all of the rainfall can be retained on land planted to cotton and alfalfa by the use of closed level terraces. The work also indicates that in special cases from two to four inches of additional water can be applied to the land by means of diversion terraces, but this requires the perfection of some system to spread and retain the water on the land. Preliminary observations made as to the results in crop yields indicate that alfalfa, and perhaps cotton, can utilize additional water advantageously.