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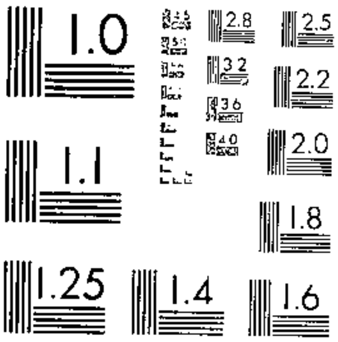

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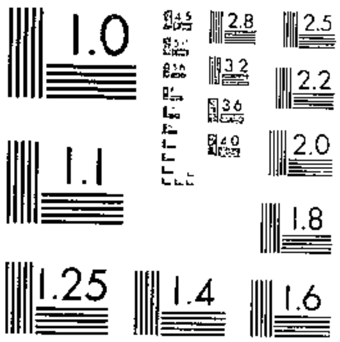

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Technical Bulletin No. 837 • January 1943

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Investigations In Erosion Control and Reclamation of Eroded Land at the Red Plains Conservation Experiment Station, Guthrie, Okla., 1930–40[1]

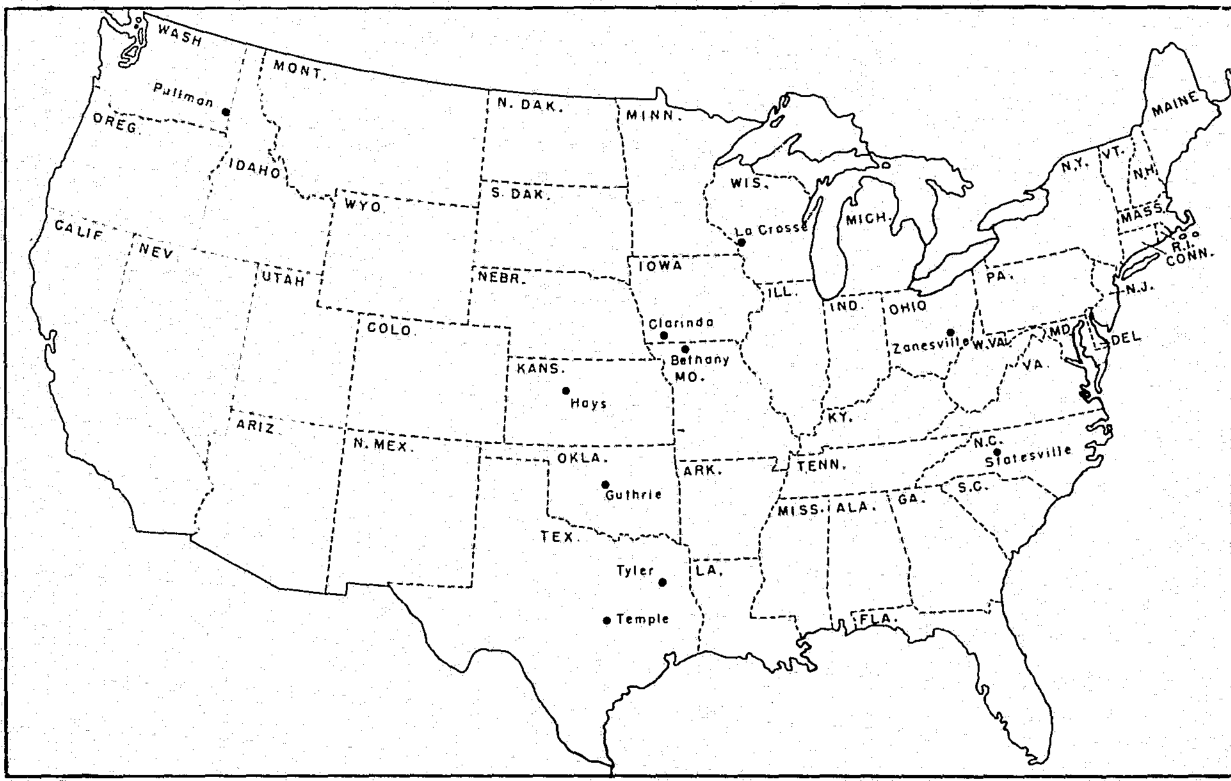
By HARLEY A. DANIEL, *project supervisor*, HARRY M. ELWELL, *assistant soil conservationist, and* MAURICE B. COX, *assistant agricultural engineer and cooperative agent, Soil Conservation Service*[2]

THE UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, IN COOPERATION WITH THE OKLAHOMA AGRICULTURAL EXPERIMENT STATION

CONTENTS

[1] Submitted for publication April 14, 1942.

[2] Former members of the station staff who contributed to the plans of the station and the development of its program are L. A. Jones, C. E. Ramser, the late S. W. Phillips, H. G. Lewis, J. W. Slosser, H. S. Riesbol, P. C. McGrew, H. E. Berrschneider, Ira T. Goddard, and W. O. Kincannon. Other investigators of the Soil Conservation Service and the Oklahoma Agricultural Experiment Station who aided in the work include H. H. Bennett, A. G. McCall, F. G. Bell, N. E. Winters, H. F. Murphy, H. J. Harper, and B. F. Kiltz.



Map of the United States showing location of 10 soil conservation experiment stations.

INTRODUCTION

This publication is the first of a series of reports designed to cover the first decade of experimental work at the 10 original soil erosion experiment stations established with funds appropriated by the Congress and carried in the appropriations for the United States Department of Agriculture.

On December 18, 1928, the Buchanan amendment to the agricultural appropriation bill for the fiscal year 1930, appropriating $160,000 for soil-erosion investigations, was adopted by the House of Representatives. The language of the amendment was as follows:

> (39) Soil-erosion investigations: To enable the Secretary of Agriculture to make investigations not otherwise provided for, of the causes of soil erosion and the possibility of increasing the absorption of rainfall by the soil in the United States, and to devise means to be employed in the preservation of soil, the prevention or control of destructive erosion and the conservation of rainfall by terracing or other means, independently or in cooperation with other branches of the Government, State agencies, counties, farm organizations, associations of business men, individuals, $160,000 of which amount $40,000 shall be immediately available.

Plans were developed for the establishment of experimental work on lands representative of large problem areas of eroding land in various parts of the country. Eventually, 10 experiment stations were organized to serve the areas (see frontispiece):

(1) Near Guthrie, Okla., to serve the Red Plains of Texas, Oklahoma, and Kansas: mainly red plains soils, chiefly residual from sandstone and shale, partly timbered.

(2) Near Temple, Tex., to serve the Texas Black Belt: prairie soils from chalk and marl.

(3) Near Tyler, Tex., to serve the Texas-Arkansas-Louisiana sandy lands region: from sedimentary deposits of coastal plain, timbered.

(4) Near Statesville, N. C., to serve the Piedmont: residual timbered soils from igneous rocks.

(5) Near LaCrosse, Wis., to serve Southwestern Wisconsin region: chiefly from loessial deposits, prairie and timbered.

(6) Near Bethany, Mo., to serve Missouri-Iowa-Kansas-Nebraska region: mainly prairie soils from glacial deposits.

(7) Near Hays, Kans., to serve Western Kansas-Nebraska region: plains soils residual, chiefly from limestone, sandstone and loess.

(8) Near Zanesville, Ohio, to serve Appalachian Mountains: residual timbered soils, chiefly from sandstone, shale, and conglomerate.

(9) Near Pullman, Wash., to serve Palouse Wheat Belt: bunchgrass soils, chiefly from loessial deposits.

(10) Near Clarinda, Iowa, to serve Missouri Valley loess area: chiefly from loessial deposits, prairie and timbered.

The research programs of the stations were designed to investigate causes, rates, and effects of erosion and to determine the most effective and practical methods of checking and controlling soil and water losses from agricultural lands. This included principally: (1) experiments with various types of vegetative cover, soil treatments, and cultural and cropping systems and row direction to determine their comparative effectiveness in preventing erosion and conserving rainfall; (2) studies of the performance of terraces (*19*, p. 5)[3] and check dams of different designs in controlling run-off without injury to soil and crops, as well as their performance in storing rainfall in the soil and substrata; (3) reclamation and revegetation of severely eroded land; (4) determination of comparative productiveness of topsoil and corresponding subsoil, together with methods of subsoil rehabilitation for crop use; and (5) the keeping of meteorological records. The investigations were carried on in cooperation with the State agricultural experiment stations.

In April 1935 the first Soil Conservation Act (Public No. 46) was passed by Congress. By this legislation the National Government was definitely committed to the policy of soil and water conservation, and provision was made for the establishment of the Soil Conservation Service in the Department of Agriculture. The stations, at this time, became an integral part of the research activities of the Service.

In 1929 the first of these field stations was established near Guthrie, Okla. (*5*, *23*) and the experimental work was organized by H. H. Bennett (*2*, *3*, *4*), at that time in charge of soil erosion investigations in the Bureau of Chemistry and Soils, and now Chief of the Soil Conservation Service, in cooperation with S. H. McCrory, Chief of the Division of Agricultural Engineering, Bureau of Public Roads, the late C. P. Blackwell, then Director of the Oklahoma Agricultural Experiment Station, and the Guthrie, Okla., Chamber of Commerce.

Several articles covering certain phases of the work of the station have appeared from time to time[4] (*7*, *10*, *11*) and summaries of progress of work during the first 5 years were made available for technicians.[5,6] The original experiments, however, extended through 1940, and this report records and interprets the data for the entire period of experimentation. Preliminary to discussion of the data the area and the station farm are briefly described.

THE AREA

The Red Plains area includes approximately 36 million acres of land in central and western Oklahoma and north and northwest-central Texas east of the High Plains, with a small part in south-central Kansas. The topography ranges from nearly level areas in the western part to rolling and broken land along the eastern edge, with slopes of from 8 to 15 percent along the larger streams.

Originally this area was under a cover of big and little bluestem, grama, buffalo grass, and other grasses, which afforded excellent

[3] Italic numbers in parentheses refer to Literature Cited, page 93.

[4] SLOSSER, J. W. COMPILATION OF RAINFALL AND RUN-OFF FROM THE WATERSHEDS OF THE RED PLAINS CONSERVATION EXPERIMENT STATION, GUTHRIE, OKLAHOMA, 1931–38. U. S. Soil Conserv. Serv. SCS-TP-32, 40 pp., plus charts and tables, illus. 1940. [Processed.]

[5] LEWIS, H. G., and RIESBOL, H. S. OUTLINE OF INVESTIGATIONS IN SOIL-EROSION CONTROL AND BRIEF SUMMARY OF PRINCIPAL RESULTS, 1930–35, RED PLAINS SOIL-EROSION EXPERIMENT STATION, GUTHRIE, OKLA. U. S. Soil Conserv. Serv. SCS-EP-7, 18 pp. illus. 1935. [Processed.]

[6] HILL, H. O., ELWELL, H. M., and SLOSSER, J. W. PROGRESS REPORT, 1930–35, RED PLAINS SOIL CONSERVATION EXPERIMENT STATION, GUTHRIE, OKLA. U. S. Soil Conserv. Serv. ESR-3, [42] pp., illus. 1937. [Processed.]

pasturage, but with the introduction of agriculture most of this cover disappeared. Some of the eastern portion of the area, lying in Oklahoma, supports a growth of blackjack and post oak, and the part in Texas has some mesquite, but the western part except along the main drainageways is mainly treeless.

Most of the area lying in Oklahoma was opened for settlement in 1889 and 1892 (*18, p. 4*), and the parts in Texas and Kansas were settled several years before. Pioneers broke the virgin sod and plowed parallel with land lines established when the territory was sectionized, and as this method of cultivation gave no consideration to direction of slope, many of the farms were cultivated up and down hill, and slopes as steep as 15 percent were planted. Very little attention was paid to rotation of crops, renewal of soil fertility, or pasture management, and after about 35 to 45 years of these land use practices, erosion has forced the more sloping shallow soils out of cultivation.

Two types of farming prevail in this area. Small grain crops, mainly wheat, predominate in that part lying in Kansas and northern Oklahoma, and row crops, principally cotton, in the more southern and larger part. General farming with livestock is followed in the rougher portions.

The soils, mainly residual from the underlying sandstones and shales, are in general highly erodible. Figure 1 shows the extent of erosion in the area as determined by the survey of the Soil Conservation Service in 1934. About 1 million acres have been completely destroyed by gullies, 14 million have lost 75 percent of the topsoil, 11 million have lost 25 to 75 percent of the topsoil, and 2 million are wind-eroded. Erosion is more serious on the light- to grayish-brown soils of the more rolling, or steeper, slopes, usually underlain by reddish sandy clay and brownish-red sandstones. Outcrops of rock are common on this land. The dark-brown to brown soils of the broad divides and gently sloping areas, underlain by fairly friable subsoils or by subsoils more compact and semi-impervious to water are less affected.

The rainfall ranges from about 20 inches in the western part to 35 inches in the eastern, though most of the area falls within the 25- to 30-inch belt. The erratic distribution of rainfall throughout the year presents a wide variety of problems. In the eastern part of the area erosion-control measures must be designed to dispose of runoff in such a way that it will not cause excessive erosion, whereas in the western part methods must be devised to conserve rainfall for crop production.

The winters as a whole are mild but are characterized by sudden changes in temperature. Temperatures below zero are not common and are usually of only a few hours duration. The soil rarely freezes below a depth of 3 to 6 inches and generally remains frozen only a few days. Snowfall is comparatively light. The summers are hot, and at times there are hot, dry winds. The frost-free period, or time from the last killing frost in spring until the first frost in fall, ranges from about 175 to 200 days, which is ample time for most crops to mature.

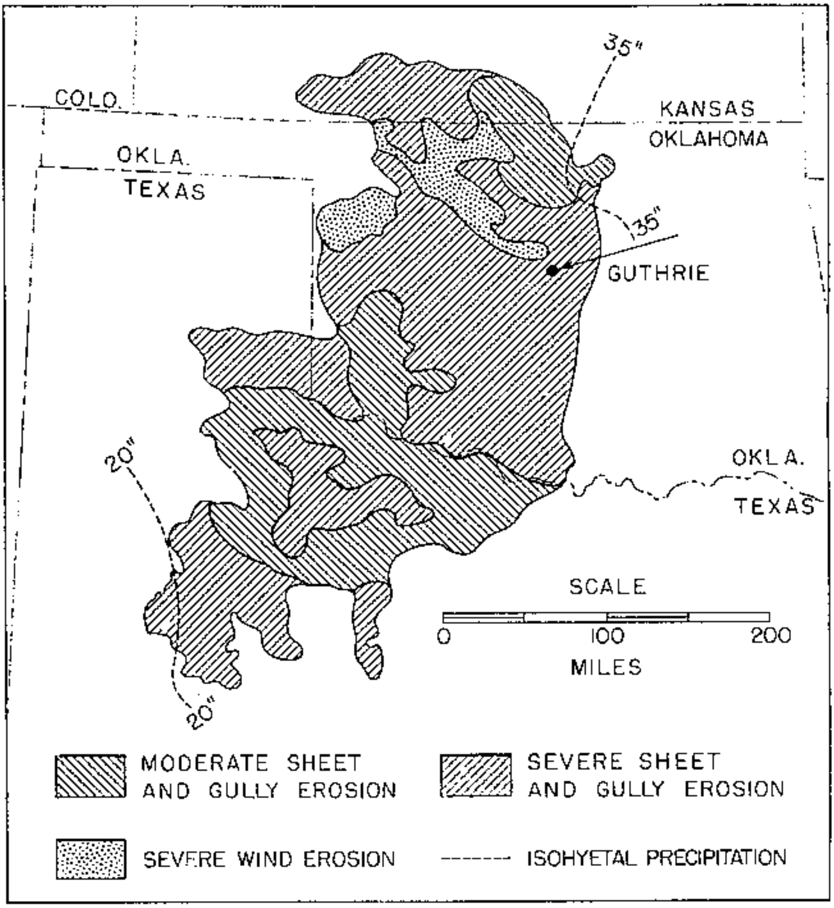


FIGURE 1.—Map of the Red Plains area showing extent and degree of erosion.

THE STATION

The site of the station, about 4½ miles south of Guthrie, Okla., in the north-central part of the area (fig. 1), was selected as being typical of conditions affecting erosion in the Red Plains. It is, however, more representative of the eastern part, or cross-timber section, originally covered with scrubby oak and native grass, (*15, p. 13*) and the southern part, where row crops predominate.

The West farm of 160 acres was acquired in 1928 and laid out in experimental areas, as shown in the map of figure 2. Surveys of this tract showed that about 70 acres (fig. 3), which had been under cultivation since 1899, had lost soil at the rate of approximately 48 tons an acre per year.[7] In 1932, 110 acres just east of this farm was acquired as part of the station, most of which has been devoted to

[7] The soil survey was conducted in 1928 by E. W. Knoble, of the Division of Soil Surveys, Bureau of Chemistry and Soils, and the engineering survey of the same year was by B. S. Clayton of the Bureau of Agricultural Engineering.

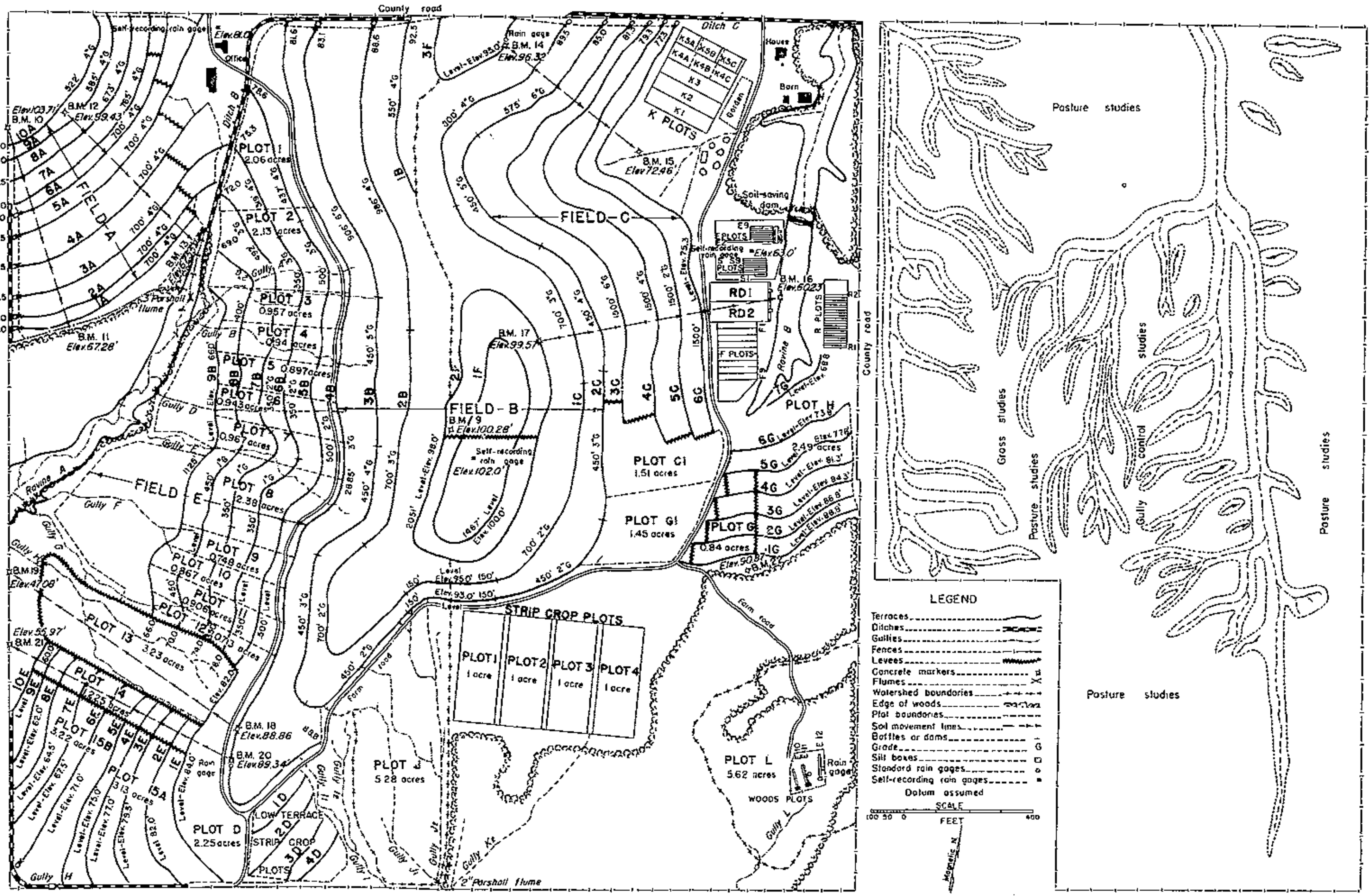


FIGURE 2.—Map of the farm of the station showing fields and experimental areas.

FIGURE 3.—This aerial photograph of the West experiment station farm in 1928 before conservation work was begun, shows numerous gullies and severe sheet erosion, the latter indicated by white patches.

gully-control and revegetation experiments. Seventy-five acres of this land had been abandoned from crop production because of erosion. The rest was virgin soil covered with native grass and scrubby blackjack oak (fig. 4). The various experiments of this farm are shown in the map of figure 2.

The soils of the station were first classified as Vernon and Kirkland and are so referred to in earlier publications of the station,[8] but were reclassified in April 1939, as Stephensville, Zaneis, Noble, Kirkland,

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FIGURE 4.—Cover of native scrubby oak and grass, typical of the cross-timber section of the area.

and Chickasha, as shown in the map of figure 5.[9] Typical profiles of virgin, cultivated, or eroded soil of four of these series are shown in figure 6.

The Stephensville, Zaneis, and Noble series, largely developed from sandstone and shale of the Permian Red Beds, and first mapped as Vernon, predominate the more rolling, or steeper, slopes. Stephensville, a shallow red sandy forested soil is underlain with a reddish-brown sandy clay or by sandstone. The parent material is usually 2 to 4 feet below the surface, but outcrops of rock are common on this series. Zaneis, occurring on land originally in prairie grass, is also shallow and immediately underlain by sandy clay, which grades into heavy compact clay and shale at about 14 to 40 inches below the surface. Noble has been developed from material washed from the upland and accumulating at the foot of slopes in rather narrow strips and has a slightly acid reaction. Deep gullies are common in cultivated fields of this soil. It is one of the better soils of the area, but occupies a small portion of the station farm.

[8] See page 1 of reference cited in footnote *4, p. 4* and page 10 of reference cited in footnote *6, p. 4*.

[9] The soils were resurveyed in 1938 by Henry P. Mikles, junior soil surveyor, Soil Conservation Service. The survey was inspected by W. T. Carter, inspector, Soil Surveys Division, Bureau of Plant Industry, and the classification was correlated and approved by the Committee on Soil and Erosion Surveys of the U. S. Department of Agriculture.

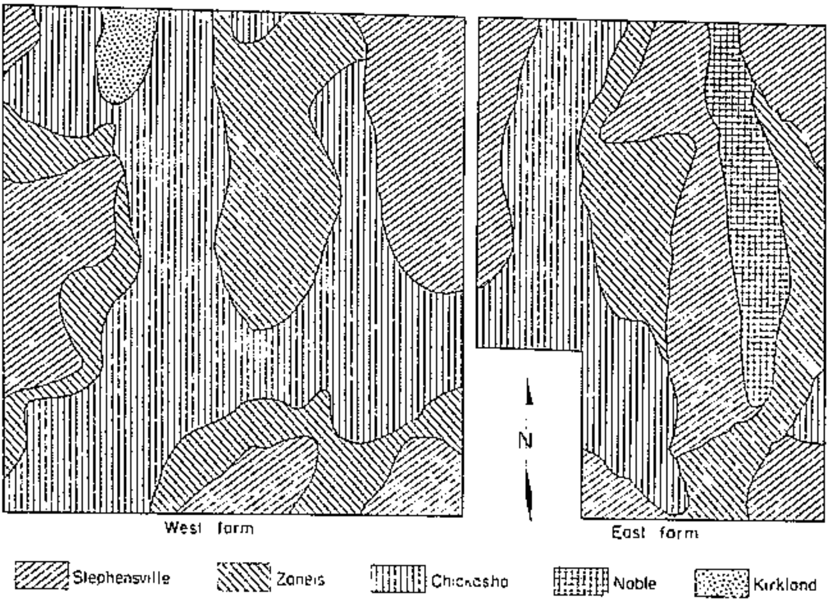

FIGURE 5.—Soil map of the station farm.

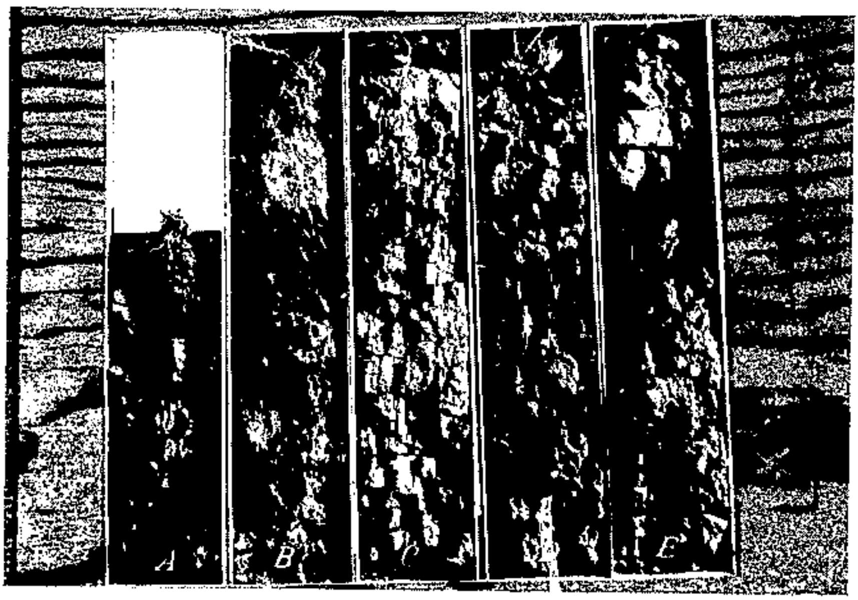

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FIGURE 6.—Profiles of typical cultivated virgin, or eroded soil of four soil series of the station: (*A*), Stephensville (originally classified as Vernon) fine sandy loam cultivated about 40 years; (*B*), Stephensville fine sandy loam, virgin soil; (*C*), Zaneis (originally classified as Vernon) fine sandy loam, cultivated 44 years; (*D*), Chickasha (originally classified as Kirkland) fine sandy loam, virgin soil; (*E*), Kirkland fine sandy loam, cultivated 44 years.

The Kirkland series, which usually occupies the gently sloping to undulating divides and ridge crests, in a virgin condition has a brown to dark-brown surface soil underlain by reddish-brown to dark-red compact impervious clay. Soil with a more rolling surface, and a slightly more friable subsoil, originally classified as Kirkland, is now mapped as Chickasha fine sandy loam. In a virgin condition this type constitutes some of the most productive soil of the station.

The chemical compositions of the profiles shown in figure 6 vary from slightly acid to basic and as a rule are low in available plant nutrients (table 1). The virgin soil, however, contains a higher percentage of total nitrogen than the eroded soil. The fine- to medium-textured surface layer of virgin soil is also conducive to infiltration, whereas the surface of eroded soil has been removed and therefore there is little storage space for water.

TABLE 1.—*Chemical composition of the surface soil and subsoil of some typical soils of the station*

Profile No.[1]	Soil			Chemical composition		
	Series	Condition	Layer	pH	Easily soluble phosphorus[2]	Total nitrogen
					P. p. m.	*Percent*
1	Stephensville[3]	Eroded	Surface	7.5	12	0.042
			Subsoil	8.0	14	.056
2	do	Virgin	Surface	6.4	8	.002
			Subsoil	8.1	20	.057
3	Zaneis[3]	Cultivated	Surface	6.3	12	.073
			Subsoil	8.1	5	.067
4	Chickasha[4]	Virgin	Surface	5.8	16	.164
			Subsoil	7.8	4	.060
5	Kirkland	Cultivated	Surface	6.9	14	.149
			Subsoil	8.4	20	.059

[1] The profiles are shown in figure 6.
[2] Determined by the fifth normal sulfuric-acid method (*15*, p. 4).
[3] Originally classified as Vernon and later reclassified into Stephensville and Zaneis.
[4] Originally classified as Kirkland.

GENERAL INVESTIGATIONAL PROCEDURE

Experiments in methods of erosion control were conducted on plots of various sizes, individual terraces, and terraced and natural watersheds under different conditions of vegetative cover, cultivation, cropping system, or terrace design, and the comparative effectiveness of these conditions was determined by measured soil and water losses, crop yields, and observations. Measurements were made by various means depending on the size and character of the area under study. For purposes of comparison water losses were computed in terms of surface inches and percentage of rainfall for the storm or period in question and soil loss in tons per acre.

The investigations included studies of results by rains of different intensities as well as by all rains. For the investigations conducted on the plots the rains causing runoff were grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour, and for the experiments on the terraces a similar classification was made of rains causing runoff from a level terrace.

The data presented show the average results for these groups of rains, as well as the annual average for the 11-year period. To present an adequate picture of the variability of the results the highest and lowest values contributing to these averages and other detailed data are attached in tabular form in the appendix.

Two types of plots were equipped with devices for measuring soil and water losses, and agronomic data were obtained from a number of others. The first type, referred to as the control plots, table 2, consisted of 13 plots 6 feet wide, 11 of which were 72.6 feet long, or 1/100 acre; 1, 145.2 feet long, or 1/50 acre; and 1, 36.3 feet long, or 1/200 acre, established on a uniform slope of 7.7 percent on virgin soil and separated by metal dividers. Total runoff from each plot was caught in a concrete basin constructed at the lower end of the plot, calibrated to measure the water volumetrically. Samples were taken of the supernatant liquid and of the sludge after the water was drained off. The quantity of soil lost from the plot was then determined from the average dry-soil content of the samples.

TABLE 2.—*Control plot treatment and cropping systems*

Group and plot No.	Land slope	Dimensions	Cropping system
Group 1:	*Percent*	*Feet*	
1	7.70	6X36.3	Continuous cotton.
2	7.70	6X145.2	Do.
3	7.70	6X72.6	Do.
4	7.70	6X72.6	Rotation—cotton, wheat, sweetclover.
5	7.70	6X72.6	Do.
6	7.70	6X72.6	Do.
7	7.70	6X72.6	Bermuda grass (clipped).
8	7.70	6X72.6	Bare hard fallow.
9	7.70	6X72.6	Continuous cotton on subsoil.
Group 2:			
10	5.17	6X72.6	Virgin woods, undisturbed.
11	5.17	6X72.6	Virgin woods, burned annually.
12	6.02	6X72.6	Continuous cotton.
13	5.17	6X72.6	Bermuda and native grass undisturbed.

The plots of the second type ranged from 1/4 to 1 acres in area and were surrounded by dikes or ridges of earth with extensions of concrete for diverting runoff to the measuring unit at the lower end of the plot. Geib divisors were used for measuring losses from most of these plots. The installation consisted of a silt box, where the heavier particles of the runoff settled and the trash was sieved out; a series of divisor boxes, each with an uneven number of identical slots in the discharge end; and a storage tank (fig. 7). Soil-laden water discharged from the silt box into the first divisor, where the discharge from the center slot was directed into another divisor, and so on until the aliquot was a convenient amount to run into the storage tank. For example, a series containing an 11-slot, a 9-slot, and a 5-slot divisor delivered 1/11 by 1/9 by 1/5, or 1/495, aliquot to the tank. Total runoff was then determined by the reverse of the amount of cut (495 in the above example), and soil loss was estimated by multiplying the dry-soil content of the water in the storage tank, by the reverse of amount of cut and adding the dry-soil content of the material in the silt box.

Water losses from two of these plots flowed over 90° V-notch metal weirs, where the depth of flow was measured continuously by Bristol self-recorders. These plots were not equipped with devices

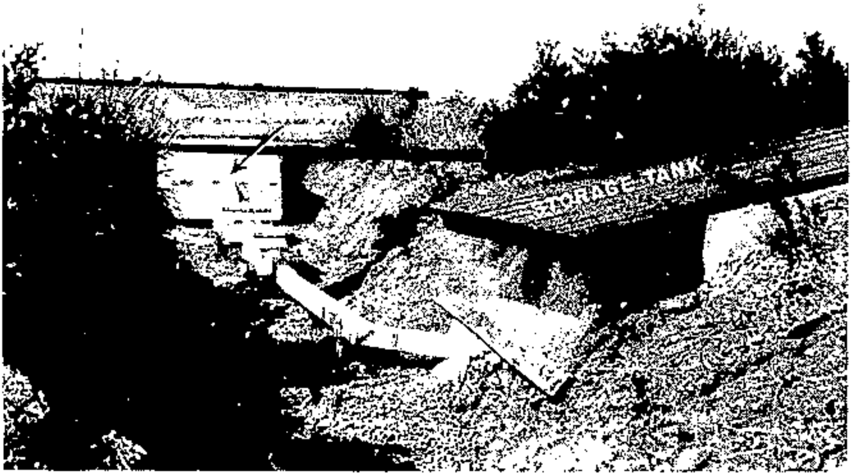

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FIGURE 7.—Geib divisor installation for measuring soil and water losses.

for sampling runoff for soil loss, and only the quantity of soil settling in the silt boxes was measured. When soil in the runoff from plots was over a predetermined minimum, amount of water displacement was taken into consideration in recording water loss.

Experiments with vegetative cover, burning of vegetation, crop rotations and cultural methods, such as contour tillage, strip cropping, hole-digging cultivation, and subsoil tillage were designed mainly for determining their importance in the conservation of soil and water. Studies were also made of fertilizer and cropping practices to determine the relative effectiveness of commercial fertilizers, green-manure crops, winter cover crops, and crop rotations in rebuilding or restoring eroded lands.

Runoff and soil loss were studied from individual terraces of different vertical spacings, grades, and lengths on both virgin and eroded soil for determination of the best features for the two soil conditions. The effectiveness of level closed-end terraces was determined by crop yields and observations. All terraces were approximately 15 inches high and 26 to 32 feet wide.

Soil and water losses from seven watersheds were also measured. These included both terraced and unterraced areas ranging from 1.22 to 35 acres. Dikes were established along the natural divides of the unterraced land in such a way as to define the watersheds without permitting artificial concentration of runoff along the dikes. Measuring equipment was installed at the lower ends of the dike outlets. The terraced watersheds drained into a common channel, and equipment was installed to measure the losses at the end of each terrace channel.

Losses from the terraces and watersheds were measured by means of Parshall flumes and Ramser silt samplers (fig. 8). By this method runoff flowed through a flume, where a Bristol self-recording gage registered the depth of flow and the time, on a chart, and from this record the total runoff and the rate of runoff from a rain were calculated. From the flume the water with its load of eroded material discharged into a silt box, where the heavier particles settled out,

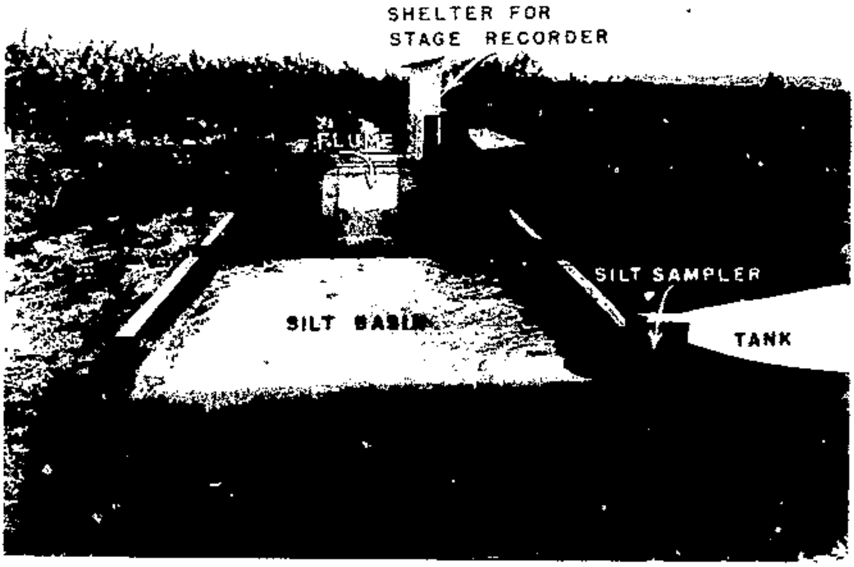

FIGURE 8.—Parshall measuring flume and Ramser silt sampler.

then flowed over a rectangular weir at the end of the box into an outlet ditch. As it passed over the weir a small amount flowed through a slot into a divisor box and hence into a storage tank. Samples were taken of the material in the storage tank and in the silt box, and the average dry-soil content was determined in the laboratory. The percentage of dry soil in the storage-tank sample multiplied by the total amount of runoff showed the quantity of soil that passed over the weir; the dry-soil content of the silt-box sample multiplied by the volume of sludge in the silt box gave the quantity of dry soil caught; and the sum of these two determinations was the total quantity of soil lost in runoff from the area that drained through the flume.

Revegetation and land-reclamation experiments were conducted on land submarginal for cultivation. Gully-control experiments on abandoned land necessitated the construction of various kinds of dams and the establishment of different types of vegetation. A grazing experiment was started on the East farm in 1939 for the purpose of studying a method for utilizing this type of land while reducing erosion. Attempts were made to solve the problem of converting eroded land into pasture by the use of commercial fertilizers and soil-building crops and to improve woodland pasture by the removal of scrubby oak.

INVESTIGATIONS AND RESULTS

METEOROLOGICAL RECORDS

Since a study of erosion necessarily involves a knowledge of the climatic conditions under which erosion occurs, daily meteorological data were recorded at the station. Amounts and intensities of rainfall were measured and recorded at various locations on the farm by Fergusson self-recording rain gages, and amounts measured also by standard Weather Bureau gages served as a check. All other meteorological data were obtained by standard Weather Bureau type equipment.

Rainfall.—Average annual precipitation for the 11-year period was 30.22 inches, or 2.09 inches below the long-time average recorded by the United States Weather Bureau at Guthrie, Okla. (table 14). This indicates that the station was operating during a period when precipitation was below average. The highest average monthly amounts (fig. 9) were recorded in May, June, August, and September and the lowest in December, January, and February. The rainfall was not well distributed throughout the year, and long drought periods frequently occurred between the intense rains of summer. During fall and winter the rainfall generally came in storms of long duration without intense bursts, but in spring and summer it usually occurred in storms of short duration and high intensities (table 3).

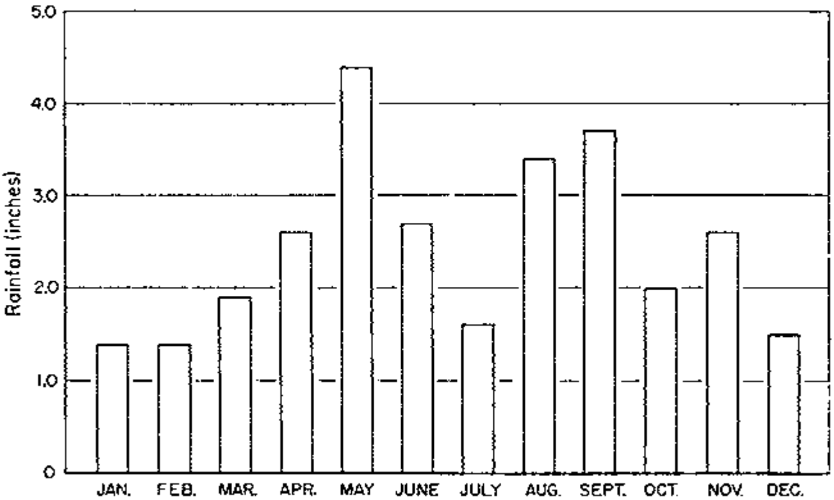

FIGURE 9.—Average monthly rainfall at the station for the 11-year period 1930–40.

TABLE 3.—*Monthly average maximum intensities and the average duration of rainfall at the station for the 11-year period 1930–40*

Month	Intensities per hour during intervals of—						Duration
	5 minutes	10 minutes	15 minutes	30 minutes	1 hour	2 hours	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Minutes*
January	0.55	0.38	0.31	0.22	0.15	0.10	398
February	1.39	1.03	.57	.58	.36	.17	548
March	1.46	1.06	.93	.62	.35	.20	462
April	2.59	2.08	1.67	1.06	.67	.35	307
May	3.70	3.06	2.45	1.82	1.13	.68	252
June	2.95	2.40	2.08	1.54	.98	.58	175
July	2.52	2.05	1.72	1.01	.60	.30	178
August	3.05	2.49	2.08	1.55	.93	.56	316
September	3.30	2.48	2.13	1.82	.97	.55	258
October	2.21	1.52	1.15	.72	.43	.20	360
November	.98	.75	.60	.45	.31	.24	543
December	.54	.42	.33	.27	.20	.13	530

Maximum rainfall intensities on the control plots for an 11-year period and average maximum intensities at Oklahoma City for 1890–1938 are shown in table 4. The 11-year maximum intensities for 5-, 10-, 15-, 30-, 60-, and 120-minute intervals were 6.48, 5.40, 4.40, 3.44, 2.33, and 1.29 inches, respectively, while those for the long-time period were 7.20, 6.30, 5.16, 4.60, 3.10, and 2.20 inches. These data are a general index of intensities that may occur in the area. The lowest maximum intensities during these time intervals, 3.60, 3.24, 2.32, 1.80, 0.93, and 0.66 inches, may be expected at least once a year.

Temperature.—The data presented in table 14 for 1934–40 show a high temperature of 116° F., low of 11° below zero, mean maximum of 71°, and mean minimum of 49°. Summer temperatures usually ranged from 85° F. to 100° F.

Humidity.—Relative humidity, recorded for a 3-year period, shows an average maximum of 95 percent and an average minimum of 29 percent (table 14). The long-time average at Oklahoma City at 7 a. m. is 79 percent and at 7 p. m., 58 percent, (*25*), while for a 7-year period at Goodwell, Okla., the average maximum is 85.5 percent and the average minimum, 36.8 percent (*13, pp. 37–38*). The highest humidity usually occurred in the early morning and the lowest during the warmest part of the day.

TABLE 4.—*Maximum annual rainfall intensities in inches per hour during specified intervals at the station for the 11-year period 1930–40, and maximum intensities at Oklahoma City, 1890–1938*

Year	Intensities per hour during intervals of—					
	5 minutes	10 minutes	15 minutes	30 minutes	1 hour	2 hours
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1930	6.48	5.04	4.40	3.24	2.33	1.19
1931	5.28	4.44	3.92	2.60	1.56	.84
1932	5.40	4.56	3.52	3.44	2.18	1.29
1933	5.88	3.60	3.12	2.38	1.70	1.09
1934	5.64	4.08	3.36	2.50	1.90	1.15
1935	6.00	4.80	4.32	3.00	2.02	1.08
1936	5.28	4.08	3.80	2.40	1.44	.71
1937	4.68	3.60	2.32	2.08	1.68	1.28
1938	4.32	3.84	3.12	1.80	1.32	.68
1939	3.60	3.24	2.88	2.40	.93	.66
1940	6.24	5.40	4.40	3.28	1.64	1.11
1930–40 [1]	6.48	5.40	4.40	3.44	2.33	1.29
1890–1938 [2]	7.20	6.30	5.16	4.60	3.10	2.20

[1] Records of experiment station control-plot gage.
[2] Records of U. S. Weather Bureau at Oklahoma City, Okla.

Evaporation.—Warm-season evaporation of water from an open metal tank, as recorded from April to October for the 7-year period 1934–40, shows an average evaporation of 59.02 inches, which is about three times greater than the amount of rainfall for the same period (table 14). Daniel and Finnell (*8, pp. 18–28*) in comparing these data with those of other stations in Oklahoma found that loss of water from open tanks was highest in July and lowest in December and January; that the greatest evaporation occurred in June, July, and August: and that the greatest water loss by evaporation in any one month was 17.70 inches. Further calculations showed that there was an average annual loss of 6.23 feet of water from a free-water surface in central and western Oklahoma. This high evaporation opportunity as recorded is an important factor in determining effective land use practices, and influences the efficiency of many supporting mechanical practices.

Control Plots

The control plots 1 to 9 (fig. 10) were established and records initiated in 1930. They have been in continuous operation since that time. Plots 10 and 11 were installed in a nearby woods the following year. Plot 12 was also initiated in 1931 on land adjacent to the woods plots and plot 13 of the same block was started in 1934. These plots were

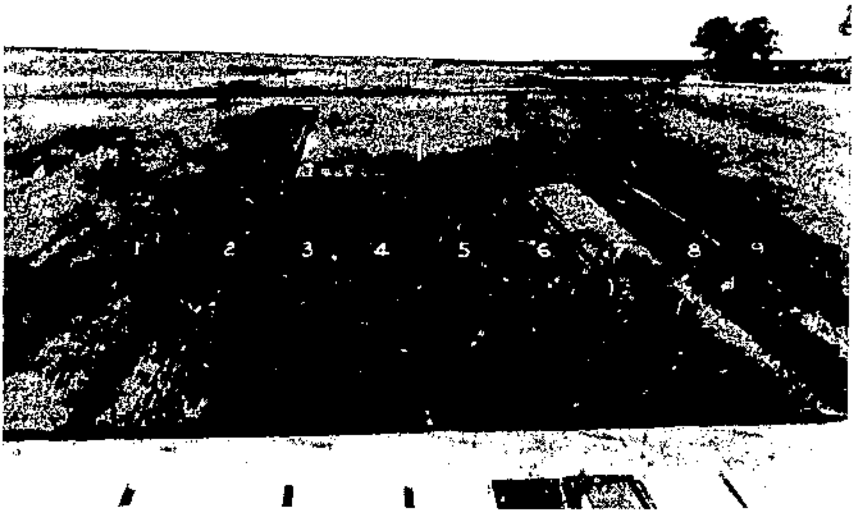

Figure 10.—View of the control plots. 25 756

known as control plots as they were installed with measuring equipment for holding and recording the entire amounts of soil and water which was lost from each plot during each rain. Figure 11 shows the average annual soil and water losses from each plot for the 9-year period ending December 1938. Beginning in 1939, all the plots of the original block except numbers 8 and 9 were given a uniform application of 3,000 pounds of limestone and 300 pounds of superphosphate per acre in order to improve the quality of vegetative cover. The year-by-year records of soil and water losses for each plot, as well as the 11-year average annual losses from each plot, are given in table 19.

The control-plot data show that a continuous vegetative cover of grass or woods gave the best protection, cutting losses to insignificant quantities. Continuous cotton on subsoil lost soil at a greater rate than the bare hard fallow land. The tendency for subsoil to erode faster than hard land was not offset in this case by the cotton plant cover. The cotton grown on subsoil without soil treatments did not produce plants large enough to afford appreciable protection to the soil. Soil losses were increased with increased length of slope.

CROPPING SYSTEM	Runoff (percent)	Soil loss (tons per acre)	PLOT
Continuous cotton	12.6	13.8	1
Continuous cotton	13.4	33.0	2
Continuous cotton	12.5	18.9	3
ROTATION Wheat, Sweetclover Cotton Plots 4, 5, and 6 — Wheat	12.4	6.9	
Sweetclover	6.8	2.5	
Cotton	11.3	3.2	
Average of 4, 5, and 6	10.2	4.2	
Bermuda grass, clipped	1.0	02	7
Fallow, undisturbed (weeds cut)	27.6	21.0	8
Continuous cotton on subsoil	26.8	29.9	9
Virgin woods	.1	.01	10
Virgin woods, burned annually	4.4	13	11
Continuous cotton	10.9	10.2	12
Bermuda and Bluestem, undisturbed	02	0	13

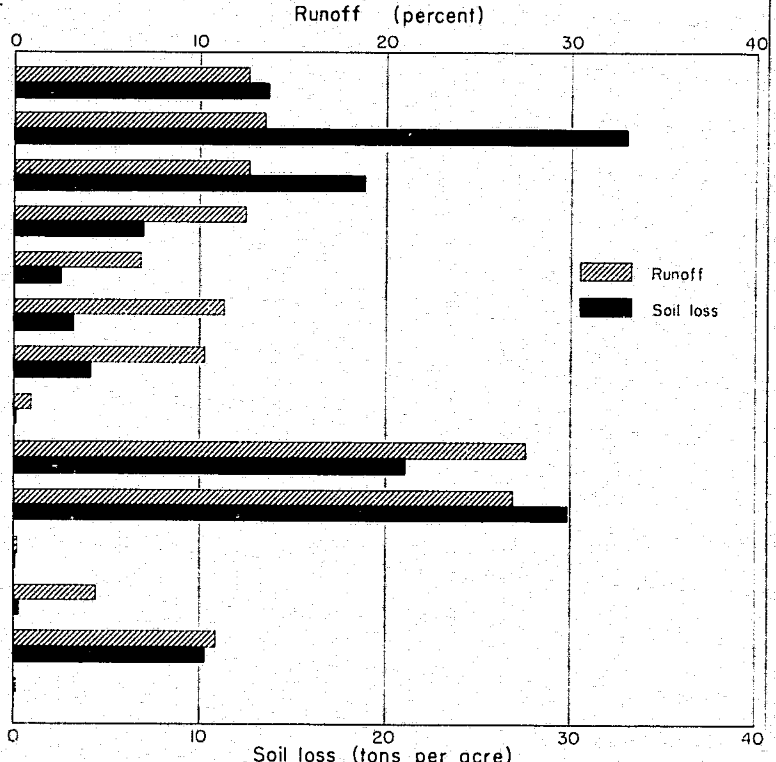

FIGURE 11.—Average annual soil and water losses from the control plots, 1930–38.

Factors which determined the extent of losses from the control plots were:

1. Kind and density of vegetation on the land.
2. Steepness of slope.
3. Length of slope.
4. Condition of the soil.
5. Amount and intensity of rainfall.

The control plots have shown vegetation to be one of the most important factors in controlling runoff and erosion. When land is well protected with grass or trees, rainfall does not run off rapidly and wash away soil. Bare soil erodes readily and may be washed away by almost every rain. Plowed and cultivated fields are particularly subject to erosion damage. The specific effect of each factor, as determined from the plots, is discussed under separate headings in the following pages.

Characteristics of the Precipitation in Relation to Runoff

Occurrence, amount, and seasonal distribution.—The relation of the occurrence, amount, and seasonal distribution of the precipitation of the area to runoff was studied on the bare hard fallow control plot. Thirty-five percent of the average annual storms (tables 15 and 16), or 20 storms a year, caused runoff from this plot. Annual runoff (fig. 12) was 27.27 percent of annual precipitation. There was considerable variation in the amounts of runoff in different seasons, but the highest percentages of water loss occurred from late spring to early fall (fig. 13) and the lowest percentages in the winter months.

The wettest year was 1932, with a precipitation of 37.40 inches, but the highest runoff was recorded from 35.30 inches in 1934. Precipitation for 1930, 1933, 1935, and 1940 was 33.66, 31.40, 31.73, and 33.28 inches, respectively (fig. 14), whereas runoffs were 7.72, 9.99, 8.82, and 9.37 inches. There was 2.68 inches more precipitation in 1937 than in 1936, but runoff in 1937 was less than in 1936. These data indicate little relation between total rainfall and the total amount of runoff.

Duration.—For the study of relation of duration of rainfall to runoff, all rains causing runoff from the bare hard fallow plot were classified into groups covering a range of 100 minutes as shown in table 17. Although the lowest average runoff was from the rains of shortest duration, there was no consistent relationship between the runoffs of the different groups of rains (fig. 15) or between the high and low runoffs within individual groups. The average runoff from the group of longest duration was less than that from four groups of shorter duration. These results indicate that duration of rainfall has little effect on amount of runoff.

Intensity.—Rains causing runoff from the bare hard fallow plot were classified according to intensity. These were arranged in groups covering a range of 0.5 inch on the basis of 30-, 15-, and 5-minute intensities

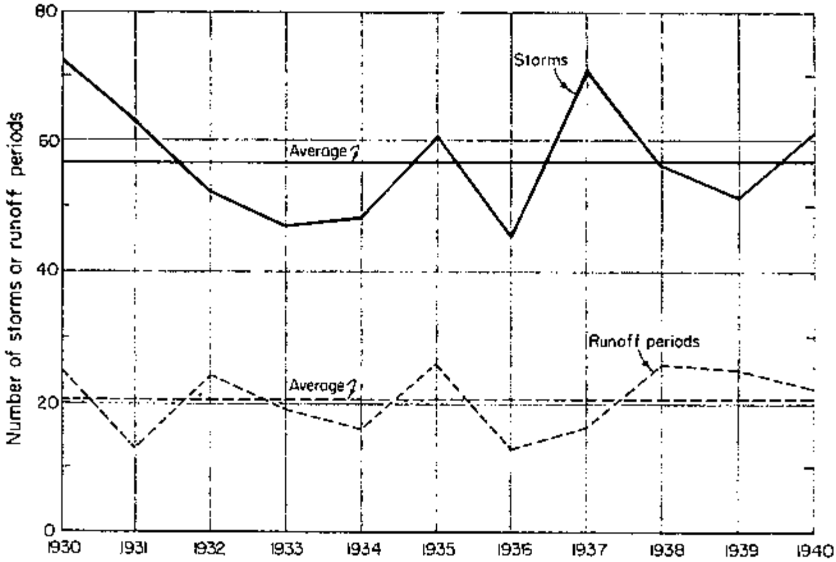

FIGURE 12.—Runoffs from bare hard fallow plot and number of rains.

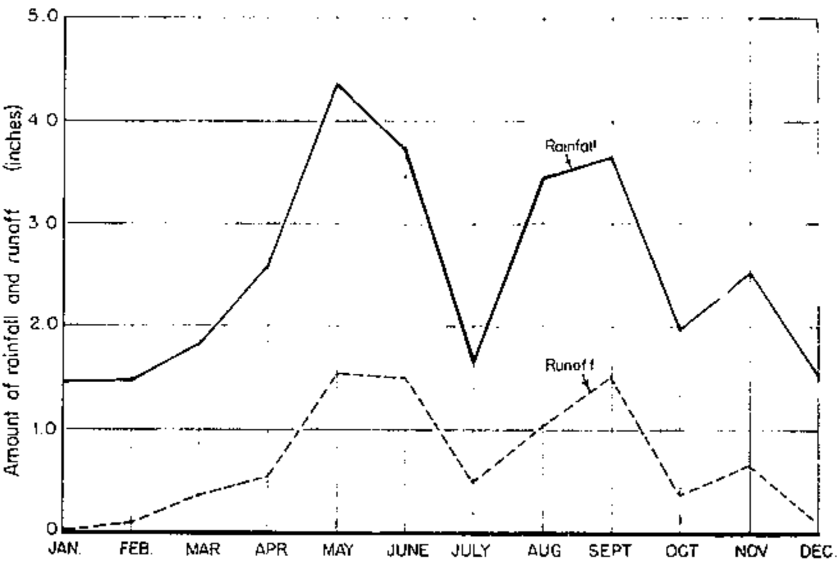

FIGURE 13.—The amount of runoff from the bare hard fallow plot and the seasonal precipitation.

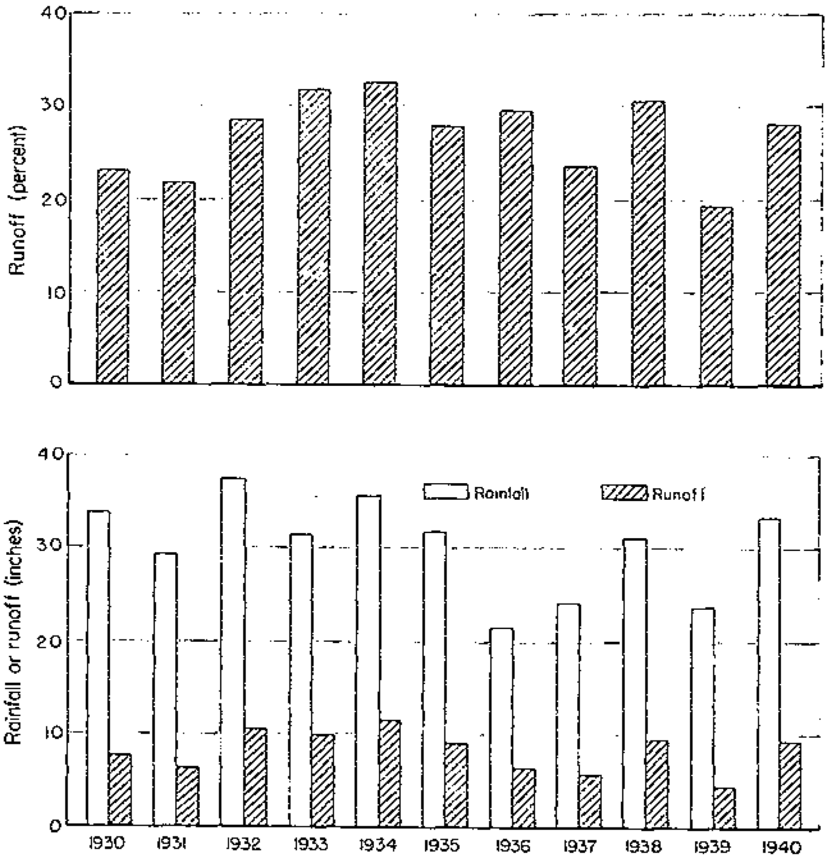

FIGURE 14.—Total annual runoff from the bare hard fallow plot and total precipitation.

as shown in table 18. Average results from the 30-minute-intensity rains (fig. 16) consistently show an increase in runoff with increase in intensity. This relationship also is borne out by the 15-minute-intensity rains while the 5-minute-intensity groups show some variation.

The high and low runoffs of some of the groups of rains do not seem to follow the general trend, but the rainfall records reveal that these high runoffs resulted from rains falling on wet soil or in a hard dash

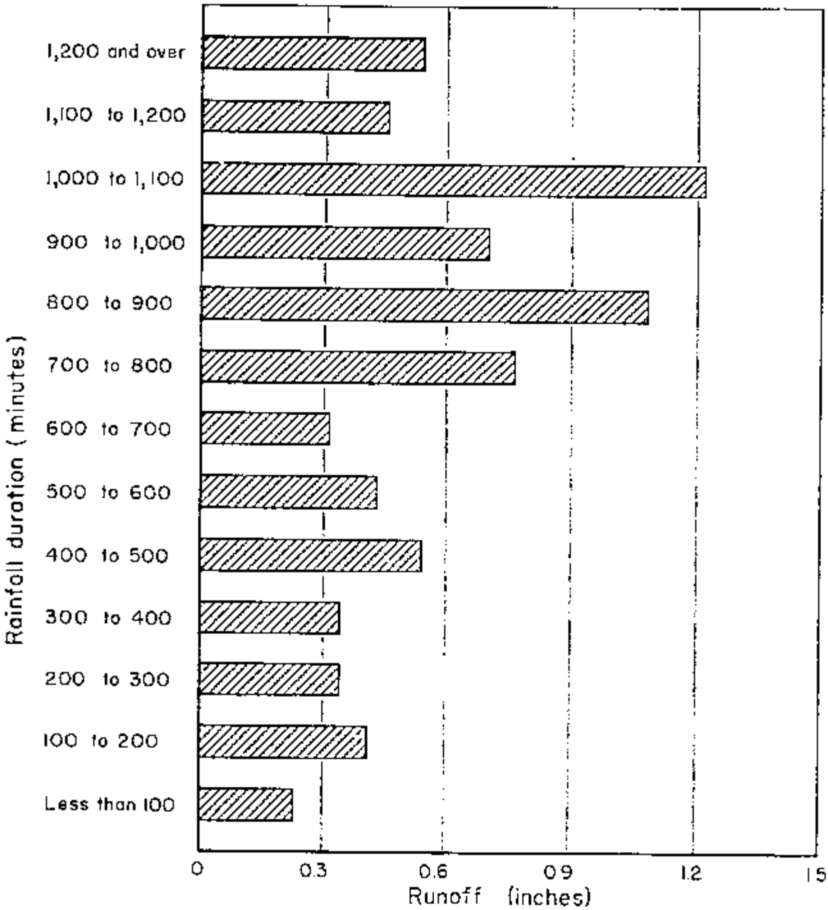

FIGURE 15.—Duration of rainfall and amount of runoff from the bare hard fallow plot.

during a shower of low intensity and that the low runoffs occurred from rains following drought periods and falling on dry soil with high absorptive capacity.

Under uniform soil-moisture conditions intensity was the most important rainfall factor causing runoff. Neal (*22, p. 33*) reports similar results from his study of the effects of rainfall characteristics on runoff and erosion.

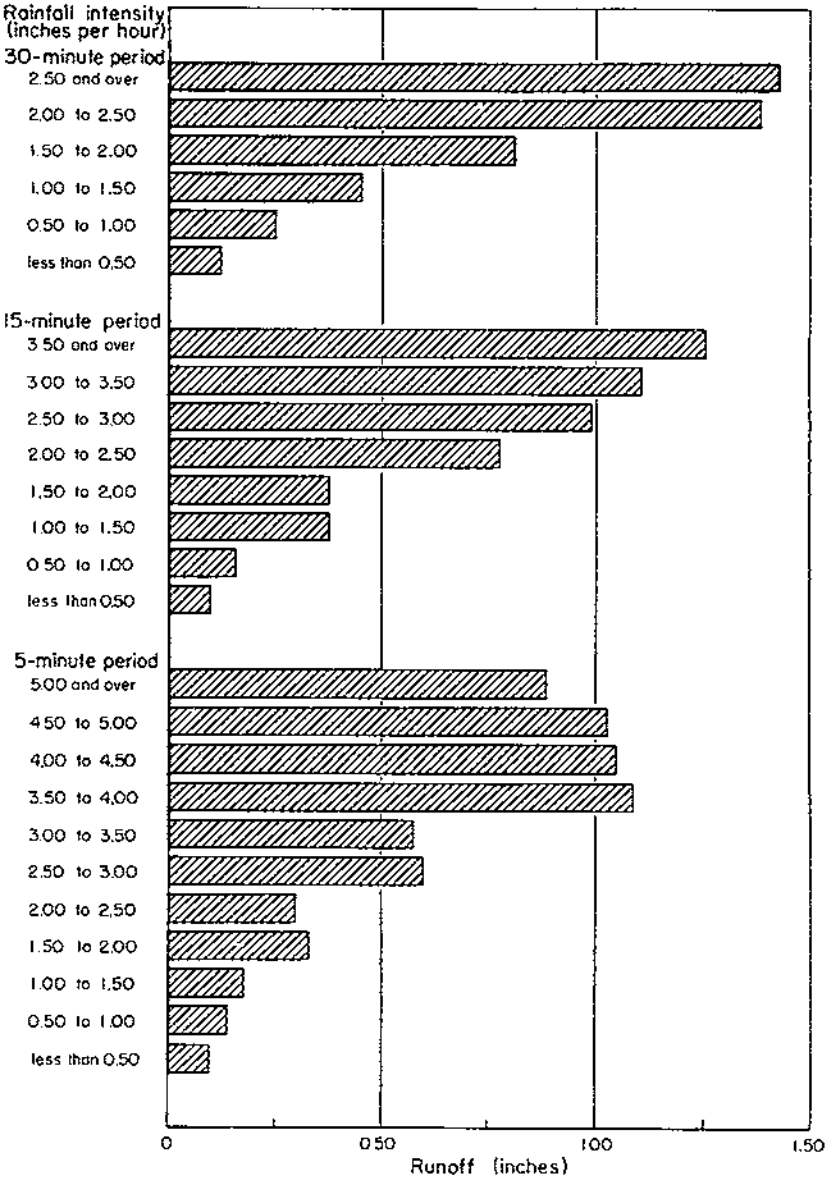

FIGURE 16.—The relationship between rainfall-intensity groups and runoff from the bare hard fallow plot.

VEGETATIVE COVER IN EROSION CONTROL

The importance of vegetative cover in controlling erosion on both wooded and prairie land has long been recognized. Just how effective plant cover is in preventing erosion was not determined, however, until inauguration of studies at the University of Missouri in 1917, whereby soil and water losses were measured. These investigations, conducted by Miller and Krusekopf (*21, p. 11*), showed that 29.4 percent of rainfall ran off from cornland, while only 12 percent was lost from sod. Similar results were reported from nine different localities in the United States by Enlow and Musgrave (*12, p. 620*), who found that in all places runoff was much less from grassland than from cultivated land and that the reduction in soil losses from grasslands was even greater than the reduction of water losses.

The vegetative-cover study at the station consisted mainly of determination of the effectiveness of native vegetation and introduced grass in protecting land. The effect of burning woodland litter on soil and water losses was also determined.

NATIVE VEGETATION AND INTRODUCED GRASS

The study of native vegetation and grass was conducted on control plots of 1/100 acre under various covers and no cover; watershed plots J and L, of 5.28 and 5.62 acres each, one abandoned to grass and the other in woods; 13, a cultivated plot of 3.23 acres; and a 2.5-acre pasture of native grass on virgin land.

Summarized data from the control plot studies are shown in table 5 and more detailed information in tables 19 and 20. Annual water loss from the bare hard fallow plot was 27.09 percent; from the clipped Bermuda grass plot, 0.91 percent; and from the Bermuda and native grass plot, 0.02 percent. The highest percentages of water loss from these plots for a single rain were 86.25, 32.79, and 0.96, respectively. Annual soil losses from bare hard fallow land and clipped Bermuda grass were 21.86 and 0.02 tons per acre, while Bermuda grass mixed with native grass had no loss. Land under continuous cotton had 12 times more water loss and 446 times more soil loss than that with clipped Bermuda grass, and 533 times more water loss than land with mixed grass.

TABLE 5.—*Average annual soil and water losses from control plots under various kinds of vegetation and from a bare hard fallow plot for the 11-year period 1930–40*

Plot No.[1]	Vegetative cover	Rainfall	Water loss		Soil loss per acre
		Inches	*Inches*	*Percent*	*Tons*
7	Bermuda grass, clipped	30.22	0.276	0.91	0.02
8	Bare hard fallow	30.22	8.188	27.09	21.86
10	Undisturbed virgin woods [2]	30.57	.036	.12	.01
11	Woods burned once a year [2] [3]	30.57	1.143	3.74	.11
12	Continuous cotton [2]	30.57	3.198	10.46	8.92
13	Bermuda grass and native grass [4]	29.52	.006	.02	0

[1] 1/100-acre plots of Stephensville (originally classified as Vernon) fine sandy loam. Plots 7 and 8 were on a 7.7-percent slope; plots 10, 11, and 13 on a 5.47-percent slope; and plot 12 on a 6.02-percent slope.
[2] Records for 1931–40.
[3] In early spring.
[4] Records for 1934–38.

Similar results were recorded from the larger watersheds, as shown in tables 6 and 21. The cultivated plot of 3.23 acres lost an average of 2,790 times more soil annually than the 2.5-acre pasture in native grass. This grass plot, cleared of scrubby oak in 1933, had an average annual water loss of 1.23 percent, or slightly less than that from the 5.62 acres of woodland. Even the high intensity rains caused only an average of 6.98 percent runoff from the native-grass pasture and 6.81 percent from the woodland. For minor rains no runoff was recorded for the pasture and only 0.76 percent for the woodland. The highest percentage of runoff for an individual rain from the badly eroded cultivated area was 99.31 percent; from native grass, 17.86 percent; and from undisturbed woods, 28.60 percent. The greatest amounts of soil loss from these areas for a single rain were 30.15, 0.02, and 0.35 tons per acre respectively.

Plot J, badly eroded, gullied, and abandoned land with a growth of subclimax grasses, had a greater percentage of runoff than the pasture in native grass or the wooded plot. Since the gullies constitute nearly 20 percent of the area and remained untreated, it is assumed that the high rate of runoff from this watershed was principally due to the gullied condition. With improvement in cover on the intervening areas as a number of natural perennial grasses appeared, observations indicate that runoff from this land is being reduced.

The most effective method of controlling erosion was with thick-growing vegetation. In the Red Plains area native and sod-forming grasses seem to provide the most erosion-resistant cover.

TABLE 6.—*Average annual soil and water losses from watersheds under various kinds of vegetative cover for the 9-year period 1930–38*

Plot designation and vegetative cover	Size of area	Land slope	Soil		Rainfall	Water loss		Soil loss per acre
			Type [1]	Condition				
	Acres	*Percent*			*Inches*	*Inches*	*Percent*	*Tons*
13, Cotton and cowpeas	3.23	5.13	Chickasha, Zaneis, and Stephensville.	Badly eroded	28.53	7.11	24.92	83.72
Pasture, Native grass	2.50	5.65	Stephensville	Virgin	26.81	.33	1.23	.03
J, Abandoned grass	5.28	4.44	Chickasha and Zaneis	Eroded and abandoned.	28.61	2.23	7.79	------
L, Undisturbed woods	5.62	4.80	Stephensville and Zaneis.	Virgin	28.68	.88	3.07	.15

[1] Stephensville and Zaneis originally classified as Vernon; Chickasha originally classified as Kirkland.

EFFECTS OF BURNING WOODLAND VEGETATION

Soil and water losses from burned and undisturbed virgin woodland were recorded from 1931 to 1940 for studies of the effects of burning woodland vegetation on erosion. Measurements were taken from control plots 10 and 11 (fig. 17), 1/100-acre plots on a land slope of 5.17 percent. All forest litter and vegetation on plot 11 were destroyed by burning every year in early spring, and plot 10 was left undisturbed.

Average annual soil and water losses from the burned area were 11 and 32 times more, respectively, than from the undisturbed woodland (tables 5, 19, and 20). The highest water loss from a single rain for the burned woodland was 51 percent and for the undisturbed woodland 2 percent. The layer of residue accumulated on the unburned woodland formed a protective cover of spongy material that reduced velocity of flow and gave the water a chance to penetrate the soil.

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FIGURE 17.—The forest litter has been burned annually in March since 1930 on the plot at the left and undisturbed on the area to the right.

These data clearly show the value of forest litter and partially decomposed vegetation in preventing runoff and soil loss.

CULTURAL METHODS IN EROSION CONTROL

The cultural methods established by the pioneers gave little attention to soil conservation, and the serious results to the land have made necessary the development of other practices. Experiments to determine the most effectual methods included contour tillage, strip cropping, hole-digging cultivation, and subsoiling.

CONTOUR CULTIVATION

In 1932 two plots of one-fourth acre each were installed for a study of effects of contour cultivation, or row direction, on runoff, soil loss, and crop yields. Rows were run on the contour on one plot and up and down the slope on the other. The contoured plot was on a slope of 6.87 percent and the other on a slope of 6.75 percent; both were on virgin Stephensville fine sandy loam planted to cotton every year, with wheat as winter cover. Water losses were measured by Bristol clock recorders in 90° V-notch weirs, but only the soil caught in the concrete tanks at the ends of the weirs was measured, as no provision had been made for sampling suspended soil passing over the weir. The results of the study are shown in table 22.

The differences in the water losses of the two plots for individual rains are not consistent, but regardless of intensity, soil loss with one exception was greater from the plot with rows parallel with slope. Water loss in general was also greater from rows up and down the slope, but four of the high-intensity rains and two of the moderate caused higher percentages of runoff from the contoured area. In general, contour cultivation conserved water from moderate and minor rains, but water loss from the contoured area for high-intensity rains was as great or greater than from rows parallel with slope.

Annual rainfall on the plots was 30.40 inches and annual water losses from rows on the contour and from rows parallel with slope were 7.99 and 9.11 percent, respectively. Soil loss from rows on the contour was less than one-half that from rows parallel with slope and cotton yields were slightly higher. These results agree with those reported by Daniel and Finnell (*8, p. 7*) showing the value of contour cultivation in increasing yields. Since there was an annual loss of 16.57 tons of soil an acre from contoured cultivated virgin cottonland, however, it is evident that contouring alone is not sufficient for conserving soil and water on steep slopes of highly erodible soil and should be supplemented by other conservation practices.

STRIP CROPPING

Types and methods of strip cropping for soil conservation have been discussed by Kell and Brown (*17*). The study at the station was designed to determine the effectiveness of certain crops for erosion-resistant strips in the Red Plains. Four 1-acre plots (fig. 18) of virgin soil on slopes ranging from 3 to 4.5 percent were chosen for the experiment. The soil of the upper two-thirds of the plots was Chickasha fine sandy loam and the rest Zaneis fine sandy loam. All the area was covered with scrubby blackjack oak trees and native grass until 1932, from which time through the period of the experiment it was cultivated in strips of cotton interspersed with strips of thick-growing vegetation. The plots were not equipped for measuring soil and water losses, however, until the spring of 1934.

Plot 1 was planted in 12-row strips of cotton alternated with strips of alfalfa, the cotton occupying about 55 percent of the area; plot 2

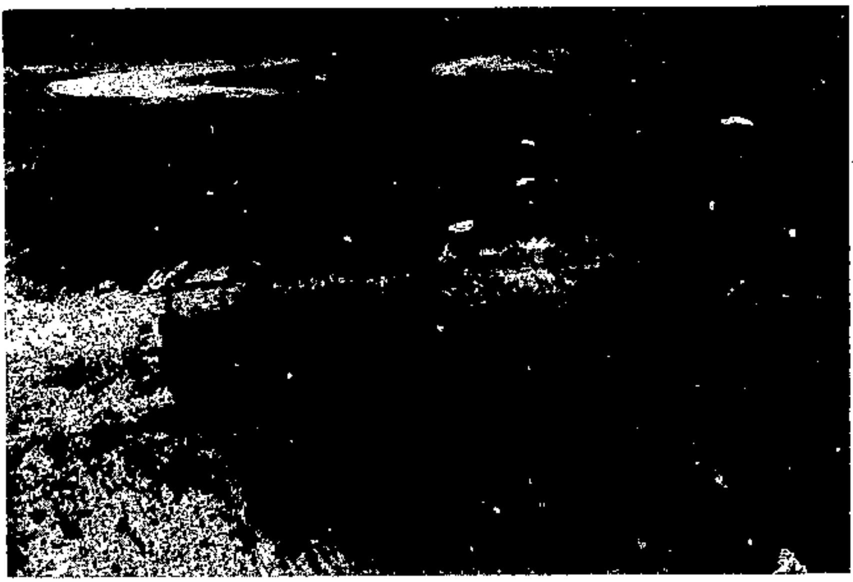

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FIGURE 18.—Experimental strip-cropped field.

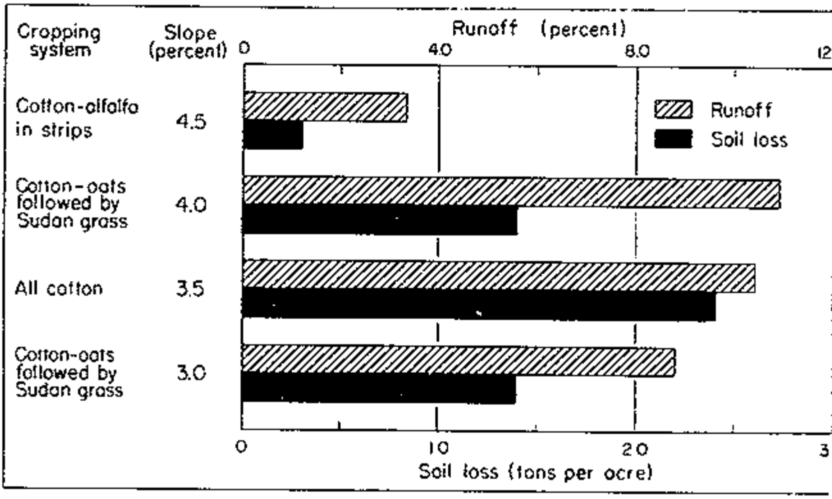

FIGURE 19.—Average annual soil and water losses from the experimental strip-cropped areas.

was also in 12-row strips of cotton occupying 45 percent of the area, with oats followed by Sudan in the alternating strips; all of plot 3 was in cotton; and plot 4 was in strips 42 feet wide planted in oats followed by Sudan, with cotton on the interval strips. All planting was on the contour, and wheat was used as winter cover following cotton on all plots.

Table 23 shows average results for the 5-year period of record and for intensity groups of rains. Although the data may not be precisely comparable because of the differences in the land slopes of the plots, each of the strip-cropped plots lost less soil than the plot entirely in cotton. Plot 1 with strips of alfalfa lost about a fifth as much soil (fig. 19) as the plots with strips of seasonal crops and about a ninth as much as the plot wholly in cotton. Oats and Sudan strips reduced runoff very little and effected a saving of only about a ton of soil an acre a year as compared with the all-cotton plot. This probably was due to the absence of cover on the land between the oats and Sudan crops in early summer—a time of year when erosive rains fall in this area.

Although the average yield from the alfalfa strips was 2,194 pounds per acre, a large amount of this yield was from annual weeds and grasses as virtually all the alfalfa plants were dead by the end of the second growing season. Since these strips were on virgin soil, this indicates that regardless of the effectiveness of alfalfa for strip cropping, this legume is not well adapted to the upland soils of the station. Since the yields of seed cotton on the strip-cropped plots were less than the yield from the plot in all cotton, the small saving in soil by the oats and Sudan strips probably does not justify the use of these crops for erosion-resistant strips in this area.

HOLE-DIGGING CULTIVATION

The results of cultivating with a hole-digging machine were studied on two ¼-acre plots of Chickasha fine sandy loam, considerably sheet-eroded, cultivated on the contour, and planted in cotton every year, with wheat as winter cover. The machine made about 10,000 holes an acre, each with a water-holding capacity of about a gallon. Both plots 1 and 2 were cultivated with sweeps and other implements ordinarily used in the tillage of cotton, but in addition plot 1 was cultivated with the hole-digging machine following ordinary cultivation.

Records for the 5-year period of the experiment are shown in table 7. There was no significant difference in the soil and water losses of the two plots, but observations showed that the machine damaged the roots of the cotton plants. Further evidence of this damage was revealed by the presence of large quantities of the severed roots which collected and clogged the screens of the measuring equipment. The yield on the plot with hole-digging cultivation was 220 pounds of seed cotton an acre as compared with 329 pounds from the plot with ordinary cultivation. Because of the extra cost of operating the machine and decreases in yields, the use of hole-digging cultivator on cotton land during the growing season is not recommended.

TABLE 7.—*Average annual soil and water losses and crop yields from plots*[1] *with and without hole-digging cultivation*[2] *for the 5-year period 1934–38*

Item	Hole-digging cultivation			Ordinary cultivation		
	Low	High	Average	Low	High	Average
Rainfall ... inches	20.87	35.30	28.44	20.87	35.30	25.44
Soil loss per acre ... tons	6.63	54.99	29.19	13.64	56.95	30.39
Water loss ... inches	1.81	7.67	4.14	1.66	8.70	4.35
Water loss ... percent	8.13	21.74	14.56	7.09	24.65	15.30
Crop yields per acre ... pounds	75	684	220	116	924	329

[1] ¼-acre plots on a 3.77-percent slope of Chickasha (originally classified as Kirkland) fine sandy loam planted to cotton every year, with wheat as winter cover.
[2] The hole-digging cultivation was in addition to ordinary cultivation.

SUBSOIL TILLAGE

The effects of subsoiling on intake of water were studied on two types of virgin soil—Zaneis fine sandy loam with a compact clay subsoil, represented by two level terraces, 1- and 2-F, and Stephensville fine sandy loam with a sandy clay subsoil, represented by plots 1- and 3-K.

For the purpose of the study, begun in 1932, the north half of each terrace, in addition to being cultivated in the usual way was subsoiled every other year to a depth of 16 to 18 inches by plowing with chisels spaced 16 inches apart, whereas the south half received only ordinary cultivation. Soil and water losses were not measured, but crop yields from the subsoiled part during the 7-year period were very little higher than those from the part not subsoiled (table 24).

The K plots, with sandy clay subsoil, were treated similarly. One plot was subsoiled every year to a depth of 16 to 18 inches in alternate 7-foot strips, and the other received only the usual treatment. In addition to comparisons of crop yields, soil-moisture content was determined on these plots. Measurements to a depth of 3 feet showed slightly more moisture in the subsoiled plot, whereas crop yields were somewhat higher from the plot not cultivated so deep.

Cropping Systems in Erosion Control

According to A. R. Hall (*14, p. 10*) rotation of crops has long been recognized as a valuable practice in erosion control, and green manuring to add organic matter to soil is a very old practice, but the use of cover crops to protect land from erosion and to improve its physical condition is of relatively recent origin (*24*). In inaugurating the cropping-systems experiments at the station, the objective, therefore, was to determine to what extent rotations modify erosion in this particular area. Experiments were also designed to determine the relative effectiveness of commercial fertilizers, green-manure crops, winter cover crops, and crop rotation in restoring soil productivity.

CROP ROTATION

A rotation of cotton, wheat, and sweetclover was planted on control plots 4, 5, and 6 for comparison with plot 3 in cotton every year. All plots were on a 7.7-percent slope of virgin Stephensville fine sandy loam cultivated with slope. The results of this experiment are recorded in tables 19 and 25. Annual soil loss from continuous cotton was 4.4 times greater than the annual average loss of the rotation, while the water losses were 11.35 and 9.29 percent, respectively. The rotation was most effective during rains of low intensity.

Average percentages of water loss were 10.07, 11.55, and 6.25 from cotton, wheat, and sweetclover, respectively, while soil losses were 9.04, 1.69, and 0.52 tons per acre. Although water loss from cotton in rotation was greater than that from sweetclover (fig. 20), it was not as great as the loss from continuous cotton. Soil loss from cotton in rotation was a little more than half that from continuous cotton. The slightly higher water loss from wheat than from cotton in rotation

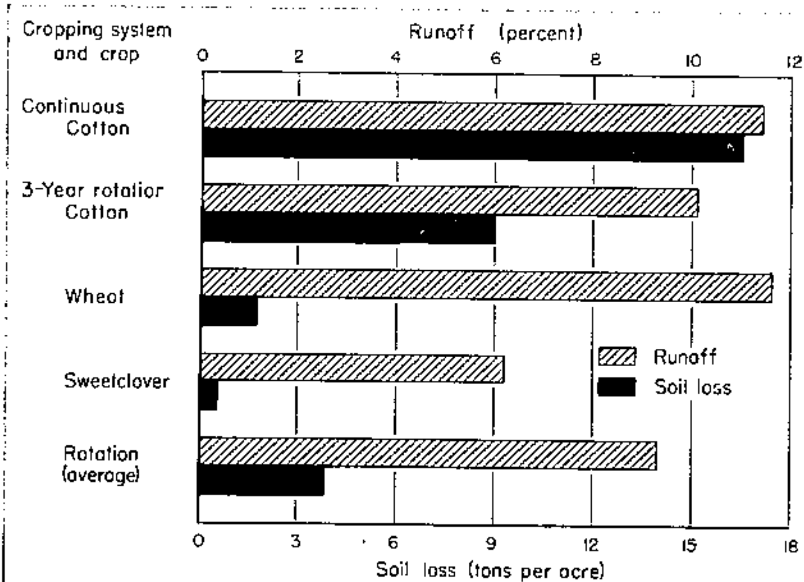

FIGURE 20.—The effect of a crop rotation on soil and water conservation.

was due mainly to absence of cover on the wheat plot following harvest, as the spring seeding of sweetclover in the wheat seldom made much growth before early fall, while cotton provided its best cover at this time.

The data, however, clearly show the value of wheat and legumes in a rotation in retarding soil loss. The order of occurrence of such crops in a rotation also seems to be an important factor, as the residue, or organic matter, accumulated from a previous crop apparently reduces velocity of running water and thereby causes greater penetration and less erosion.

FERTILIZATION AND CROPPING PRACTICES

The experiments with the effects of fertilization and cropping practices on the restoration of eroded land were located on three different areas, and the results are all shown in table 26. One experiment was on naturally eroded land, the Chickasha and Zaneis soil of field E, which is estimated to have lost a total of 1,900 tons of soil an acre, or approximately 11 inches, during 40 years of continuous cultivation. Nine plots were planted in cotton, some of which had winter cover crops or treatments of commercial fertilizer, or both, and some neither, and three plots were in 2-year rotations including cotton and a green-manure crop, one of which received a treatment of superphosphate. Although the various treatments produced some increase in crop yields, the increase was not enough to cover the cost of the fertilizer and extra labor involved. Commercial fertilizer effected the greatest response but green-manure crops also produced notable increases.

Another experiment included continuous crops and 3-year rotations with and without legumes, which except for the check plots received applications of commercial fertilizer. A rotation of corn, oats, and cotton was placed on artificially eroded plots of the R series, or plots from which 10 inches of surface soil had been removed to simulate a badly eroded condition. The best result from this rotation was from the plot receiving 300 pounds of 4–12–4 fertilizer per acre. This treatment, however, made only a slightly higher yield than 200 pounds of superphosphate. A rotation of cotton, wheat, and sweetclover was grown on both the desurfaced soil of the R series of plots and on the virgin soil of the control plots. Although the desurfaced plots received 1 ton of lime, 300 pounds of 4–12–4 fertilizer per acre with the cotton, and 100 pounds of superphosphate with the sweetclover, the 8-year average rotation yield was 264 pounds less than that from the virgin plots, which received no treatment. The best response from continuous cotton was from the plots that had winter cover crops of Austrian winter peas and vetch and treatments of superphosphate. Continuous cotton is not recommended, however, for this type of land because of the high rate of soil and water losses which occurred (table 36) from similar eroded land on the control plots.

The third study was of the effects of fertilizer on virgin land low in phosphorus. Continuous cotton and a 2-year rotation of cotton and lespedeza were grown on the nine F plots, which were located on this type of soil. The commercial fertilizers used affected the yields of seed cotton very little. An annual application of 300 pounds of 4–0–4 actually decreased the average yield, while similar amounts of 4–12–0 and 4–12–4 produced only slight increases.

In general, the best results obtained from the three studies were from phosphate fertilization and legume crops. Where legumes were not grown in the rotation, commercial nitrogen in a complete fertilizer produced slight increases in yields from eroded land. Fertilizer treatments did not show enough returns from yields of cotton, oats, and corn, however, to pay the expense of the extra labor involved and the cost of the fertilizer. Because of the compactness and poor physical condition of this shallow soil, storage capacity for water was limited. Since rainfall is erratic in this area and moisture often the limiting factor in the production of summer crops, cultivation of such land is hazardous. Crop growth on fertilized land was often abundant in early spring and in rainy seasons, but during dry years and the hot days of summer there was frequently not enough moisture to supply the abundant growth afforded by the use of fertilizer. The results of the study emphasize the fact that every possible effort should be made to conserve topsoil.

Terraces in Erosion Control

Terraces properly constructed and maintained have long been recognized as the basic mechanical method of preventing erosion.[10] In semiarid regions the primary function of terraces is to conserve moisture, while in humid regions it is to shorten length of slope over which water must pass and reduce velocity of runoff from fields. Terraces are also expected to meet the requirements of the soils and slopes of the land on which they are placed. Systems of design must therefore be worked out to meet the particular conditions of the area to be protected. To this end terraces of various designs were constructed on different soils and slopes of the station for studies of their performance under such conditions. These were made by comparisons of runoff and soil loss in runoff as measured at the ends of the individual terraces and also by crop yields. The study covered the 8-year period 1931–38.

TERRACE SPACING AND LENGTH OF SLOPE

For determination of the proper vertical spacing for terraces, the effects of length of slope on erosion were studied on both terraces and control plots.

The plot study included measurements of soil and water losses from plots 36.3, 72.6, and 145.2 feet long on a 7.7-percent slope of virgin Stephensville fine sandy loam planted continuously to cotton. The results obtained are recorded in tables 19 and 27. Average percentages of runoff from the three plots for the 11-year period were not widely different (fig. 21), but doubling the length of slope increased soil loss 1.58 times. Similar results were obtained for high-, moderate-, and low-intensity rains.

The terrace study included terraces 1 to 6 of field A and they were installed on virgin Chickasha and Stephensville soil. Two of the terraces had a vertical spacing of 2 feet; two, 3.5 feet; and two, 5 feet. All were on an average land slope of 5.5 percent, with 6–A at the top and the others following down slope in reverse numerical order. Spacings were duplicated from opposite ends of the slope.

[10] United States Soil Conservation Service. terrace grades, lengths, and spacings. SCS-TP-19, 31 pp., illus. 1938. [Processed.]

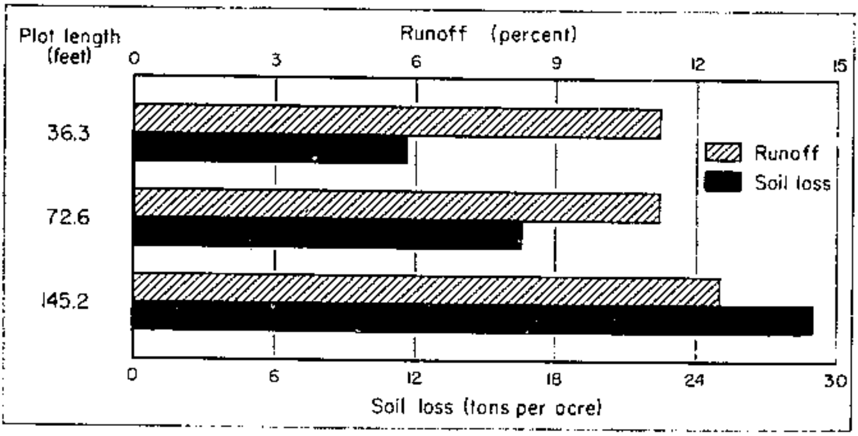

FIGURE 21.—Effect of length of slope on soil and water losses.

The data in table 28 show that the soil loss increased with increase in spacing, though not in direct proportion to spacing, for both the period of record and for high-, moderate-, and low-intensity rains. The greater soil loss in the wider intervals is attributed to the longer slopes between the terraces (fig. 22).

Runoff, however, increased substantially with reduction in spacing (fig. 23). There was a slight variation in this trend for the moderate rains but not enough to be significant. Since runoff from the control plots was virtually the same from the different slope lengths, the greater runoff from the narrower terrace spacings is attributed to the change in the slope and surface conditions resulting from the method of terrace construction and maintenance.

Composite cross sections of the terraces 3 years after construction show that the sizes of the ridges were not in proportion to the sizes of the respective interval areas. The average cross-sectional area

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FIGURE 22.—Erosion in the interval between terraces with wide vertical spacing following a 2.16-inch rain.

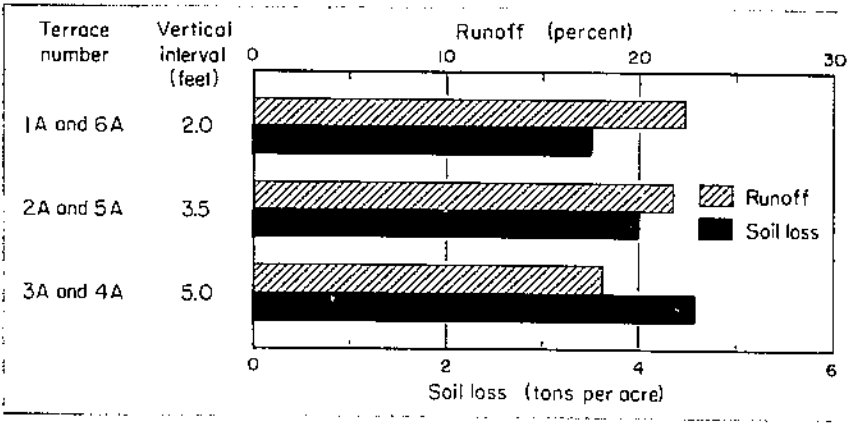

FIGURE 23.—Soil and water losses from end of terraces with different vertical intervals.

of the two ridges of the 2-foot spacings was 6.13 square feet; of the 3.5-foot spacings, 7.36 square feet; and of the 5-foot spacings, 5.26 square feet. The widest spacings actually had the smallest terraces and therefore less change in surface conditions. The method of maintaining the terraces was to backfurrow the ridge at least once each season and to leave the dead furrow in the interval between the terraces. This system of tillage increased the base width and the height of the terrace ridge and lowered the surface of the interval. Figure 24 shows a cross section of terraces 1-, 2-, 3-, and 4-A in 1931, after the land had been cultivated 1 year, and again in 1938 at the end of the experiment. The lowering of the surface of the interval indicates the loss of soil that took place during two processes—removal of soil by runoff and movement of soil from the interval onto

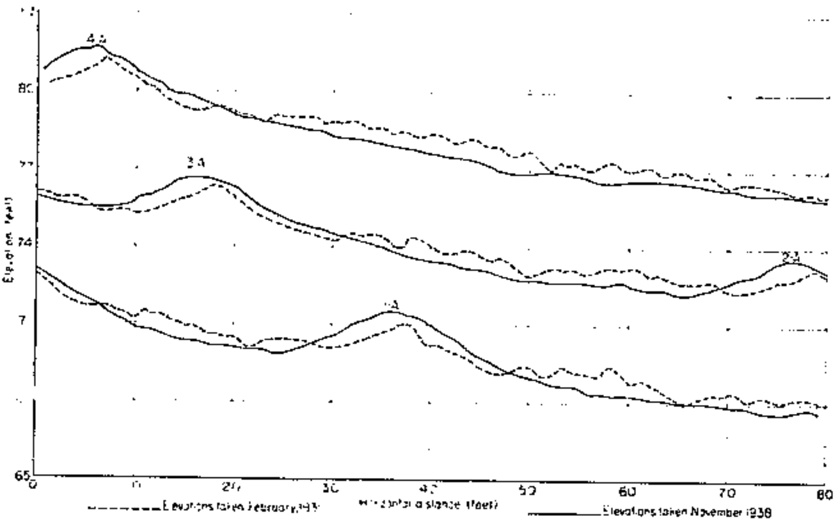

FIGURE 24.—Cross sections of terraces of various spacings showing soil movement on intervals and ridges from 1931 to 1938.

the ridge during maintenance. With the closer spacings the latter process moved the friable surface soil onto the ridge and left more of the shallow subsoil exposed in the interval. Thus the fertility and the absorptive capacity of the soil in the interval was reduced, as is indicated by the crop yields of the respective areas (table 33). Average yields of the three crops of the rotation on the terraces were 3.5, 2.8, and 1.5 times more from the ridge than from the interval.

Although subsequent experience has shown that the terraces were not correctly installed and maintained for a spacing study, soil loss was greater from the longer slopes on both the plots and the terraces. The results as a whole indicate that the vertical spacing of 3.5 feet is the most satisfactory spacing studied for the soils and slopes of the station.

TERRACE GRADE

The experiment with terrace grades was conducted on terraces 3- to 5-C, with constant grades of 2, 4, and 6 inches per 100 feet, and on level open-end terraces 6-C and 6-E. The C terraces were 1,500 feet long with about the same spacing; on Zaneis and Chickasha soils, 1,000 feet of which was virgin and the rest of which had been cultivated and was slightly sheet-eroded; and were planted to a rotation of cotton, oats, and corn or darso. Terrace 6-E was 648 feet long, on badly eroded compact clay of the Chickasha, Zaneis, and Stephensville series, and planted to a rotation of cotton and cowpeas.

The three graded terraces had virtually the same runoff (fig. 25), but assuming that grade was the only variable between the terraces, soil loss increased almost directly with increase in grade. The level terraces had lower losses of both soil and water than the graded terraces. Although these terraces are not directly comparable in length or soil type, terrace 6-E, on eroded soil, had greater losses than 6-C,

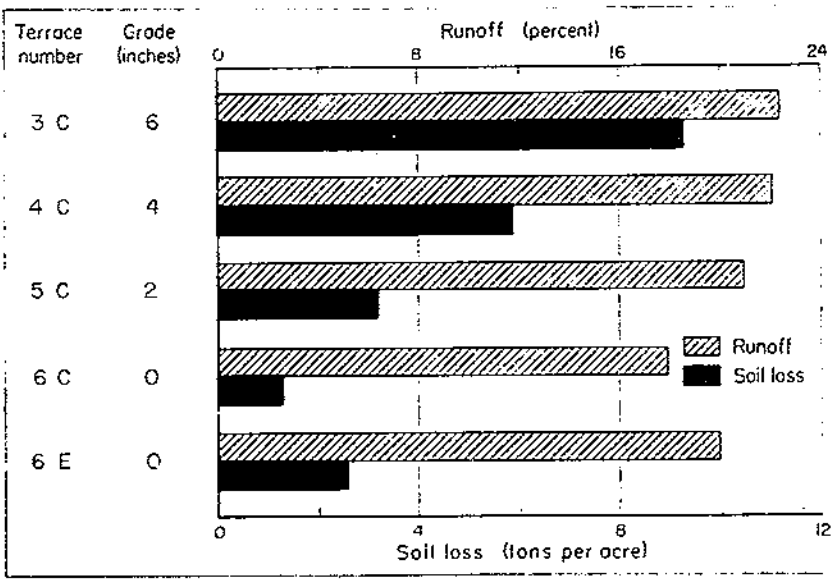

FIGURE 25.—Soil and water losses from terraces with different grades.

mainly on virgin soil. The data in table 29 show that the results from high, moderate, and low intensity rains are in about the same order. An excellent contrast of runoff from graded terraces and a level terrace on clay soil underlain with compact subsoil following a 4.07-inch rain is shown in figure 26. Runoff attains higher velocities on the steeper grades and carries away more soil.

Water moved very slowly from the level terraces, and the eroded and compact soils on which they were placed often could not absorb the amount of water retained fast enough to prevent damage to crops. Many times the rest of the field was in good working condition several days before the channels of the level terraces were dry enough for cultivation. The fault of the 6-inch grade was that water attained enough velocity to scour the channel and wash out crops. Three-year yields of cotton and oats from level terraces 6-C and the terrace of 6-inch grade were about the same, but they were less than yields from the other terraces of the same field (tables 32 and 35). The highest average yield from all crops was from the terrace of 2-inch grade.

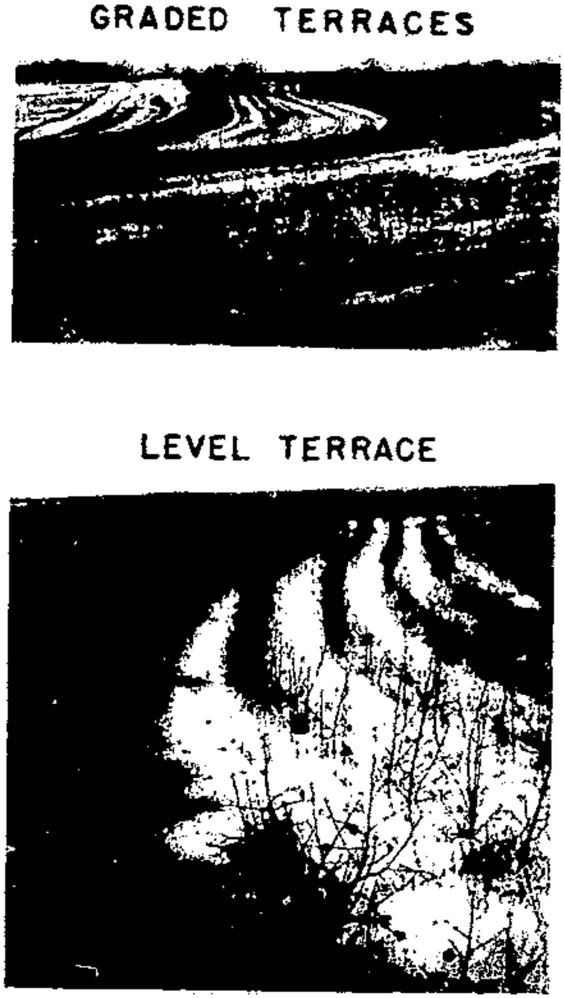

FIGURE 26.—Runoff from the ends of graded and level terraces on clay soil underlain with compact subsoil following a 4.07-inch rain.

Although open-end level terraces conserved more soil than graded terraces, they cannot be recommended for impermeable soils or for clay soils because of reduction in yields by excess moisture. No study was made of level open-end terraces on deep permeable soil. When crop yields and soil and water losses are all considered, 2 inches has proved to be the most satisfactory grade for terraces on this land with compact subsoil and low infiltration rate.

CLOSED-END LEVEL TERRACES ON VIRGIN AND ERODED SOIL

Experiments with level closed-end terraces included comparisons of their performance on badly eroded and virgin soil. This study included eight terraces of plot 14 of field E, 1- and 2- F of field B, and four terraces of plot G.

The terraces of plot 14 were on Chickasha, Zaneis, and Stephensville soil eroded to such an extent that the compact B horizon was exposed on most of the area. The land slope was about 4.49 percent; the vertical spacings from 2 to 3.5 feet; and the crops, a rotation of cotton and cowpeas. The cowpeas were used mainly as green manure, but cotton yields (table 33) were recorded for comparison with yields of other terraces. Water impounded by these terraces penetrated the compact unweathered clay subsoil and soft sandstone very slowly and as a result often stood in the channels from 2 to 3 weeks during April, May, or June, or long enough to delay cultivation and plant growth. Similar results occurred on terraces 1- and 2- F, completely encircling the top of a knoll in field B, virgin land classified as Zaneis fine sandy loam, but also with an impervious subsoil. These terraces were in a rotation of cotton, oats, and corn or darso, and large areas were frequently completely destroyed. Such a condition is shown in figure 27.

Closed-end terraces, however, were more satisfactory on deep permeable soil. The four terraces of plot G, ranging from 101 to 196 feet in length and with vertical spacings of 2 to 3.5 feet, were on virgin Stephensville and Chickasha soil with a sandy loam subsoil

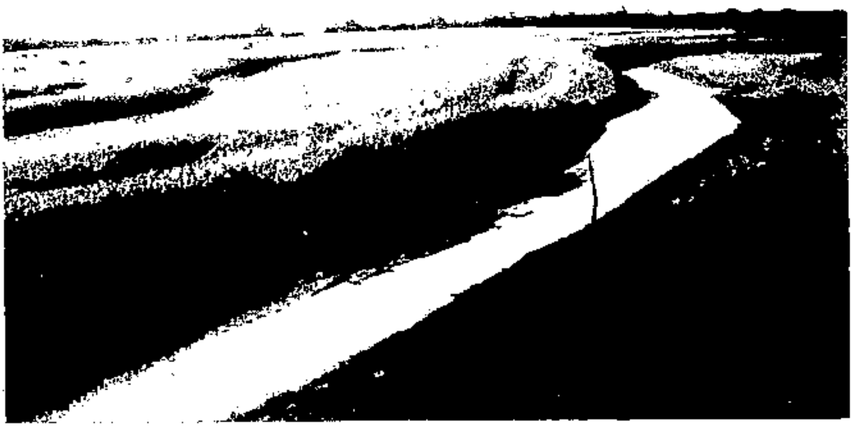

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FIGURE 27. Water impounded by closed-end level terraces on heavy compact clay soil.

similar to that shown in profile B of figure 6. This land originally covered with scrubby oak and brush, was cleared and terraced in 1929 and 1930, after which it was planted to a rotation of cotton and cowpeas. During the period of study, water did not stand in the channels long enough to show any appreciably harmful effects on yields of cotton. Closed level terraces also have proved to be satisfactory on other deep fertile soils in the more arid sections of the Red Plains (*6, p. 6; 6*).

TERRACE LENGTH FOR VARIABLE GRADES ON VIRGIN AND ERODED SOIL

Studies of the performance of long terraces with variable grades of virgin and eroded soil included comparisons of measured soil and water losses from terraces 1- and 2-C and 2- and 3-B and observations of four terraces in field E not equipped for individual measurement.

The C terraces were on soil which was virtually in a virgin condition, whereas the B terraces were on severely eroded and gullied slopes. Terraces 1-C and 2-B had variable grades of 0 to 4 inches and 2-C and 3-B, variable grades of 0 to 6 inches. Lengths ranged from 2,350 to 2,885 feet. Results for the period and for the intensity groups of rains are shown in table 30.

Since the terraces were unequal in length, direct comparisons of long terraces of different grades cannot be made. There was a difference of 175 feet in the length of 1-C, of 0- to 4-inch grade, and 2-C, of 0- to 6-inch grade, on virgin soil, and a difference of 320 feet between 2-B, of 0- to 4-inch grade, and 3-B, of 0- to 6-inch grade, on eroded soil. Regardless of the difference in length, the two C terraces, on virgin soil and with variable grades of 0 to 4 inches and 0 to 6 inches, respectively, had only a slight difference in soil and water losses (fig. 28). It is not understood why there was not a greater difference in the soil losses of these two grades since the constant-grade terraces had greater losses from the steeper grades (table 29). Results from the B terraces on eroded land, however, more nearly conform to results from the terraces of constant grade.

When the average lengths of the terraces of similar grades are considered, the 0- to 4-inch grade terraces averaged 2,443 feet and the 0- to 6-inch grade terraces, 2,690 feet. If comparison of average results from the two 0- to 4-inch grade terraces and from the two 0- to 6-inch grade terraces on both virgin and eroded soil is feasible, there was no significant difference in the runoffs from the two systems of grades and only 0.92 tons an acre more soil loss from the 0- to 6-inch grade. It is possible that the greater lengths of the terraces with the steeper grades may account for this small difference in the soil loss of the two systems.

Regardless of the lengths and grades of the terraces, the greatest differences in soil and water losses were between virgin and eroded land. Part of this difference may be due to the variation in plant cover on the land, since crop yields (table 34) on the virgin soil were higher than those on the eroded land.

Since there was so little difference in the losses from all the terraces measured, the results of the study do not indicate the optimum length or the limitation in length for terraces of the two systems of variable grades or for terraces on virgin and eroded soil. They do indicate, however, that terraces may be longer on permeable soil than on eroded soil or heavy compact clay.

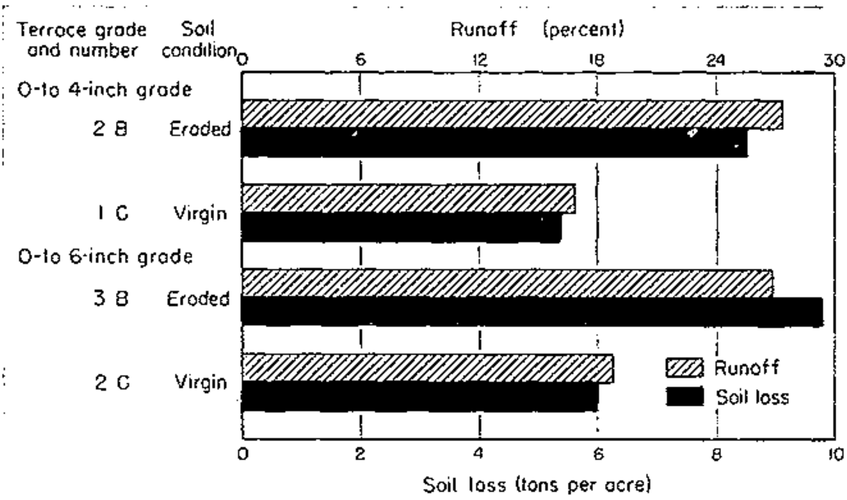

FIGURE 28.—Soil and water losses from the ends of terraces with variable grades, on virgin and eroded land.

The terraces of field E ranged from 1,300 to 1,937 feet in length (fig. 2) and were on badly eroded soil. These terraces were constructed in such a way that each terrace contained a level portion of from about one-third to one-fifth its total length and graded portions, each with grades ranging from 1 to 4 inches. Observations showed that these terraces, especially those of variable grades not exceeding 3 inches, performed satisfactorily.

TERRACE MAINTENANCE

A study of terrace maintenance was made for the 9-year period 1930-38. Five short level terraces of plot H, on virgin Stephensville soil and in a cropping system of corn and kafir, were laid out with rows across the ridges and up and down the slope. This method of cultivation resulted in the terraces being plowed down to such an extent that they had to be rebuilt with terracing equipment every other year.

The method of maintaining all the other terraces of the station was to backfurrow the ridge during seedbed preparation at least once a season and to leave the dead furrow in the interval area between the terraces. All planting and cultivation paralleled the terraces. Under this system of farm tillage no maintenance was necessary except filling in at gully crossings, and terraces 15 inches high, 26 to 32 feet wide, and as long as 2,856 feet, performed satisfactorily.

A number of readings were made in the fall of each year from 1931 to 1938 to determine the extent of soil movement on terraces of various slopes. Elevations taken at 1-foot intervals on six soil-movement lines on four of the terraces are shown in figure 24. The method of maintaining terraces by plowing toward the ridge increased the width of the base and crown, heightened the ridge, moved the channel uphill, and lowered the level of the surface of the interval area between the terraces.

TERRACED AND UNTERRACED LAND

Comparisons of measured quantities of soil removed by erosion from terraced and unterraced land indicate only in a general way the effectiveness of terracing, for under the present experimental technique such measurements are not precisely comparable. Unterraced areas are measured as closed watersheds; that is, all eroded material is carried to the lower part of the area where it passes through a measuring device. On the other hand, drainage areas formed by terrace ridges, and interterrace areas, are not entirely closed, and a considerable quantity of the soil eroded from the upper parts of these intervals is deposited in the lower parts, or terrace channels, and does not pass on with the runoff through the measuring devices at the ends of the terraces (fig. 29). Under some systems of terrace maintenance some of the soil deposited in the channels is periodicaly moved onto the ridges, as shown by the soil-movement lines in figure 24, and from the lower sides of the ridges this may be eroded into the next channel down slope. Over a long period this cycle of erosion, deposition, and transposition through maintenance operations is repeated many times, and as a result a continual down-slope movement of soil takes place, varying from an insignificant amount on gently sloping soils of favorable porosity to a serious quantity on steep highly erodible soils of low infiltration rate and limited absorptive capacity. Obviously all of this loss through interterrace erosion is not measured by the devices placed at the ends of the terrace channels. A more accurate comparison of terraced and unterraced land is therefore made from runoff and crop yields.

Comparisons of soil and water losses from terraced and unterraced land included three watersheds on badly eroded Chickasha, Zaneis, and

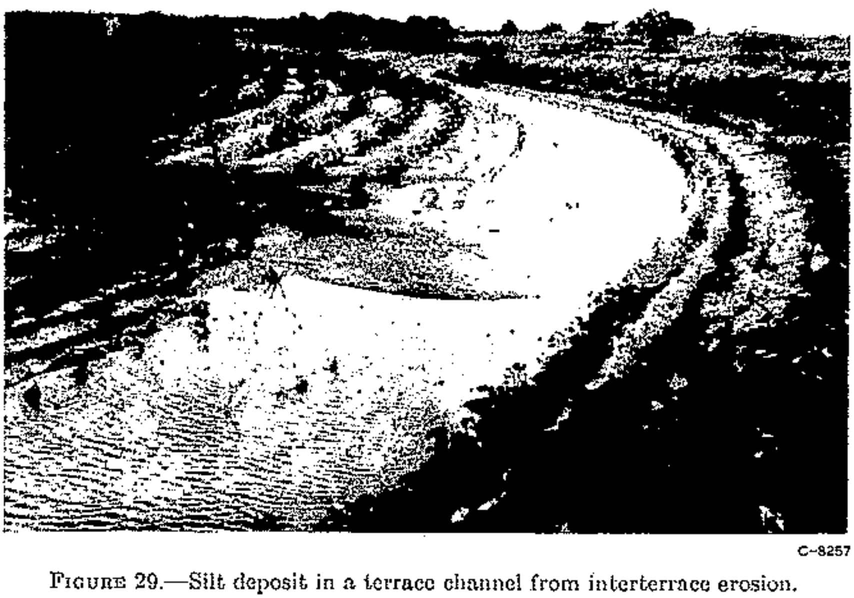

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FIGURE 29.—Silt deposit in a terrace channel from interterrace erosion.

Stephensville soil—plot 13, 3.23 acres of unterraced land on a land slope of 5.13 percent; plot 15–A, 3.13 acres on a land slope of 3.42 percent, occupied by four level terraces; and ravine A, 35 acres on a land slope of 4.94 percent, all of which was in graded terraces except about 1½ acres. Plots 13 and 15–A were in a rotation of cotton and cowpeas and ravine A, in rotations of cotton, oats, and corn or darso; and cotton with various legumes. Soil and water losses (table 31) are accentuated for the unterraced plot because it developed gullies rapidly and was located on a steeper land slope than the areas on which the terraces were constructed.

Runoff from unterraced plot 13 was 1.7 times that of the level terraces of plot 15–A and 1.2 that of the graded terraces of ravine A. Runoffs from these areas for high, moderate, and low intensity rains are in about the same order.

Although soil removed from the lower sides of the ridges and interval areas by the processes of terrace maintenance and interterrace erosion was not measured, soil loss in runoff from terraced watershed 15–A, as measured at the ends of the terraces, was 4.43 tons an acre as compared with 83.72 tons from unterraced watershed 13. This great saving in soil is accounted for by the shorter lengths of slope as a result of terracing and the lower velocity with which water moved from terraced land. On unterraced land excess water apparently proceeds at constantly increasing velocity to the first depression, where it develops little rills or gullies as it flows to an outlet. Cultivation of such land augments erosion by depositing loose soil in the drainageways; hence erosion increases as long as cultivation continues. Especially is this true on the shallow soils of the Red Plains area.

Because of the differences in the soil types and surface conditions of the terraced and unterraced areas, it is difficult to make direct comparisons of crop yields. The discussion therefore is based on general summary crop-yield data in table 32 and the detailed results compiled in tables 33, 34, and 35.

Yields of the terrace ridges, channels, and intervals were determined from six standard rows on the ridge, three in the channel, and from a number of rows in the intervals varying with the width of the interval. On all areas the ridge produced higher yields (fig. 30) than the interval with one exception. This indicates that the fertile surface soil had been moved into the ridges during the processes of construction and maintenance and that plant nutrients were the limiting factor for crop production during seasons of average rainfall. In dry years, however, moisture was the limiting factor, as is indicated by the fact that the terrace ridge was the first part of the field to show retarded plant growth. Figure 31 shows the stunted condition of darso on terrace ridges during a dry season.

Terraces on some of the deep fertile soils increased the yields of summer crops slightly, but decreased yields of spring crops. The failure of oats to respond to terracing was probably due to the fact that the period of highest rainfall in this area comes during the growing season of oats, and moisture is not often a limiting factor in the production of this crop.

Cotton yields were less from the terraced watersheds on eroded land, but both of the terraced watersheds used in this comparison contained level terraces, which were not satisfactory on the heavy compact subsoil on which they were placed. Corn yields on all the graded terraces were higher than on adjacent unterraced land except on ter-

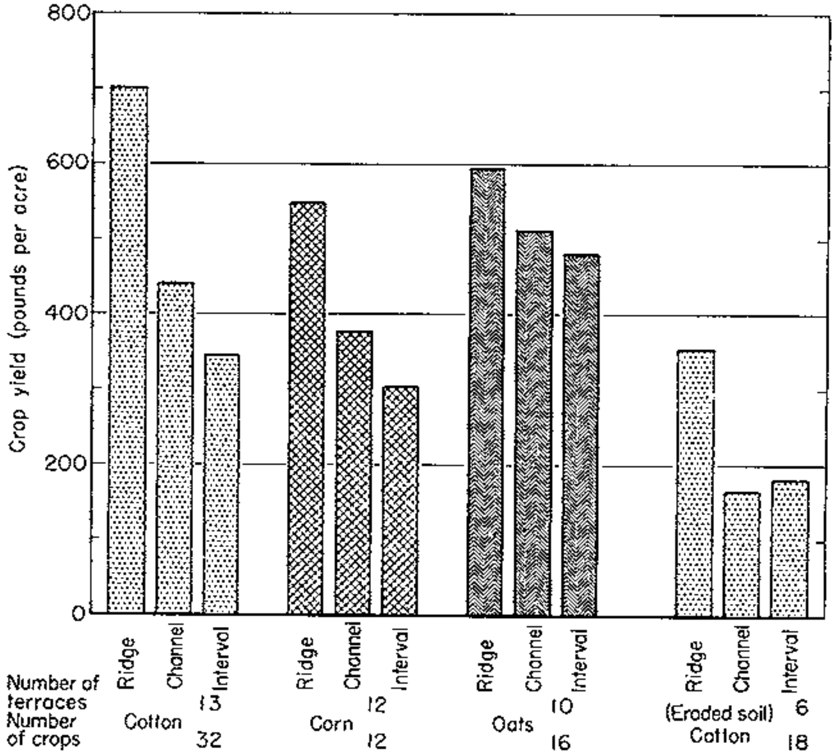

FIGURE 30.—Crop-yield distribution on ridge channel and interterrace areas.

FIGURE 31.—Darso in a terraced field during the dry season of 1936. The stunted condition of the plants on the terrace ridge is evident.

race 3-C—the terrace of 6-inch grade. The only one of the graded terraces that increased cotton yields was the terrace with the grade of 2 inches. The average cotton yield of level closed-end terraces on virgin land with deep fertile soil was slightly higher than that of adjacent unterraced land.

In the Panhandle of Oklahoma, on deep fertile soil the average annual grain yield of wheat and milo for a 10-year period was increased 3 bushels an acre by conserving water with level closed-end terraces (*6, p. 7*). Similar results were obtained at Spur, Tex. where closed level terraces increased the annual yield of lint cotton on an average of 68 pounds an acre in a 12-year period (*9*). Results of the study at this station indicate, however, that before terraces will increase the yields of crops the soil must contain enough available plant nutrients for normal crop production and have an open porous structure that will absorb water readily.

Outlet Channels and Waterways

Methods of controlling erosion at the ends of terraces, in terrace outlet channels, and in waterways are important problems in any effective terrace system. Several methods of control in outlet channels and in waterways were investigated, but since the terraces of the station were equipped with flumes and silt boxes for measuring soil and water losses, little attention was paid to outlets.

BITULITHIC LININGS FOR OUTLET CHANNELS

The lower 200 feet of the outlet channel of the terraces of field A (fig. 2) was selected for the bitulithic-lining experiment. This outlet drained 9.83 acres of land, and the runoff necessitated a cross-sectional area of about 8 square feet; the maximum section was 2 feet wide on the bottom and 2 feet deep, with banks on about a 1:1 slope.

After the banks of the ditch were properly graded, a mixture of 15 gallons of tarvia KP to 1 cubic yard of rock crushed to pass a ¾-inch screen was applied to the bottom and banks in 0.5-, 1-, 1.5-, and 2-inch thicknesses, respectively, in 50-foot lengths. This particular type of tarvia was used because it could be mixed cold. The cost of completing each section is shown in table 8.

TABLE 8.—*Comparative cost of labor and material for bitulithic lining of a terrace outlet channel by 50-foot sections of different thicknesses*

Length of section (feet)	Lining thickness	Materials				Labor [1]		Total cost of section
		Rock		Tarvia KP		Time required	Cost	
		Amount	Cost	Amount	Cost			
	Inches	*Tons*	*Dollars*	*Gallons*	*Dollars*	*Man-hours*	*Dollars*	*Dollars*
50	2.0	4	12.00	45	14.40	48	12.00	38.40
50	1.5	3	9.00	36	10.80	46	11.50	31.30
50	1.0	2	6.00	24	7.20	39	9.75	22.95
50	.5	1	3.00	12	3.60	35	8.75	15.35

[1] Labor and material costs were calculated with labor valued at $2 per 8-hour day, rock at $3 per ton, and tarvia at 20 cents per gallon plus 10 cents per gallon freight charges.

After compacting and curing, the mixture formed an apparently stable and elastic paving, but the first runoff of high intensity completely destroyed the 0.5-inch layer and badly pot holed the 1-inch section. The other two sections withstood the pressure of the flowing water very well but were later damaged by heaving, following freezing and thawing.

CHECK DAMS IN ROADSIDE DITCHES

Runoff from about 21 acres of terraced land in field C flowed into a ditch that served as a roadside drainageway. Concrete baffles were first installed in this ditch, but they were soon undermined by erosion and were replaced by a system of 12 masonry check dams so planned that the crest of the notch of one dam was level with the lip of the next dam upstream except where the channel passed through solid rock. Each dam had a rectangular notch 6 feet wide and 2 feet deep with a vertical drop of 2.5 feet from the crest of the notch to the lip of the apron and a stilling basin 4.5 feet long and 6 inches deep. These structures were made of various materials including concrete, hollow cement blocks, local sandstone, cement mortar, and used brick. Where the dams were founded on firm earth, cut-off walls 8 inches wide and 1 foot deep were placed beneath the head walls. The lips of the stilling pools and aprons were built below the overfalls to prevent erosion under the toe of the dam. Construction costs were generally high (table 9), but the cost depended greatly on availability of materials and labor. Best results were obtained from the dams solidly built, with cut-off walls sunk deep enough into the sides and bottom of the ditch to prevent seepage and with head-wall extension high enough to accommodate maximum flows and long enough to prevent water flowing around the end of the dam.

TABLE 9.—*Comparative time and cost of building a system of check dams* [1] *in field C*

Material	Material cost	Labor [2]		Total cost
		Time	Cost	
	Dollars	*Man-hours*	*Dollars*	*Dollars*
Concrete	13.35	71	17.75	31.10
Brick	16.22	88	22.00	38.22
Cement blocks	18.00	41	10.25	28.25
Stone masonry	15.80	100	25.00	40.80

[1] Each dam was 6 feet wide and 2 feet deep, with a vertical drop of 2.5 feet from the crest of the notch to the lip of the apron and with a stilling basin 4.5 feet long and 6 inches deep.
[2] Labor and material costs were calculated with labor valued at $2 per 8-hour day, rock at $3 per ton, and used brick at $10 per thousand.

Masonry dams similar to those in field C were constructed in the outlet ditch of field B draining about 17 acres of terraced land. All of these structures when properly constructed, regardless of the masonry material used, were satisfactory and required little or no maintenance.

Although dams of this type are expensive, they may be justified in deep narrow ditches along roadsides or in gullies where vegetation cannot be successfully grown, in narrow drainageways through valuable farming land, or where an overfall occurs at the lower end of a shallow drainageway.

VEGETATION IN WIDE SHALLOW WATERWAYS

The value of vegetation and cheaply constructed baffles in maintaining waterways in terraced fields was studied in two ditches, one draining 3.13 acres of terraces on watershed 15-A and the other draining 35 acres in field B. Cresoted plank baffles were installed in the ditch of plot 15-A, each of which was 6 feet long, with wing walls a foot higher than the crest and fastened to the main board at an angle of about 45°. The only protection devised against undercutting of the plank was to set the bottom of each baffle slightly below the crest of the structure downstream and to place loose-rock aprons below each baffle. The cost of material for these structures was $1.50 per 10 linear feet of 2- by 12-inch pressure-creosoted bridge lumber and about 2 man-hours of labor for installation.

The same type of structure was installed in the waterway draining field B into ravine A, a ditch 2 feet deep with a flat bottom 14 feet wide. Each baffle was constructed from one creosoted plank 16 feet long, including the length of the wing walls fastened at each end at an angle of 45°. The cost of these baffles included about 10 cents per linear foot for the board, 3 man-hours for installation, and a minor expense for a few short posts. Roots of Bermuda grass set in the ditches immediately after installation of the baffles developed a dense growth the first season, which prevented all erosion between the baffles (fig. 32). After about 5 years it was necessary to remove some silt from the waterways, but this was the only maintenance necessary.

Three concrete baffles were installed at the north end of ditch B, but wood structures gave as good, or better, results. Vegetation almost completely covered the soil around the wood baffles, whereas vegetation did not become established in the pits, or holes, formed by

FIGURE 32. Terrace-outlet ditch after Bermuda grass had become established between creosoted plank baffles.

the increased velocity of water as it passed over the spreaders. Baffles in other waterways, made of any materials found on the farm, such as poles, old wire, and loose rock, were used successfully to prevent erosion until a protective cover of grass could be established. Broad shallow ditches properly protected by creosoted wood baffles or other cheap material until vegetation is established afforded a satisfactory and economical means of handling runoff from terraced fields in this area. It is recognized, however, that this type of structure requires considerable attention to prevent damage from heavy rains occurring during the period while the vegetative cover is being developed.

Rate of Erosion

On the basis of actual soil losses from the control plots, terraces, and watersheds, calculations were made to determine the length of time during which 1 inch of soil is removed in the Red Plains under various conditions of cover, cultural treatment, and cropping system.

Estimates for the various conditions, as shown in table 10, indicate that plot 13 of field E, badly eroded and gullied, unterraced land cultivated across the gullies to a rotation of cotton and cowpeas, had the highest rate of erosion. Approximately 1 inch of soil was removed from this land each 2 years. Badly eroded land under continuous cotton on the control plots lost 1 inch of soil in 6 years. Virgin land in the same crop lost 1 inch in 11 years, whereas a rotation including cotton will lose the same quantity in 47 years. Woods and grasslands have shown virtually no soil loss.

Table 10.—*Estimated period of time during which 1 inch of topsoil may be lost under various land conditions, on the basis of actual losses from the experimental areas*

Area designation [1]	Cropping condition or cropping system	Estimated period of time in which given quantities of soil may be lost [2]
Control plots: [a]		*Years*
3	Continuous cotton	11
4, 5, 6	Average rotation of cotton, wheat, sweetclover	47
7	Bermuda grass, clipped	8,750
8	Bare hard fallow	8
9	Continuous cotton on subsoil	6
10	Virgin woods, undisturbed	17,500
Terraces: [4]		
5 C, 2-inch grade	Rotation of cotton, oats, corn, or darso	55
6 C, level	do	132
Watersheds:		
Plot 13, Unterraced	Rotation of cotton and cowpeas	2
Plot L	Native woods and grass	[illegible],166
Pasture	Native grass	7,833

[1] Control plots, plot L and pasture area were established on virgin land, terraces 5 and 6 C on virgin and slightly eroded land; and plot 13 on badly eroded land. Terraces are 1,500 feet long with 1,000 feet of virgin soil.

[2] Computed from weights of actual losses from the different areas and the weight (175 tons) of an acre-inch of soil of the station as determined by Middleton, Slater, and Byers (26, p. 21).

[3] Plots 3, 4, 5, 6, and 9 cultivated up and down the slope.

[4] Cultivated on contour.

[5] Cultivated across gullies.

Although terraces, crop rotations, and proper soil treatments reduce soil loss, it is difficult even under the best combination of conservation practices to avoid soil losses on cultivated land in this area. According to the records, the most satisfactory terrace on the heavy soils of the farm is 5-C, 1,500 feet long, with a uniform grade of 2 inches. On this area cotton, oats, and corn or darso were grown in rotation on the contour, with the oats followed by cowpeas and the cotton by a winter cover of wheat. Under these conditions, soil loss has been at the rate of 1 inch in 55 years.

Revegetation and Reclamation of Eroded Land

Following the findings of the erosion surveys made in 1929, which revealed the rapidity with which land is being abandoned in the Red Plains because of erosion. revegation and land-reclamation experiments were undertaken by the Oklahoma Agricultural Experiment Station (*28, pp. 9-19*), in an attempt to find new stable uses for land submarginal for cultivation. These experiments were designed to show the importance of checking erosion in its early stages, revegetation, and gully control, removing woody vegetation for grass culture, and the value of such land for pasture.

IMPORTANCE OF CHECKING EROSION

Soil and water losses from terraces and control plots were measured to determine the difference in the rate of erosion from virgin and eroded land. Although measurements from terraces 1- and 2-C on virgin Chickasha and Zaneis fine sandy loam, and 2- and 3-B, on the eroded phase of the same soil types, are not precisely comparable because of the differences in the lengths of the terraces, they indicate in general the difference in erosion from the two soils (table 30). Average results from the terraces on virgin soil and on eroded soil show that eroded land lost 1.51 times more water and 1.60 times more soil than virgin land. Similar losses resulted from high-, moderate-, and low-intensity rains.

Further evidence of greater erosion from eroded land is provided by results recorded in tables 19 and 36 from the control plots. Percentage of runoff from artificially eroded Stephensville soil planted to continuous cotton with rows up and down slope was 2.19 times more and soil loss 1.67 times more than the losses from adjacent surface soil planted in the same way (fig. 33). Since the crop yield of the surface soil was considerably higher than that of the desurfaced, these differences in soil and water losses might be attributed to the difference in plant cover except that while the desurfaced plot lost virtually the same amount of water as the virgin bare hard fallow plot, its soil loss was 1.26 times more. Evidently soil condition was the factor governing the greater erosion from the desurfaced soil.

The virgin sandy loam surface of these soils provides a favorable condition for the downward movement and absorption of water, and when this layer is removed by erosion the storage capacity is reduced. The compact clay subsoil has very little fertility and as soon as it becomes wet it tends to disperse and deflocculate and thereby reduce rate of infiltration. Excess water accumulates, and often forms deep, narrow gullies, as shown in figure 34. As the banks of the gullies slough, large undispersed fragments of shale and unweathered parent material move down slope (fig. 35), and when such conditions are allowed to continue for a long time the parent material becomes

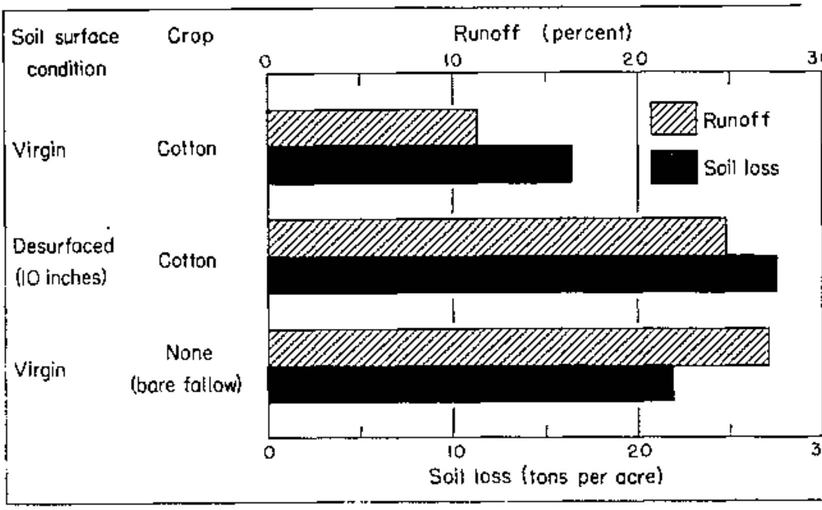

FIGURE 33.—Soil and water losses from virgin and desurfaced land in continuous cotton and from bare hard fallow on virgin surface soil.

exposed as shown in figure 36. The results of the study clearly show the importance of checking erosion before the land becomes seriously eroded, for as the soils of the area erode further erosion is accelerated.

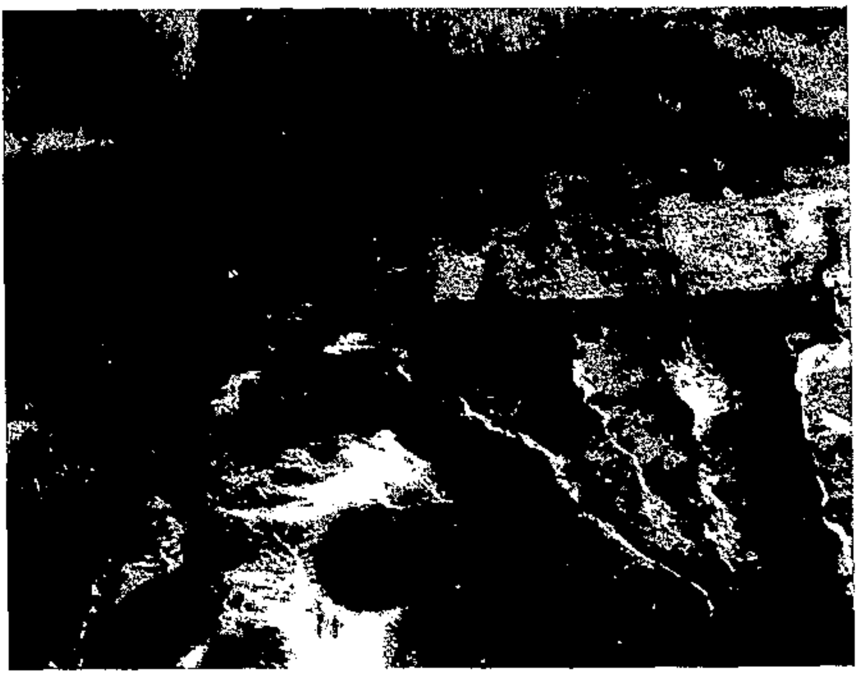

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FIGURE 34.—Narrow, deep gullies forming on sheet-eroded land.

C-8258

FIGURE 35.—Fragments of shale, soft sandstone, and unweathered parent material collected in a silt box. (End of silt box removed to facilitate cleaning.)

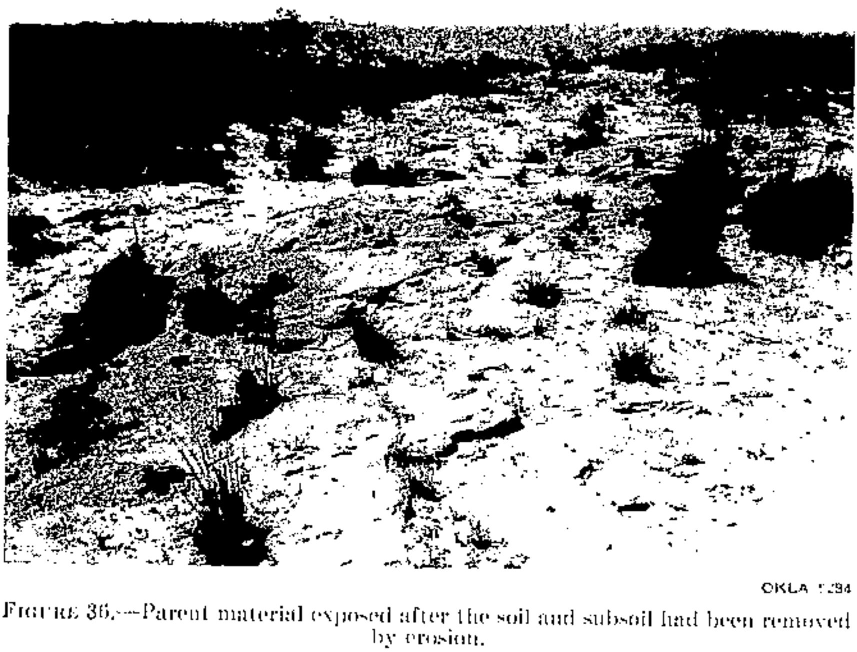

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FIGURE 36.—Parent material exposed after the soil and subsoil had been removed by erosion.

75 750

FIGURE 37. A typical gully on the East farm.

185827—43——4

75,752

FIGURE 38.—Silt caught above loose-rock dams of this type often provides favorable conditions for plant development, but such dams do not provide protection for the areas immediately below the structures.

C-8526

FIGURE 39.—Brush and other vegetative residues in use for gully control after the slope of the banks had been reduced by plowing.

REVEGETATION AND GULLY CONTROL

In 1932, a farm adjacent to the station was acquired for reclamation and gully-control experiments. This area, designated as the East farm, contained about 110 acres of land, 75 acres of which were badly gullied. After 37 years of continuous cultivation this area had been removed from crop production and abandoned to a sparse growth of annual and perennial grasses. The gully pictured in figure 37 shows the severity of erosion on this farm. The soils were of the Chickasha, Zaneis, and Stephensville series, and an erosion survey showed that an average of about 12 inches of surface soil had been removed.

An attempt was made to divert runoff from the original channels by building small contour ridges between and above the courses of the gullies. These small terraces were built in one or two rounds with a horse-drawn long-wing plow and wherever possible were drained onto grassland. This economical method of construction was used so that the cost might not exceed the value of the land.

The gully-control work was conducted principally with temporary dams made of various materials found on the farm. Loose-rock dams of the type shown in figure 38 were more useful if designed to catch soil on which native grass could become established. Brush-and-pole dams of various designs were tried at several places (fig. 39), but burrowing animals and rodents found a harbor in them and they were effective only about 2 years, unless vegetation was established in the gullies shortly after they were built. This was done by placing soil, removed from the gully in the building process, above the dam and setting in sod of native grasses (*Sorghastrum nutans*, *Paspalum floridanum*, *Andropogon scoparius*, and *Andropogon furcatus*). Bermuda grass sod bags were tried but with little success. Attempts were made to establish trees and vines on the shallow eroded soil of the farm, but a great many of the plants died.

The most satisfactory results in reclaiming gullies were obtained by installing vegetative residue dams, plowing down the gully banks to about a 1:1 slope as shown in figure 39, and planting legumes, especially biennial sweetclover broadcast 15 pounds to the acre and applying 100 pounds of lime and 50 pounds of superphosphate per acre. Figure 40 shows a gully after such treatment and with the second year's growth of sweetclover. Lespedeza sericea made a good growth in several gullies and eroded spots without being fertilized. Little and big hop clover, yellow trefoil, bur-clover, Korean lespedeza, vetch, and kudzu failed even when treated with fertilizer and lime.

Other experiments to determine the value of fertilizer and sweetclover in revegetating land were conducted on adjacent badly eroded Chickasha fine sandy loam. Three areas, each consisting of five plots, were planted to sweetclover and treated as shown in table 11. Two of the series were planted in shallow contour furrows and one in a smooth seedbed.

TABLE 11.—*Yields of sweetclover*[1] *from badly eroded plots planted in shallow furrows and smooth seedbeds and treated with different kinds of fertilizer for the year 1935*

Plot No.	Fertilizer [2]	Amount of fertilizer per acre	Yield per acre of second-year growth according to method of planting	
			Shallow listed rows on contour	Smooth seedbed
		Pounds	*Pounds*	*Pounds*
1	None		668	105
2	Superphosphate	40	1,210	270
3	Rock phosphate	40	2,002	165
4	Superphosphate Limestone	40 80	1,700	555
5	Rock phosphate Limestone	40 80	2,150	500

[1] Planted at the rate of 2½ pounds of seed per acre in rows 3 feet apart.
[2] Placed under seed in drill rows at the time of planting.

Light applications of rock phosphate and lime increased the yield of the second year's growth three to four times where the seed was planted in shallow furrows. All phosphate treatments, alone or with lime, produced increases in yields. The higher yields from the furrowed area, however, indicate the value of moisture conserved by the shallow furrows. Similar results on other soils of Oklahoma are reported by Harper (*16, p. 28*), who says that—

recent data * * * on the application of fertilizers in the drill row with the sweetclover seed indicate that the rock phosphate is more effective in increasing the yield of sweetclover than equal amounts of superphosphate applied under similar conditions.

The series of plots were then seeded to native grasses. Blue grama (*Bouteloua gracilis*) in combination with the volunteer sweetclover produced enough cover the fourth year to prevent erosion (fig. 41).

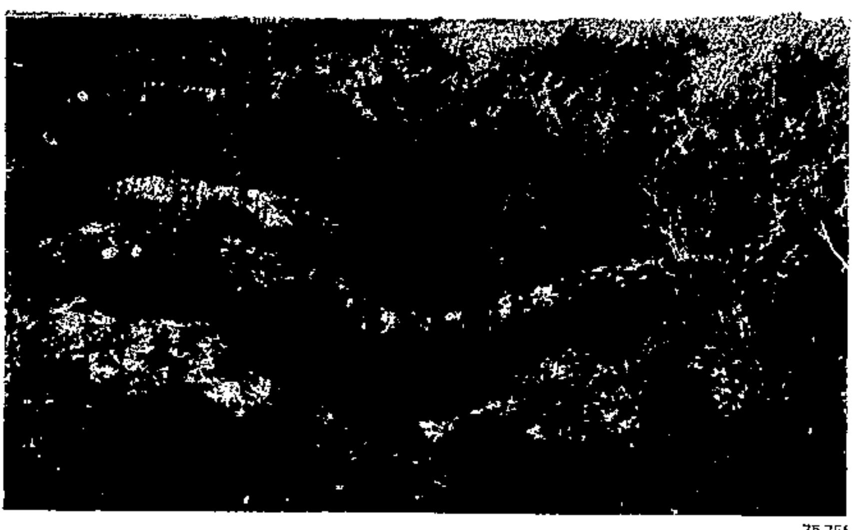

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FIGURE 40.—Vegetative cover established on a gully temporarily stabilized by a plant-residue dam.

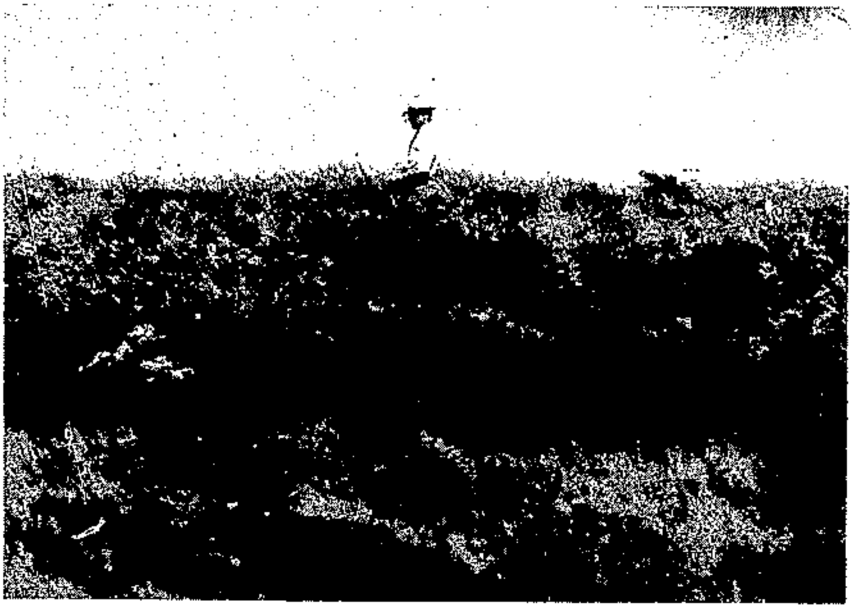


FIGURE 41.—A second year's growth of native grass and volunteer sweetclover on badly eroded land.

This indicates that badly eroded land may be made to produce enough forage to increase the organic-matter material of the soil and that native grasses may be established on such land.

Studies were also made of seed plantings of the following grasses on well-prepared seedbeds: Little bluestem (*Andropogon scoparius*), prairie beardgrass (*Andropogon ternarius*), silver beardgrass (*Andropogon saccharoides*), big bluestem (*Andropogon furcatus*), blue grama (*Bouteloua gracilis*), vine-mesquite (*Panicum obtusum*), switchgrass (*Panicum virgatum*), purpletop (*Triodia flava*) dropseed (*Sporobolus airiodes*), Indian grass (*Sorghastrum nutans*), Bermuda grass (*Cynodon dactylon*), buffalograss (*Buchloe dactyloides*), Dallis grass (*Paspalum dilatatum*), and western wheatgrass (*Agropyron smithii*). Blue grama and dropseed made a fair ground cover the first year after seeding. All the Andropogons made a very poor cover even after the third year of growth, and the other grasses failed completely. The Andropogons, especially little and big bluestem, seem to require a more fertile soil than blue grama or dropseed. The poor physical condition and low available-nitrogen content of the eroded soil on which the Andropogons were seeded apparently was the primary cause of their failure to make a vigorous growth. Evidently badly eroded soil must have more organic matter before seedings or sod plantings of native climax grasses will produce much growth.

The low nutrient requirements of native subclimax grasses and their ability to survive even under the most severely eroded conditions are evident in many fields of the area. Figure 42 shows grasses that have withstood much punishment. The ability of these grasses to resist erosion is an important factor in the process of revegetation. Their tufts form small mounds that retard erosion, and as the soil continues

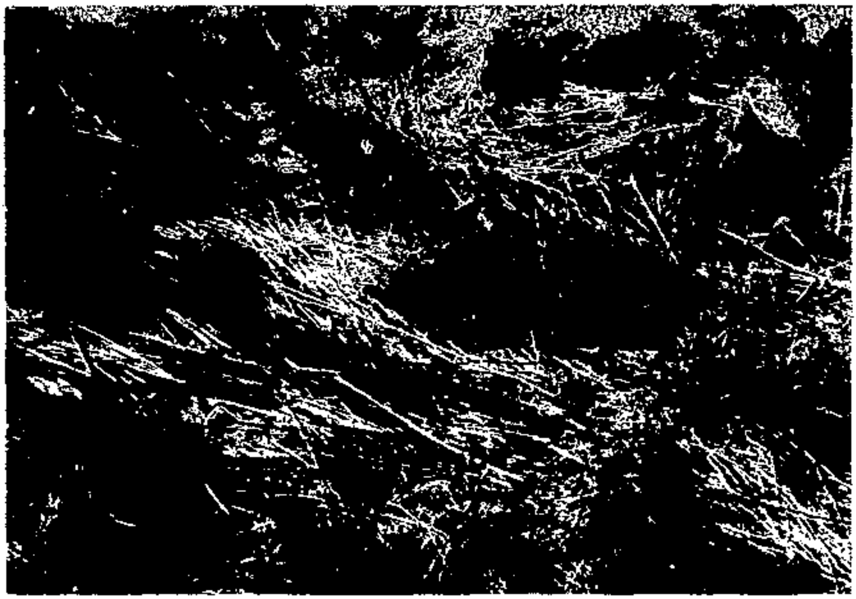
OKLA-6915

FIGURE 42.—Some of the native subclimax grasses offer considerable resistance to erosion.

to weather and the vegetation to decompose there is a surface accumulation of residue that creates conditions conducive to plant succession. The addition of organic material (fig. 43) between the tufts accelerates this process and makes conditions more favorable for the infiltration of water.

The process of reestablishing native grasses by natural plant succession is slow, even under favorable environmental conditions. It has taken about 25 years to reestablish a protective cover of these grasses on an abandoned field of an adjacent farm. The erosion problem of the field is now about solved, and the grass is ready for utilization. Figure 44 shows this field with its luxuriant growth of tall grass reminiscent of the original land cover and the range type of land use that disappeared as man plowed the Plains.

The results of the study indicate that the length of time required by nature for revegetating eroded land through processes of plant succession may be shortened by the use of economical conservation practices and the introduction of such legumes as lespedeza sericea and sweetclover. If good stands of legumes are obtained the first season the land may be planted to grass the second or third year. The vegetative cover produced, however, depends upon the accumulation of residue and organic matter from the legumes and the water-holding capacity and general physical condition of the soil. Much more research is needed on plant succession, revegetation, and land utilization during the revegetative process.



75.753

FIGURE 43.—The addition of organic material to the bare soil between the tufts of native grass retards erosion and thereby accelerates the process of plant succession.

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FIGURE 44.—A good protective cover of native grass reestablished through natural processes of succession on land that had been out of cultivation about 25 years.

75,748

FIGURE 45.—Successful utilization of scrubby oak land necessitates the removal of sprouts and weeds which may be accomplished by the use of an ordinary mowing machine.

REMOVING WOODY VEGETATION FOR GRASS CULTURE

Recent surveys of land utilization in a part of the area, as reported by the Bureau of Agricultural Economics,[11] show that large acreages are classed as woodland pasture. These pastures are covered with a growth of scrubby oak interspersed with native grass that makes a good growth when not crowded out by the trees. Since native grass provides a more erosion-resistant cover than mixed vegetation in this area, an attempt was made in 1935-36 to improve the value of such pastures by removing the scrubby oak from 35 acres of this type of land on the East farm.

The cost of clearing the land was high, but farmers adjacent to the station found that they could cut about 10 to 16 ricks of firewood an acre from similar land. Under usual conditions such wood brings from $1 to $1.50 a rick, and returns from the sale of the wood should aid materially in meeting the cost of clearing.

After the trees had been removed the growth of sprouts from the stumps presented another problem. Burning them proved an undesirable method of control as it destroyed the grass around the stumps and the cost was about $3 an acre. Since mowing is recommended by Aldous (*1, p. 9*) for destroying noxious plants and weeds in pastures, this method was tried on the clumps of sprouts. Clipping them with an ordinary farm mower (fig. 45) the first of May and again about the middle of August when the grass was cut for hay prevented them from competing with the growth of the grass, and as they were cut at the same time as the weeds there was no additional expense.

[11] U. S. Bureau of Agricultural Economics. MAJOR USES OF LAND IN OKLAHOMA BY CIVIL TOWNSHIPS, 1935. Mimeograph No. 1, [82] pp., illus. Stillwater, Okla. 1939. [Processed.] (Prepared in the Office of the State Land Use Planning Specialist for Okla.)

OKLA 6906

FIGURE 46. Native-grass meadow the third year after removal of woody vegetation.

The area was protected from fire, and the grass soon spread and provided enough cover to prevent erosion. The first year after clearing, it produced about half a ton of hay an acre, the second year slightly more, and the third year three-fourths ton. Rainfall the first 2 years was 11.64 and 8.96 inches below the average of the area but was about normal the third year with a slightly above-normal distribution throughout the growing season. The meadow was used for hay the first 2 years to avoid overutilization and was cut early in August to allow the grass to seed before frost. Figures 46 and 4 show portions of this land before the scrubby oak was removed and the third year after it had been reclaimed for native grass. Under this method of utilization, the native grass produced enough forage to permit restricted grazing the third year.

PASTURE INVESTIGATIONS FOR EROSION CONTROL

In 1939 the entire East farm, which occupies about 110 acres of land, was converted into a grazing experiment in cooperation with the Oklahoma Agricultural Experiment Station. About 75 acres of this area was abandoned land and the remaining portion was virgin soil, which had been cleared of native scrubby oak in 1935-36. An erosion survey showed that an average of about 12 inches of surface soil had been removed by sheet and gully erosion from the abandoned land prior to 1932, when the farm was leased. Although the soils and plants on the virgin land were slightly higher in nitrogen and minerals than those on the eroded area, analytical data from the Oklahoma Agricultural Experiment Station show this type of vegetation, which occupies this section of the State, to be low in phosphorus and calcium. Since these elements are very essential in the growth of the livestock, a mixture of equal parts of steamed bonemeal, powdered limestone, and common salt was provided at a convenient location for the cattle. The animals used in the tests ranged from medium to good quality yearling steers (fig. 47).

It was planned to graze the pasture during the growing season, but because of a delay in getting the experiment under way the first year, 14 grade yearling steers occupied this farm from June 6 to October 3, 1939, or a total of 119 days. The data in table 12 show a total gain of 2,716 pounds for all the steers, which is an average of 24.7 pounds of beef per acre. The average gain per head was 194 pounds, which was an average daily gain of 1.6 pounds per head. During the second test, 20 steers occupied the same pasture from May 1 to October 1, 1940, or 153 days. They produced a total of 5,530 pounds of beef, or an average gain of 276.5 pounds each, which is a daily gain of 1.8 pounds per animal. This is an average of 50.3 pounds of beef per acre.

TABLE 12.—*Gains made by yearling steers grazed on 75 acres of land formerly abandoned from cultivation and 35 acres of cleared scrubby woodland* [1]

[Progress report—2 years only]

Item		Grazing season of—	
		1939 (June 6 to Oct. 3)	1940 (May 1 to Oct. 1)
Animals	number	14	20
Grazing period	days	119	153
Carrying capacity per steer	acres	7.9	5.5
Selling weight (Oklahoma City)	pounds	9,072	15,330
Initial weight (Oklahoma City)	do	6,356	9,800
Net gain	do	2,716	5,530
Gain per acre	do	24.7	50.3
Average daily gain per steer	do	1.6	1.8

[1] Data collected by Bruce R. Taylor, assistant professor of animal husbandry, Oklahoma A. and M. College.

The percentages of grass consumed by the steers during the two seasons of summer grazing are shown in table 13. The highest utilization occurred on the virgin land, but there was sufficient vegetation left at the end of each growing season on both areas to protect the land from erosion. The annual production of 25 to 50 pounds of beef per acre should be sufficient to place this formerly useless land on a profitable basis of operation.

TABLE 13.—*Percentage of grass cover consumed by steers during summer grazing on 110 acres of abandoned and virgin land*

Year	Abandoned revegetated land (75 acres)	Cleared woodland native grass (35 acres)
	Percent	*Percent*
1939	10.19	20.79
1940	25.20	67.12

FIGURE 47.—Native grass on the East farm in a stage of revegetation. Erosion has been controlled and satisfactory pasturage furnished for beef cattle.

RESULTS OF INVESTIGATIONS AND THEIR APPLICATION TO LAND USE IN THE RED PLAINS

According to erosion surveys, the general farming practices which have been followed throughout the Red Plains, have permitted serious erosion. The soils are highly erodible but until the land was broken for cultivation the native cover of prairie grasses protected them from erosion. With the introduction of arable agriculture, the grasses gradually disappeared and under the systems of farming generally adopted, millions of acres became eroded to such an extent that they have been abandoned for cultivation. The most serious erosion occurs on the shallow soils of the rolling slopes, while the deeper soils of the broad nearly level divides are less affected. Soil and water conservation investigations at the Red Plains Conservation Experiment Station have shown that this severe erosion can be materially reduced by wise land use and practical conservation measures.

These investigations have shown that it is difficult, if not impossible, to control erosion on the shallow soils of the rolling slopes when they are utilized for the production of cultivated row crops. These soils should be put in permanent cover, such as native grass, and if grazed conservatively, satisfactory returns may be secured. Cultivated crops should be restricted to the nearly level areas with deep soils and protected from erosion by adequate conservation practices.

Some of these soil-conserving practices are easily installed, whereas, others require technical assistance. The main point is that each of the better farming practices started is one step nearer the ultimate objective of a complete soil conservation program.

Contour cultivation.—Tillage on the contour is a conservation practice conducive to conserving soil and water. It is effective in controlling soil and water losses from moderate rains but this practice alone is not adequate for controlling losses from high-intensity rains. Contour tillage should be a part of any conservation plan for use on cultivated land.

Crop rotation.—A simple crop rotation of cotton, wheat, and sweetclover was effective in reducing runoff and erosion. This practice on cotton land has been of material aid in maintaining crop production. The extent to which any crop rotation is effective in reducing soil and water losses is primarily dependent upon the proportion of close-growing vegetation in the rotation, the time period and season that it occupies the land. Another important item is the amount of residue left on the land. Close-growing cultivated plants that produce protective land cover during the critical soil loss periods of May, June, August, and September are especially valuable in the conserving of soil.

Effect of burning vegetation.—Burning of vegetation causes a loss of nitrogen, destruction of organic matter, and increases soil and water losses. In order to maintain a protective cover on all land covered by grass, timber, stubble mulch, and other dense vegetation, burning and overutilization should be discouraged.

Strip cropping.—The practice of strip cropping with cotton in strips 42 feet wide, interspersed between strips of oats, Sudan or alfalfa of the same width reduced soil erosion. Alfalfa is not generally adapted to the upland soils of the area and consequently failed the second season. The lack of a suitable close-growing cultivated crop limits the value of strip cropping in this area.

Terraces.—The water-storage capacity of the soil should be considered before deciding what type of terrace to construct. Level terraces may be used satisfactorily on sandy land or soils with deep permeable profiles, where rate of infiltration is rapid, but graded terraces not exceeding 2 inches per 100 feet are the most satisfactory type on medium- and fine-textured soils underlain with compact clay subsoil. Terraces should be spaced as close together as farming conditions permit, but the size of the ridge should vary with the soil conditions, intensity of rainfall, and width of the interval between the terraces. Maintenance can be accomplished most economically by adaptation of normal tillage operations.

Outlet channels.—Broad shallow vegetated ditches were the most satisfactory and economical means of handling runoff from terraced fields. Masonry structures properly installed were satisfactory in ditches, but the expense of such dams is justified only in deep narrow roadside ditches, in gullies that cannot be vegetated, in narrow drainageways through valuable farming land, or where an overfall occurs in a shallow drainageway.

Terraces with other conservation practices.—The present information indicates that in general a well-planned system of terraces with crop rotations including as many close-growing sodlike crops of grasses and legumes as possible planted on the contour is the best combination of erosion-control practices for soils which are suitable for cultivation in the Red Plains. In addition, the conservation of crop residues and manures is essential and the use of lime and mineral fertilizers is recommended when needed. It is difficult, though, even under the best combination of erosion-control practices to prevent some erosion from occurring on cultivated land in this area. The most satisfactory terrace at the station, on heavy soil and in a rotation of cotton, oats, and darso, lost soil in runoff during the 8 years of measurement at the rate of 1 inch in 55 years.

Reclaiming eroded land.—The experiments definitely showed that any process of restoring soil fertility is slow and that crop production is hazardous on badly eroded shallow soil where both plant nutrients and moisture are limiting factors in plant growth. Terrace studies indicated that regardless of the type of terrace used on shallow eroded soil under cultivation runoff is only slightly less than that from unterraced land. The plant-cover experiments, however, demonstrated that thick-growing vegetation reduces runoff even on eroded soil. There is virtually no runoff from grass and woods. All investigations showed that the most satisfactory method of reclaiming shallow eroded land in this area is to establish grass or other thick-growing vegetation.

All shallow and badly eroded land should be returned to grass so that it may resist further erosion and through soil-building processes be restored to a state of stabilized use. Native prairie grasses reestablished themselves on eroded land, but the processes of natural succession take about 25 years. Such land may be revegetated in a comparatively short time by the use of low-cost conservation practices and the introduction of such legumes as lespedeza sericea and sweetclover lightly fertilized. If good stands of legumes are obtained the first season, land may be planted to grass the second or third year. If the area to be revegetated is severely gullied, special treatments to stabilize the gullies will be necessary. The vegetative cover produced, however, depends on the accumulation of residue and organic matter afforded by the legumes and the fertility, water-holding capacity, and general physical condition of the soil. Native grass seeded on eroded land following sweetclover, together with the volunteer growth of the clover, produced enough cover the third year to prevent erosion. Native grass thus established on this formerly useless and abandoned land has controlled erosion and the results of two seasons of grazing indicate that satisfactory pasturage was provided.

Removing woody vegetation for grass culture.—Large areas of land in the Red Plains, consisting of mixed scrubby oak and native grass cover, have been classified as woodland pasture. The value of these pastures may be improved by removing the trees and brush without impairing the erosion-control value of the land cover. Such pastures may be maintained and satisfactory pasturage provided by controlling grazing, mowing of weeds and sprouts, and eliminating burning.

Land use for shallow soils not suitable for cultivation. Areas of scrubby oak land are often adjacent to abandoned cultivated fields where revegetation is necessary. By combining both the areas to be revegetated and the formerly scrubby oak land into pasture, some returns may be obtained during the revegetation process. Through this method of land use the formerly useless land may be made more stable and the returns from livestock compares favorably to that produced on the range land of the area. The present information indicates that this system may constitute the most desirable form of land use for the seriously eroded and shallow soils of the Red Plains.

SUMMARY

The site for the conservation experiment station near Guthrie, Okla., was selected in 1928 and established in 1929 for the purpose of investigating methods of controlling erosion in the Red Plains, an area of nearly level to rolling land extending through central and western Oklahoma and from south-central Kansas to northwestern Texas.

This land-type area is characterized by grayish-brown to dark-brown soils underlain by red and gray sandstone and shales known as the Permian Red Beds. These highly erodible soils were originally protected by a cover of prairie grasses. General farming is now followed throughout most of the area, with cotton as the principal crop in the southern and larger part of the area and small grain in the northern part.

Experiments in methods of erosion control were conducted on plots of various sizes, individual terraces, and terraced and natural watersheds under different conditions of vegetative cover, cultivation, cropping system, or terrace design, and the comparative effectiveness of these conditions was determined by measured soil and water losses, crop yields, and observations. The various experiments at the station covered periods of from 5 to 11 years, and results reported are for the period of record.

Annual precipitation at the station was 30.22 inches, with the highest amounts in May, June, August, and September and the lowest in January and February. Long drought periods frequently occurred, however, between the short intense rains of summer. Fall and winter rains were generally of long duration and low intensities. The winters as a whole were mild, and the soils rarely froze below a depth of 6 inches. The summers were hot, and at times there were hot dry winds. Warm-season evaportaion from a free-water surface was 59.02 inches.

Annual runoff from the bare hard fallow control plot resulting from 20 of the 57 storms recorded, was 27.09 percent of the annual precipitation. The highest percentages of runoff occurred from the intense rains of late spring to early fall and the lowest in the winter months. Intensity was a more important factor in causing runoff than either amount or duration of rainfall.

The most effective method of controlling erosion was with thick-growing vegetation, and of this, grass was the best erosion-resistant cover. Native grass alone, or mixed with Bermuda grass, allowed virtually no soil loss. Burning forest litter and vegetation on woodland increased soil and water losses 11 and 32 times as compared with undisturbed woodland.

Of the tillage methods employed, cultivation on the contour was the best practice for conserving soil. On a fine sandy loam with a land slope of 6.75 percent, the soil loss from rows cultivated on the contour was less than one-half of that from rows cultivated up and down the slope. The fact, however, that cotton on contoured virgin land lost 16.57 tons of soil an acre a year indicates that this conservation practice alone is not sufficient for protecting highly erodible soils on steep slopes and should be supplemented by other practices. Tillage with a hole-digging machine following ordinary cultivation during the growing season of cotton reduced crop yields and was not effective in conserving soil and water. Subsoil tillage also had little effect in increasing the infiltration capacity of the soil.

Soil loss was 4.4 times more from continuous cotton than from a 3-year rotation of cotton, wheat, and sweetclover. The soil lost from cotton in rotation was only a little more than half that from continuous cotton. Strip cropping with alfalfa, oats, and Sudan as the erosion-resistant strip in cotton also proved a soil-conserving system. Although the strip seeded to alfalfa provided an effective protective cover, the alfalfa plant itself failed of its purpose, because of the fact that it is not well adapted to the upland soils of this area and had practically been supplanted by weeds and grasses at the end of the second season. Oats and Sudan strips reduced soil loss about a ton annually as compared with continuous cotton, but since yields of seed cotton from the strip-cropped plots were less than yields from the all-cotton plot, the small saving in soil loss by this system probably does not justify its use as a conservation practice.

Properly constructed terraces conserved soil and water, but even under the best combination of conservation practices cultivated land lost some soil at the ends of open terraces. When placed on deep soil with high rates of absorption and with enough plant nutrients for normal crop production well-designed terraces increased the yields of cotton and corn. They did not, however, increase the yields of oats, the growing season of which comes during a period of high rainfall.

The soil loss as measured at the end of the terraces increases with the increase in spacings, but not in direct proportion. Of the spacings studied, 3.5 feet was the most satisfactory on the soils and slopes of the station.

Soil loss also increased with increase in grade. Level terraces lost less soil and water than terraces of 2-, 4-, and 6-inch grades, but when placed on eroded soil or clay with a compact subsoil not permeable enough to absorb the amount of water retained, they were not successful for crop production. When crop yields and soil and water losses are all considered, 2 inches per 100 feet gave the most satisfactory performance of the grades tested on eroded and compact soil. Level terraces with closed ends were satisfactory only on deep permeable virgin soil with high absorptive capacity.

Since there was very little difference in the soil and water losses from terraces 2,350 to 2,856 feet long, with variable grades of 0.4 and 0.6 inches, the optimum length or limitation in length for terraces was not determined, but long terraces were more satisfactory on permeable soil than on eroded soil or heavy compact clay. There was no significant difference in the soil losses of 0.4- and 0.6-inch grades on virgin land, but on eroded land the 0.4 grades had the smaller loss.

Terraces cultivated across the ridges, or up and down the slope, had to be rebuilt with terracing equipment every other year. Little or no maintenance was required if the ridge was back-furrowed during seedbed preparation and the dead furrow left in the interval. Maintenance by plowing toward the ridge increased the width of the base and crown of the terrace, heightened the ridge, moved the channel uphill, and lowered the interval between the terraces.

Broad shallow vegetated ditches were the most satisfactory and economical means of handling runoff from terraced fields.

Badly eroded land lost soil 1.60 times faster than virgin land. Fertilization with phosphates and legumes, and with commercial nitrogen afforded some increase in crop yields on eroded land, but returns did not justify the fertilizer treatment.

Best results in controlling gullies were obtained by installing check dams, plowing down the gully banks to about a 1 : 1 slope, and planting sweetclover followed by native grass. Loose rock and brush and pole dams were more useful in gully control when supplemented with vegetation.

All shallow and badly eroded land should be returned to grass so that it may resist further erosion and through soil-building processes be restored to a state of stabilized use. Abandoned land may be revegetated in a comparatively short time by the use of low-cost conservation practices and the introduction of such legumes as lespedeza sericea and sweetclover lightly fertilized. A good cover of native grass was obtained in 3 years on virgin land by clearing it of scrubby oak, controlling sprouts, preventing fires, and avoiding overutilization. Native grass thus established on this formerly useless, abandoned, and scrubby oak land has controlled erosion and the results of two seasons of grazing indicate that satisfactory pasturage was provided.

The results of investigations at the station have been interpreted in terms of their applicability to the Red Plains Area.

APPENDIX

In order to avoid an excess of tabular material throughout the text, the data of the individual tables necessary for deriving the summary tables and figures used in the text have been placed in this appendix as tables 14 to 36.

The data presented in this appendix probably will be of little interest to the casual reader, but, as they give specific records of the results of experimentation for 5 to 11 years, they will be of practical value and interest to technical readers.

TABLE 14.—*Meteorological data, Guthrie, Okla., for the 7-year period 1934–40*

Month	Temperature				Average relative humidity		Average precipitation	Average precipitation	Evaporation[1]		
	Highest	Lowest	Average						Daily		Average total monthly
			Maximum	Minimum	Maximum	Minimum			Highest	Lowest	
	°F.	°F.	°F.	°F.	Percent	Percent	Inches	Inches	Inches	Inches	Inches
January	76	-13	45	24	91	30	1.15				
February	86	3	46	28	97	32	1.11				
March	96	13	64	39	96	20	1.87				
April	96	17	70	47	97	27	3.00	2.38	0.701	0.002	7.16
May	100	37	79	58	98	31	4.37	4.08	.523	.002	7.33
June	107	47	86	66	97	31	5.73	3.68	.662	.050	8.66
July	113	51	96	72	96	30	1.63	3.59	.971	.068	12.29
August	116	52	97	72	94	31	3.42	3.47	.985	.011	11.52
September	107	41	85	64	97	30	3.67	1.22	.602	.053	6.75
October	99	27	76	52	92	25	1.97	1.77	.472	.011	5.31
November	87	6	58	36	95	28	2.56				
December	79	2	50	30	94	30	1.56				
Year	116	-11	71	49	97	29	30.22				
Warm season								20.99	.985	.002	50.02

[1] Records for 1938, 1939, and 1940 only.
[2] Average of experiment station records for 11-year period 1930–40.
[3] Average of U. S. Weather Bureau records at Guthrie, Okla., for the 43-year period 1898–1940 = 32.31 inches.

TABLE 15.—*Annual number of storms and amount of precipitation on the bare hard fallow control plot*[1] *of the station in relation to number and amount of runoffs for the 11-year period 1930–40*

Year	Storms[2]	Runoffs	Precipitation	Runoff	
	Number	*Number*	*Inches*	*Inches*	*Percent*
1930	72	25	33.66	7.72	22.94
1931	63	13	29.20	6.30	21.58
1932	52	24	37.40	10.71	28.64
1933	47	19	31.40	9.99	31.82
1934	48	16	35.30	11.52	32.63
1935	61	26	31.73	8.82	27.80
1936	45	13	21.45	6.37	29.70
1937	71	16	24.13	5.70	23.62
1938	56	26	31.36	9.56	30.48
1939	51	25	23.56	4.57	19.40
1940	61	22	33.28	9.37	28.16
Average 1930–40	57	20	30.22	8.24	27.27

[1] 1/100-acre plot on a 7.7-percent slope of Stephensville (originally classified as Vernon) fine sandy loam.
[2] Includes rain and snow storms.

TABLE 16.—*Monthly average number of storms and amount of precipitation on the bare hard fallow control plot*[1] *of the station in relation to number and amount of runoffs for the 11-year period 1930–40*

Month	Storms[2]	Runoffs	Precipitation	Runoff	
	Number	*Number*	*Inches*	*Inches*	*Percent*
January	4.64	0.45	1.45	0.05	3.45
February	3.91	.36	1.44	.10	6.94
March	3.09	.73	1.87	.35	18.72
April	4.55	2.18	2.60	.53	20.38
May	7.45	3.45	4.37	1.56	35.70
June	7.09	3.55	3.73	1.51	40.48
July	3.73	1.27	1.63	.49	30.06
August	5.09	2.18	3.42	1.04	30.41
September	5.45	2.64	3.67	1.51	41.14
October	4.82	1.73	1.97	.33	16.75
November	4.00	1.45	2.56	.68	26.56
December	3.18	.45	1.50	.08	5.33

[1] 1/100-acre plot on a 7.7-percent slope of Stephensville (originally classified as Vernon) fine sandy loam.
[2] Includes rain and snow storms.

TABLE 17.—*Runoff of groups of rains classified according to duration, from the bare hard fallow control plot,*[1] *for the 11-year period 1930–40*

Rainfall-duration group (minutes)	Average duration of group	Rains	Runoff		
			Low	High	Average
	Minutes	*Number*	*Inches*	*Inches*	*Inches*
Over 1,200	1,768	16	0.035	1.992	0.537
1,100–1,200	1,137	5	.042	1.004	.452
1,000–1,100	1,060	2	.549	1.871	1.210
900–1,000	941	5	.103	1.780	.702
800–900	842	4	.269	1.953	1.084
700–800	762	6	.040	2.831	.765
600–700	653	9	.015	.981	.305
500–600	547	19	.029	2.282	.429
400–500	440	13	.011	1.963	.536
300–400	313	26	.005	1.250	.339
200–300	251	37	.009	2.432	.339
100–200	145	35	.016	1.513	.406
Less than 100	50	43	.011	1.000	.227

[1] 1/100-acre plot on a 7.7-percent slope of Stephensville (originally classified as Vernon) fine sandy loam.

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TABLE 18.—*Runoff of groups of rains classified according to intensity from the bare hard fallow control plot*[1] *for the 11-year period 1930–40*

Rainfall-intensity group during specified intervals (inches)	Average intensity of group	Rains	Runoff		
			Low	High	Average
	Inches	*Number*	*Inches*	*Inches*	*Inches*
30-minute:					
Over 2.50	2.96	9	0.591	2.432	1.433
2.00 to 2.50	2.20	11	.796	2.831	1.380
1.50 to 2.00	1.69	20	.251	1.780	.809
1.00 to 1.50	1.20	41	.037	1.953	.454
0.50 to 1.00	.71	74	.005	1.992	.253
Under 0.50	.35	51	.009	.644	.110
15-minute:					
Over 3.50	3.07	8	.591	1.963	1.258
3.00 to 3.50	3.10	10	.262	2.831	1.106
2.50 to 3.00	2.78	14	.226	2.252	.992
2.00 to 2.50	2.18	16	.251	1.780	.780
1.50 to 2.00	1.69	31	.005	1.095	.377
1.00 to 1.50	1.10	53	.037	1.992	.376
0.50 to 1.00	.72	60	.011	1.310	.155
Under 0.50	.37	20	.009	.644	.099
5-minute:					
Over 5.00	5.70	10	.226	1.963	.893
4.50 to 5.00	4.74	6	.502	1.407	1.034
4.00 to 4.50	4.27	8	.262	2.831	1.046
3.50 to 4.00	3.65	12	.354	2.252	1.093
3.00 to 3.50	3.13	19	.087	1.544	.560
2.50 to 3.00	2.72	17	.005	1.953	.603
2.00 to 2.50	2.26	29	.040	.777	.305
1.50 to 2.00	1.81	28	.018	1.992	.327
1.00 to 1.50	1.30	46	.011	1.310	.183
0.50 to 1.00	.80	30	.009	.792	.141
Under 0.50	.41	18	.009	.644	.103

[1] 1/100-acre plot on a 7.7-percent land slope of Stephensville (originally classified as Vernon) fine sandy loam.

TABLE 19.—*Annual summary of rainfall, runoff, and erosion on the control plots on Stephensville (Vernon) fine sandy loam, Guthrie, Okla.*

CONTINUOUS COTTON; 7.7-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Soil amendment[2]	Soil cover or crop		Runoff			Erosion[4]	
		Material	Winter cover[3]	Harvested crop	Per plot	Depth	Precipitation	Per plot	Per acre
No. 1:	*Inches*				*Cu. ft.*	*Inches*	*Percent*	*Pounds*	*Tons*
1930	33.66	Cottonstalks	Cottonstalks	Cotton	70.6	3.89	11.6	212.6	21.26
1931	29.20	do	do	do	55.0	3.03	10.4	78.5	7.85
1932	37.40	do	do	do	129.9	7.16	19.1	479.3	47.93
1933	31.40	do	do	do	99.9	5.50	17.5	130.6	13.06
1934	35.30	do	do	do	125.5	6.91	19.6	161.2	16.12
1935	31.73	do	do	do	53.7	2.96	9.3	88.0	8.80
1936	21.45	do	do	do	47.5	2.62	12.2	53.6	5.36
1937	24.13	do	do	do	12.2	.67	2.8	17.2	1.72
1938	31.36	do	do	do	35.1	1.93	6.2	19.0	1.90
1939	23.56	do	do	do	31.9	1.76	7.5	13.5	1.35
1940	33.28	do	do	do	22.9	1.26	3.8	25.4	2.54
Average	30.22				62.2	3.43	11.4	116.3	11.63
CONTINUOUS COTTON; 7.7-PERCENT SLOPE; 1/50-ACRE									
No. 2:									
1930	33.66	Cottonstalks	Cottonstalks	Cotton	245.1	3.38	10.0	579.6	14.49
1931	29.20	do	do	do	286.2	3.94	13.5	1,015.5	25.51
1932	37.40	do	do	do	407.0	5.61	15.0	3,521.6	88.04
1933	31.40	do	do	do	385.0	5.30	16.9	1,323.6	33.09
1934	35.30	do	do	do	565.1	7.78	22.1	1,506.4	37.66
1935	31.73	do	do	do	260.5	3.59	11.3	1,866.0	46.64
1936	21.45	do	do	dc	217.6	3.00	14.0	1,004.4	25.11
1937	24.13	do	do	do	92.4	1.27	5.3	243.8	6.09
1938	31.36	do	do	do	216.1	2.98	9.5	825.6	20.64
1939	23.56	do	do	do	118.6	1.63	6.9	222.1	5.55
1940	33.28	do	do	do	232.8	3.21	9.6	593.7	14.84
Average	30.22				275.1	3.79	12.5	1,154.8	28.83

See footnotes at end of table.

TABLE 19.—*Annual summary of rainfall, runoff, and erosion on the control plots on Stephensville (Vernon) fine sandy loam, Guthrie, Okla.*—Continued

CONTINUOUS COTTON; 7.7-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Soil amendment[2]	Soil cover or crop		Runoff			Erosion[4]	
		Material	Winter cover[3]	Harvested crop	Per plot	Depth	Precipitation	Per plot	Per acre
No. 3:	*Inches*				*Cu. ft.*	*Inches*	*Percent*	*Pounds*	*Tons*
1930	33.66	Cottonstalks	Cottonstalks	Cotton	160.2	4.41	13.1	351.2	17.56
1931	29.20	do	do	do	140.0	3.86	13.2	231.4	11.57
1932	37.40	do	do	do	194.7	5.36	14.3	1,371.0	68.55
1933	31.40	do	do	do	175.9	4.84	15.4	291.0	14.55
1934	35.30	do	do	do	251.5	6.93	19.6	302.6	15.13
1935	31.73	do	do	do	103.1	2.84	9.0	368.2	18.41
1936	21.45	do	do	do	97.4	2.68	12.5	235.9	11.80
1937	24.13	do	do	do	33.5	.92	3.8	36.3	1.81
1938	31.36	do	do	do	96.2	2.65	8.5	208.7	10.44
1939	23.56	do	do	do	33.9	.94	4.0	6.9	.35
1940	33.28	do	do	do	83.1	2.29	6.9	221.2	11.06
Average	30.22				124.5	3.43	11.4	329.5	16.47

3-YEAR ROTATION: COTTON, WHEAT, AND SWEETCLOVER; 7.7-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Material	Winter cover[3]	Harvested crop	Runoff per plot	Depth	Precipitation	Erosion per plot	Per acre
No. 4:									
1930	33.66	None	Wheat	Oats	163.1	4.49	13.4	61.6	3.08
1931	29.20	do	Sweetclover	Sweetclover	113.3	3.12	10.7	19.6	.98
1932	37.40	Rotation residues	Rotation residues	Cotton	167.0	4.60	12.3	786.2	39.31
1933	31.40	None	Wheat	Wheat	200.5	5.52	17.6	53.4	2.67
1934	35.30	do	Sweetclover	Sweetclover	61.1	1.68	4.8	4.4	.22
1935	31.73	Rotation residues	Rotation residues	Cotton	89.6	2.47	7.8	182.8	9.14
1936	21.45	None	Wheat	Wheat	120.5	3.32	15.5	24.1	1.20
1937	24.13	do	Sweetclover	Sweetclover	81.7	2.25	9.3	21.7	1.08
1938	31.36	Rotation residues	Rotation residues	Cotton	84.4	2.32	7.4	82.4	4.12
1939[5]	23.56	None	Wheat	Wheat	38.0	1.05	4.4	5.1	.25
1940	33.28	do	Sweetclover	Sweetclover	71.5	1.97	5.9	19.5	1.01
Average	30.22				108.2	2.98	9.9	114.6	5.73

3-YEAR ROTATION: WHEAT, SWEETCLOVER, AND COTTON; 7.7-PERCENT SLOPE; 1/100-ACRE

No. 5:									
1930	33.66	None	Sweetclover	Sweetclover	119.2	3.28	9.8	10.2	0.51
1931	29.20	Sweetclover	do	Cotton	109.9	3.03	10.4	117.8	5.89
1932	37.40	None	Wheat	Wheat	149.2	4.11	11.0	19.6	.98
1933	31.40	do	Sweetclover	Sweetclover	87.7	2.42	7.7	16.8	.84
1934	35.30	Rotation residues	Rotation residues	Cotton	228.6	6.30	17.8	224.6	11.23
1935	31.73	None	Wheat	Wheat	127.8	3.52	11.1	35.2	1.76
1936	21.45	do	Sweetclover	Sweetclover	14.8	.41	1.9	2.0	.10
1937	24.13	Rotation residues	Rotation residues	Cotton	29.7	.82	3.4	19.5	.98
1938	31.36	None	Wheat	Wheat	57.0	1.57	5.0	7.4	.37
1939	23.56	do	Sweetclover	Sweetclover	.3	.01	.0	.0	.00
1940	33.28	Rotation residues	Rotation residues	Cotton	59.6	1.64	4.9	56.0	2.80
Average	30.22				89.4	2.46	8.2	46.3	2.31

3-YEAR ROTATION: SWEETCLOVER, COTTON, AND WHEAT; 7.7-PERCENT SLOPE; 1/100-ACRE

No. 6:									
1930	33.66	Sweetclover	Sweetclover	Cotton	146.0	4.02	12.0	266.4	13.32
1931	29.20	None	Wheat	Wheat	117.0	3.22	11.0	10.4	.52
1932	37.40	do	Sweetclover	Sweetclover	122.2	3.37	9.0	11.2	.56
1933	31.40	Rotation residues	Rotation residues	Cotton	183.5	5.06	16.1	142.0	7.10
1934	35.30	None	Wheat	Wheat	249.7	6.88	19.5	26.6	1.33
1935	31.73	do	Sweetclover	Sweetclover	70.3	1.94	6.1	7.6	.38
1936	21.45	Rotation residues	Rotation residues	Cotton	88.3	2.43	11.4	90.6	4.53
1937	24.13	None	Wheat	Wheat	52.1	1.44	6.0	12.1	.60
1938	31.36	do	Sweetclover	Sweetclover	12.2	.34	1.1	1.0	.05
1939	23.56	Rotation residues	Rotation residues	Cotton	29.2	.80	3.4	19.1	.95
1940 [5]	33.28	None	Wheat	Wheat	118.1	3.25	9.8	115.5	5.78
Average	30.22				108.1	2.98	9.9	63.9	3.19

See footnotes at end of table.

TABLE 19.—*Annual summary of rainfall, runoff, and erosion on the control plots on Stephensville (Vernon) fine sandy loam, Guthrie, Okla.*—Continued

CONTINUOUS BERMUDA GRASS; GRASS CLIPPED TO SIMULATE GRAZING; 7.7-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Soil amendment [2]	Soil cover or crop		Runoff			Erosion [4]	
		Material	Winter cover [3]	Harvested crop	Per plot	Depth	Precipitation	Per plot	Per acre
No. 7:	*Inches*				*Cu. ft.*	*Inches*	*Percent*	*Pounds*	*Tons*
1930	33.66	None (clippings)	Bermuda grass	None (grass)	34.6	0.95	2.8	1.3	0.06
1931	29.20	do	do	do	5.0	.14	.5	.2	.01
1932	37.40	do	do	do	22.9	.63	1.7	.6	.03
1933	31.40	do	do	do	9.5	.26	.8	1.1	.06
1934	35.30	do	do	do	11.1	.31	.9	.6	.03
1935	31.73	do	do	do	5.3	.15	.5	.3	.01
1936	21.45	do	do	do	6.4	.18	.8	.2	.01
1937	24.13	do	do	do	3.6	.10	.4	.1	.00
1938	31.36	do	do	do	1.2	.03	.1	.1	.00
1939	23.56	do	do	do	3.5	.10	.4	.0	.00
1940	33.28	do	do	do	7.1	.20	.6	.3	.01
Average	30.22				10.0	.28	.9	.4	.02

FALLOW UNDISTURBED EXCEPT FOR REMOVAL OF WEEDS BY CUTTING; 7.7-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Material	Winter cover	Harvested crop	Runoff per plot	Runoff depth	Runoff precipitation	Erosion per plot	Erosion per acre
No. 8:									
1930	33.66	None	None	None	280.3	7.72	22.9	361.8	18.09
1931	29.20	do	do	do	228.3	6.29	21.5	126.6	6.33
1932	37.40	do	do	do	370.2	10.20	27.3	277.0	13.85
1933	31.40	do	do	do	362.1	9.98	31.8	402.0	20.10
1934	35.30	do	do	do	418.1	11.52	32.6	584.2	29.21
1935	31.73	do	do	do	320.3	8.82	27.8	684.6	34.23
1936	21.45	do	do	do	231.2	6.37	29.7	314.1	15.70
1937	24.13	do	do	do	206.6	5.69	23.6	577.2	28.86
1938	31.36	do	do	do	346.7	9.55	30.5	457.3	22.86
1939	23.56	do	do	do	166.2	4.58	19.4	204.4	10.21
1940	33.28	do	do	do	339.5	9.35	28.3	819.1	40.95
Average	30.22				297.2	8.18	27.1	437.1	21.86

DESURFACED (8 TO 10 INCHES DEPTH); CONTINUOUS COTTON; 7.7-PERCENT SLOPE; 1/100-ACRE

No. 9:									
1930	33.66	Cottonstalks	Cottonstalks	Cotton	322.3	8.88	26.4	705.0	35.25
1931	29.20	do	do	do	250.8	6.91	23.7	273.8	13.69
1932	37.40	do	do	do	427.4	11.77	31.5	1,019.0	50.95
1933	31.40	do	do	do	343.9	9.47	30.2	569.4	28.47
1934	35.30	do	do	do	438.0	12.07	34.2	838.4	41.92
1935	31.73	do	do	do	273.3	7.53	23.7	726.6	36.33
1936	21.45	do	do	do	211.2	5.82	27.1	394.8	19.74
1937	24.13	do	do	do	150.1	4.14	17.1	221.9	11.10
1938	31.36	do	do	do	268.7	7.40	23.6	637.2	31.86
1939	23.56	do	do	do	107.9	2.97	12.6	198.3	9.91
1940	33.28	do	do	do	209.4	5.77	17.3	472.6	23.63
Average	30.22				273.0	7.52	24.9	550.6	27.53

VIRGIN WOODS SCRUB OAK AND SOME NATIVE GRASS, UNDISTURBED; 5.17-PERCENT SLOPE; 1/100-ACRE

No. 10:									
1931	29.77	None (leaves)	Trees-leaves-grass	None	1.3	0.04	0.1	0.4	0.02
1932	37.73	do	do	do	2.3	.06	.2	.4	.02
1933	31.85	do	do	do	2.7	.07	.2	.5	.03
1934	34.96	do	do	do	5.3	.15	.4	.2	.01
1935	32.80	do	do	do	.8	.02	.1	.1	.00
1936	21.52	do	do	do	.0	.00	.0	.0	.00
1937	25.21	do	do	do	.3	.01	.0	.0	.00
1938	33.12	do	do	do	.2	.01	.0	.0	.00
1939	23.90	do	do	do	.0	.00	.0	.0	.00
1940	34.86	do	do	do	.0	.00	.0	.0	.00
Average	30.57				1.3	.04	.1	.2	.01

VIRGIN WOODS SCRUB OAK, SOME GRASS AND WEEDS, BURNED OVER ANNUALLY; 5.17-PERCENT SLOPE; 1/100-ACRE

No. 11:									
1931	29.77	None (ashes)	Trees-leaves-grass	None	15.8	0.44	1.5	2.4	0.12
1932	37.73	do	do	do	119.9	3.30	8.8	7.8	.39
1933	31.85	do	do	do	78.0	2.15	6.8	4.0	.20
1934	34.96	do	do	do	80.9	2.23	6.4	1.6	.08
1935	32.80	do	do	do	76.2	2.10	6.4	3.7	.19
1936	21.52	do	do	do	4.7	.13	.6	.4	.02
1937	25.21	do	do	do	15.5	.43	1.7	.7	.03
1938	33.12	do	do	do	.8	.02	.1	.0	.00
1939	23.90	do	do	do	1.5	.05	.2	.2	.01
1940	34.86	do	do	do	21.4	.59	1.7	1.1	.05
Average	30.57				41.5	1.14	3.7	2.2	.11

See footnotes at end of table.

TABLE 19.—*Annual summary of rainfall, runoff, and erosion on the control plots on Stephensville (Vernon) fine sandy loam, Guthrie, Okla.*—Continued

(ADJOINING WOODS PLOT). CONTINUOUS COTTON, PLOWED (SPADED) IN FALL ONLY; 6.02-PERCENT SLOPE, 1/100-ACRE

Plot No.[1] and year	Precipitation	Soil amendment[2]	Soil cover or crop		Runoff			Erosion[4]	
		Material	Winter cover[3]	Harvested crop	Per plot	Depth	Precipitation	Per plot	Per acre
No. 12:	*Inches*				*Cu. ft.*	*Inches*	*Percent*	*Pounds*	*Tons*
1931	29.77	None	None	Cotton	21.7	0.60	2.0	29.0	1.45
1932	37.73	Cotton stalks	Cottonstalks	do	180.6	5.00	13.2	712.4	35.62
1933	31.85	do	do	do	202.2	5.57	17.5	164.0	8.20
1934	34.96	do	do	do	245.8	6.77	19.4	221.4	11.07
1935	32.80	do	do	do	95.5	2.63	8.0	291.6	14.58
1936	21.52	do	do	do	92.2	2.54	11.8	78.0	3.90
1937	25.21	do	do	do	55.7	1.53	6.1	52.0	2.60
1938	33.12	do	do	do	110.6	3.05	9.2	89.9	4.50
1939	23.90	do	do	do	36.6	1.01	4.8	8.5	.42
1940	34.86	do	do	do	120.2	3.31	9.5	137.4	6.87
Average	30.57				116.1	3.20	10.5	178.4	8.92

(ADJOINING WOODS PLOTS). BERMUDA AND BLUESTEM GRASS, UNDISTURBED, 5.17-PERCENT SLOPE; 1/100-ACRE

Plot No.[1] and year	Precipitation	Material	Winter cover	Harvested crop	Runoff per plot	Depth	Precipitation	Erosion per plot	Per acre
No. 13:									
1934	34.96	None (dead grass)	Mixed grass	None	1.8	0.05	0.0	0.1	0.00
1935	32.80	do	do	do	.0	.00	.0	.0	.00
1936	21.52	do	do	do	.0	.00	.0	.0	.00
1937	25.21	do	do	do	.0	.00	.0	.0	.00
1938	33.12	do	do	do	.0	.00	.0	.0	.00

[1] All plots have a uniform length of 72.6 feet except No. 1 which is 36.6 and No. 2 which is 145.2. All row crops planted up and down slope. Cotton crops, unless otherwise noted, have soil prepared by plowing (spading) the latter part of March. The plots in crop rotation are plowed only preceding the crop of cotton. Plots 1 to 12 were established on virgin soil, plots 1 to 9 during 1929 and plots 10 to 12 during 1930. Plot 13 was established during 1933.

[2] Soil amendment refers to any incorporation with the soil during the calendar year.

[3] Winter cover refers to portion of calendar year preceding the harvested crop.

[4] Prior to 1939 soil losses were determined by weighing entire wash-off. For 1939 and 1940 losses were calculated from weight of aliquot samples.

[5] Received an application of 3 pounds of superphosphate and 30 pounds of lime.

TABLE 20.—*Soil and water losses from control plots under various kinds of vegetation and from a bare hard fallow plot by classified groups of rains [1] for the 11-year period 1930–40*

Plot No.[2]	Vegetative cover and rainfall group	Rainfall				Water loss						Soil loss per acre		
		Rains	Amount			Amount			Percent of rainfall					
			Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
		Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
	Annual for the period:													
7	Bermuda grass, clipped	57	21.45	37.40	30.22	0.000	0.950	0.276	0.00	2.82	0.91	0.00	0.06	0.02
8	Bare hard fallow		21.45	37.40	30.22	4.578	11.520	8.188	19.39	32.63	27.09	6.33	40.95	21.86
10	Undisturbed virgin woods [3]		21.52	37.73	30.57	.000	.150	.036	.00	.43	.12	.00	.03	.01
11	Woods burned once a year [3] [4]		21.52	37.73	30.57	.020	3.300	1.143	.10	8.75	3.74	.00	.39	.11
12	Continuous cotton [3]		21.52	37.73	30.57	.600	6.770	3.198	1.01	19.93	10.46	.42	35.62	8.92
13	Bermuda grass and native grass [5]		21.52	34.96	29.52	.000	.050	0.006	.00	.14	.02	.00	.00	.00
	Groups of rains for the period:													
	High-intensity rains:													
7	Bermuda grass, clipped	21	1.20	5.76	2.49	.000	.298	.083	.00	11.52	3.33	.00	.02	.01
8	Bare hard fallow		1.20	5.76	2.49	.591	2.831	1.348	30.83	86.25	54.14	1.16	20.10	4.90
10	Undisturbed virgin woods [3]	19	1.12	5.85	2.50	.000	.092	.012	.00	2.09	.48	.00	.01	.00
11	Woods burned once a year [3] [4]		1.12	5.85	2.50	.000	1.270	.302	.00	48.12	12.08	.00	.17	.02
12	Continuous cotton [3]	13	1.12	5.85	2.50	.055	2.826	.829	3.35	69.40	33.16	.06	11.06	2.67
13	Bermuda grass and native grass [5]		1.46	5.85	2.64	.000	.042	.004	.00	.96	.15	.00	.00	.00
	Moderate-intensity rains:													
7	Bermuda grass, clipped	29	.52	4.15	1.51	.000	.449	.030	.00	32.79	1.99	.00	.00	.00
8	Bare hard fallow		.52	4.15	1.51	.125	1.953	.704	5.03	79.56	46.62	.26	4.90	1.54
10	Undisturbed virgin woods [3]	27	.48	4.36	1.70	.000	.018	.002	.00	.96	.12	.00	.01	.00
11	Woods burned once a year [3] [4]		.48	4.36	1.70	.000	.847	.108	.00	51.11	6.35	.00	.09	.01
12	Continuous cotton [3]	10	.48	4.36	1.70	.000	1.007	.331	.00	53.66	19.47	.00	7.38	.99
13	Bermuda grass and native grass [5]		.62	3.23	1.65	.000	.000	.000	.00	.00	.00	.00	.00	.00
	Low-intensity rains:													
7	Bermuda grass, clipped	31	.36	4.12	.90	.000	.013	.001	.00	2.24	.07	.00	.00	.00
8	Bare hard fallow	31	.36	4.12	.90	.000	1.992	.278	.00	92.47	30.89	.00	1.58	.42
10	Undisturbed virgin woods [3]	29	.36	4.10	.91	.000	.011	.000	.00	.27	.04	.00	.01	.00
11	Woods burned once a year [3] [4]	29	.36	4.10	.91	.000	.166	.007	.00	22.70	.77	.00	.01	.00
12	Continuous cotton [3]	29	.36	4.10	.91	.000	.570	.086	.00	38.34	9.45	.00	2.03	.11
13	Bermuda grass and native grass [5]	6	.29	1.65	.56	.000	.000	.000	.00	.00	.00	.00	.00	.00

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] 1/100-acre plots of Stephensville (originally classified as Vernon) fine sandy loam. Plots 7 and 8 were on a 7.7-percent slope; plots 10, 11, and 13 on a 5.17-percent slope; and plot 12 on a 6.02-percent slope.
[3] Records for 1931–40.
[4] In early spring.
[5] Records for 1934–38.

TABLE 21.—*Soil and water losses from watersheds [1] under various kinds of vegetative cover and classified rainfall groups [2] for the 9-year period 1930–38*

Plot designation	Vegetative cover and rainfall group	Size of area	Land Slope	Rainfall				Water loss						Soil loss in runoff per acre		
				Rains	Amount			Amount			Percent of rainfall					
					Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
	Annual for the period:	*Acres*	*Percent*	*Number*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
13	Cotton and cowpeas	3.23	5.13	54	19.76	34.40	28.53	3.72	11.15	7.11	14.05	37.57	24.92	37.78	124.30	83.72
	Pasture, native grass	2.50	5.65	56	19.31	33.69	26.81	.00	1.23	.33	.00	4.70	1.23	.00	.13	.03
J	Abandoned grass	5.28	4.44	54	20.74	34.40	28.61	.44	3.38	2.23	1.82	15.40	7.79			
L	Undisturbed woods	5.62	4.80	55	19.76	34.40	28.68	.00	2.88	.88	.00	10.59	3.07	.00	.43	.15
	Groups of rains for the period:															
	High-intensity rains:															
13	Cotton and cowpeas	3.23	5.13	10	1.61	4.22	2.79	.42	3.08	1.24	14.22	94.37	44.44	7.63	23.20	16.81
	Pasture, Native grass	2.50	5.65	6	1.90	4.22	3.01	.00	.43	.21	.00	10.19	6.98	.00	.01	.01
J	Abandoned grass	5.28	4.44	10	1.61	4.22	2.79	.00	1.95	.72	.00	53.17	25.81			
L	Undisturbed woods	5.62	4.80	10	1.61	4.22	2.79	.01	1.26	.19	.40	28.60	6.81	.001	.35	.05
	Moderate-intensity rains:															
13	Cotton and cowpeas	3.23	5.13	20	.72	4.57	1.98	.39	1.46	.92	24.02	99.31	46.46	3.33	30.15	11.59
	Pasture, Native grass	2.50	5.65	14	1.22	4.57	2.08	.00	.32	.02	.00	17.88	.96	.00	.02	.001
J	Abandoned grass	5.28	4.44	20	.72	4.57	1.98	.01	.95	.30	.82	53.07	15.15			
L	Undisturbed woods	5.62	4.80	20	.72	4.57	1.98	.00	.46	.05	.00	25.70	2.27	.00	.26	.02
	Low-intensity rains:															
13	Cotton and cowpeas	3.23	5.13	5	.70	1.38	1.05	.11	.51	.32	8.66	59.26	30.48	.44	9.30	2.78
	Pasture, Native grass	2.50	5.65	4	.70	1.38	.99	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	Abandoned grass	5.28	4.44	5	.70	1.38	1.05	.02	.20	.07	1.57	28.57	6.67			
L	Undisturbed woods	5.62	4.80	5	.70	1.38	1.05	.00	.02	.01	.00	2.86	.76	.00	.002	.001

[1] Watershed 13, badly eroded Chickasha, Zaneis and Stephensville; Pasture, virgin Stephensville; Watershed J, eroded and abandoned Chickasha and Zaneis; Watershed L virgin Stephensville and Zaneis. (Stephensville and Zaneis originally classified as Vernon; Chickasha originally classified as Kirkland).

[2] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.

TABLE 22.—*Soil and water losses and crop yields from row-direction plots by classified groups of rains[1] for the 7-year period 1932–38*

Plot No.[2]	Row direction and rainfall group	Rainfall: Rains	Rainfall: Amount Low	Rainfall: Amount High	Rainfall: Amount Average	Water loss: Amount Low	Water loss: Amount High	Water loss: Amount Average	Water loss: Percent of rainfall Low	Water loss: Percent of rainfall High	Water loss: Percent of rainfall Average	Soil loss per acre Low	Soil loss per acre High	Soil loss per acre Average	Yields of seed cotton per acre Low	Yields of seed cotton per acre High	Yields of seed cotton per acre Average
		Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*	*Pounds*	*Pounds*	*Pounds*
	Annual for the period:																
1	Rows parallel with slope	54	21.45	37.40	30.40	0.640	5.150	2.770	2.65	16.40	9.11	3.29	71.34	38.24	222	604	404
2	Rows on contour					.093	4.080	2.430	.38	12.99	7.99	.37	30.62	16.57	224	672	432
	Groups of rains for the period:																
	High-intensity rains:																
1	Rows parallel with slope	12	1.60	5.76	2.80	.157	1.350	.760	7.64	44.68	26.30	2.12	36.49	11.71			
2	Rows on contour					.160	1.683	.766	5.73	49.70	26.51	.88	10.62	4.98			
	Moderate-intensity rains:																
1	Rows parallel with slope	16	.58	3.26	1.46	.110	1.560	.440	8.21	54.89	30.14	.07	17.38	5.31			
2	Rows on contour					.030	1.530	.370	2.75	59.87	25.34	.07	10.84	2.57			
	Low-intensity rains:																
1	Rows parallel with slope	5	.36	1.27	.73	.060	.240	.150	12.24	34.29	20.55	.14	3.04	1.18			
2	Rows on contour					.000	.180	.100	.00	25.71	13.70	.00	1.99	.63			

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] ¼-acre plots of Stephensville (originally classified as Vernon) fine sandy loam. Plot 1 was on a 6.87-percent slope and plot 2 on a 6.75-percent slope.

TABLE 23.—*Soil and water losses and crop yields from plots in strips of different crops and from a plot not strip cropped and in cotton by classified groups of rains [1] for the 5-year period 1934–38*

Plot No.[2]	Crop and rainfall group	Degree of slope	Rainfall: Rains	Rainfall: Amount: Low	Rainfall: Amount: High	Rainfall: Amount: Average	Water loss: Amount: Low	Water loss: Amount: High	Water loss: Amount: Average	Water loss: Percent of rainfall: Low	Water loss: Percent of rainfall: High	Water loss: Percent of rainfall: Average	Soil loss per acre: Low	Soil loss per acre: High	Soil loss per acre: Average	Crop yield per acre: Seed cotton [3]	Crop yield per acre: Alfalfa hay [4]	Crop yield per acre: Oat grain [5]	Crop yield per acre: Sudan hay [6]
	Annual for the period:	*Percent*	*Number*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	Cotton, with alfalfa in strips [7]	4.5					0.211	2.638	0.911	0.73	8.46	3.28	0.03	0.75	0.26	412	2,194	----	----
2	Cotton, with oats followed by Sudan [7]	4.0					1.398	6.129	3.038	5.80	19.66	10.94	.84	1.79	1.41	377	----	464	1,411
3	All cotton	3.5	56	20.47	32.00	27.80	1.542	4.712	2.898	6.40	15.11	10.43	1.18	3.84	2.37	484	----	----	----
4	Oats followed by Sudan, with cotton [7]	3.0					1.116	6.076	2.450	4.55	19.48	8.81	.64	2.24	1.36	449	----	637	2,635
	Groups of rains for the period:																		
	High intensity rains:																		
1	Cotton, with alfalfa in strips	4.5					.031	1.776	.460	1.27	41.70	14.52	.03	.50	.13	----	----	----	----
2	Cotton, with oats followed by Sudan	4.0	6	1.56	5.72	3.17	.218	2.761	.944	11.00	64.82	29.78	.13	.66	.37	----	----	----	----
3	All cotton	3.5					.033	2.628	.687	1.37	61.68	21.67	.03	1.49	.70	----	----	----	----
4	Oats followed by Sudan, with cotton	3.0					.242	2.511	.929	9.09	58.95	29.31	.20	.70	.40	----	----	----	----
	Moderate intensity rains:																		
1	Cotton, with alfalfa in strips	4.5					.028	.386	.167	1.93	16.58	7.80	.00	.10	.04	----	----	----	----
2	Cotton, with oats followed by Sudan	4.0	8	1.46	4.44	2.14	.264	.892	.646	18.11	40.73	30.19	.01	.50	.32	----	----	----	----
3	All cotton	3.5					.188	1.601	.886	12.90	90.98	41.40	.34	.87	.68	----	----	----	----
4	Oats followed by Sudan, with cotton	3.0					.213	.996	.558	12.75	42.50	26.07	.11	.55	.35	----	----	----	----

	Low intensity rains:																		
1	Cotton with alfalfa in strips	4.5					.001	.104	.053	.10	12.88	5.58	.00	.02	.01	...	...	...	...
2	Cotton, with oats followed by Sudan	4.0	2	.81	1.09	.95	.203	.359	.281	18.61	44.38	20.58	.02	.05	.03	...	...	...	...
3	All cotton	3.5					.098	.317	.207	9.00	39.18	21.79	.04	.16	.10	...	...	...	...
4	Oats followed by Sudan, with cotton	3.0					.153	.324	.239	13.99	39.99	25.16	.02	.07	.04	...	...	...	...

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] 1-acre plots of Chickasha (originally classified as Kirkland) and Zaneis (originally classified as Vernon) fine sandy loam planted on the contour and in wheat winter cover following cotton.
[3] Average yield for 1932–38.
[4] Average yields for 1934–38.
[5] Average yield for 1933–38.
[6] Average yield for 1934, 1937, and 1938. The 1935 and 1936 crops were complete failures.
[7] Cotton was planted in strips of 12 rows each between areas of erosion-resistant crops and occupied 0.55 of plot 1, 0.45 of plot 2, and 0.60 of plot 4.

Table 24.—*The effect of subsoil tillage*[1] *compared to ordinary cultivation on seed cotton yields and moisture content of areas with compact clay subsoil and with sandy clay subsoil for the 7-year period 1932–38*

Year	Average rainfall	F terraces (compact clay)		K plots (fine sandy clay)			
		Yield with subsoil tillage	Yield with ordinary cultivation	With subsoil tillage		With ordinary cultivation	
				Yield	Soil moisture	Yield	Soil moisture
	Inches	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Percent*
1932	37.40	551	551	698	10.52	870	9.41
1933	31.40	262	390	902	9.44	988	9.00
1934	35.30	177	176	214	10.68	240	10.62
1935	31.73	776	726	447	10.91	514	10.63
1936	21.45	364	346	274	10.88	278	9.92
1937	24.13	401	401	492		469	
1938	31.36	586	405	1,304		1,384	
Average yield		445	428	619		678	
Average soil moisture					10.48		9.91

[1] Subsoil tillage was in addition to ordinary cultivation, and to a depth of 16 to 18 inches every other year.

TABLE 25.—*Soil and water losses from control plots in a rotation of cotton, wheat, and sweetclover and in continuous cotton by classified group of rains*[1] *for the 11-year period 1930–40*

Plot number,[2] crop,[3] and rainfall group	Rainfall				Water loss						Soil loss per acre		
	Rains	Amount			Amount			Percent of rainfall					
		Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
	Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
Annual for the period:													
3, Continuous cotton					0.920	6.930	3.430	3.81	19.63	11.35	0.35	68.52	16.47
Rotation:													
4, 5, 6, Cotton	57	21.45	37.40	30.22	.803	6.298	3.042	3.30	17.83	10.07	.95	39.31	9.04
4, 5, 6, Wheat					1.047	6.880	3.489	4.44	19.49	11.55	.25	5.78	1.69
4, 5, 6, Sweetclover					.007	3.366	1.889	.03	10.69	6.25	.00	1.08	.52
Average					.007	6.880	2.807	.03	19.49	9.29	.00	39.31	3.75
Groups of rains for the period:													
High-intensity rains:													
3, Continuous cotton					.059	2.489	.805	3.55	62.70	32.33	.08	29.58	5.09
Rotation:													
4, 5, 6, Cotton	21	1.20	5.76	2.49	.022	2.502	.756	1.33	63.03	30.36	.15	16.68	3.03
4, 5, 6, Wheat					.291	2.106	.863	10.90	58.70	34.66	.02	3.72	.47
4, 5, 6, Sweetclover					.007	1.313	.470	.58	50.69	18.88	.00	.43	.13
Average					.007	2.502	.696	.58	[illegible]	27.95	.00	16.68	1.21
Moderate-intensity rains:													
3, Continuous cotton					.000	1.641	.377	.00	66.93	24.97	.00	8.20	1.67
Rotation:													
4, 5, 6, Cotton	29	.52	4.15	1.51	.000	1.926	.362	.00	64.38	23.97	.00	4.15	.87
4, 5, 6, Wheat					.000	1.005	.326	.00	69.08	21.59	.00	.78	.10
4, 5, 6, Sweetclover					.000	.795	.177	.00	52.96	11.72	.00	.29	.04
Average					.000	1.926	.288	.00	69.08	19.09	.00	4.15	.34
Low-intensity rains:													
3, Continuous cotton					.000	1.515	.145	.00	50.12	16.11	.00	3.42	.28
Rotation:													
4, 5, 6, Cotton	31	.36	4.12	.90	.000	1.324	.111	.00	40.00	12.33	.00	.54	.09
4, 5, 6, Wheat					.000	1.020	.098	.00	40.98	10.88	.00	.13	.02
4, 5, 6, Sweetclover					.000	.921	.050	.00	22.35	5.56	.00	.08	.01
Average					.000	1.324	.086	.00	40.98	9.59	.00	.54	.04

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] 1/100 acre plots on a 7.7-percent slope of Stephensville (originally classified as Vernon) fine sandy loam.
[3] A 3-year rotation of cotton, wheat, and sweetclover on plots 4, 5, and 6.

TABLE 26.—*Average yields of continuous crops and crops in rotation on naturally eroded, artifically eroded, and virgin soil, with and without fertilization for the 8-year period 1931–38*

Area designation	Crop or rotation	Winter cover or green-manure crop	Commercial fertilizer: Kind	Commercial fertilizer: Amount per acre	Seed cotton per acre: Yield	Seed cotton per acre: Weighted check	Seed cotton per acre: Gain or loss
NATURALLY ERODED SOIL [1]							
Field E:				*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
3	Cotton	None	None	----	210	210	----
4	do	Rye	4-12-4	300	469	205	264
5	do	None	4-12-4	300	399	200	199
6	do	Rye	None	----	169	194	−25
7	do	None	None	----	189	189	----
9	do	Vetch	None	----	312	222	90
10	do	do	0-12-4	300	450	255	195
11	do	do	4-12-4	300	508	287	221
12	do	do	None	----	320	320	----
	2-year rotation:						
8	Cotton and sweetclover.	Sweetclover	Superphosphate	[2] 100	[3] 396	189	207
1	Cotton and mung beans.	Mung beans	None	----	[3] 359	210	149
2	Cotton and soybeans	Soybeans	None	----	[3] 220	210	10
ARTIFICIALLY ERODED SOIL [4]							
R plots:	3-year rotation:						
2, 3, 4	Corn, oats, cotton	Cowpeas or mung beans.	None	----	[5] 192	192	----
5, 6, 7	do	do	Lime with corn only	2,000	[5] 209	192	17
8, 9, 10	do	do	Lime with corn only Superphosphate with cotton.	2,000 200	[5] 298	192	106
11, 12, 13	do	do	Lime with corn only 4-12-4 with cotton	2,000 300	[5] 350	192	158
14, 15, 16	Cotton, wheat, and sweetclover	Sweetclover	4-12-4 with cotton Lime and Superphosphate with clover.	300 2,000 100	[5] 562	562	----
4, 5, 6 [6]	do	do	None	----	[5] 826	562	264
17	Cotton	None	Superphosphate	200	306	306	----
18	do	Rye	do	200	392	306	86
19	do	Austrian Winter peas.	do	200	448	306	142
20	do	Vetch	do	200	468	306	162
VIRGIN SOIL [7]							
F plots:							
1	Cotton	Wheat	None	----	711	711	----
2	do	do	4-12-0	300	744	726	18
3	do	do	0-12-4	300	741	740	1
4	do	do	None	----	755	755	----
5	do	do	4-0-4	300	666	727	−61
6	do	do	4-12-4	300	738	699	39
7	do	do	None	----	671	671	----
	2-year rotation:						
8	Cotton and Korean lespedeza	do	do	----	[8] 985	671	314
9	do	do	do	----	[8] 1,000	671	329

[1] Plots of Chickasha (originally classified as Kirkland) and Zaneis (originally classified as Vernon) fine sandy loam ranging from 0.7 to 2.38 acres.
[2] Fertilized when in sweetclover.
[3] 3-year average yields.
[4] 1/100-acre plots of Stephensville (originally classified as Vernon) fine sandy loam, with 10 inches of surface soil removed.
[5] Average yield of the three crops of the rotation.
[6] 1/100-acre control plots of virgin Stephensville fine sandy loam.
[7] 1/40-acre plots of Stephensville fine sandy loam.
[8] 2-year average yield.

TABLE 27.—*Soil and water losses from control plots of various lengths by classified groups of rains*[1] *for the 11-year period 1930–40*

Plot No.[2]	Rainfall group and length of plot	Rainfall				Water loss						Soil loss per acre		
		Rains	Amount			Amount			Percent of rainfall					
			Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
		Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
	Annual for the period:													
1	36.3 feet					0.067	7.150	3.431	2.78	19.58	11.35	1.35	47.93	11.63
3	72.6 feet	57	21.45	37.40	30.22	.920	6.930	3.430	3.81	19.63	11.35	.35	68.52	16.47
2	145.2 feet					1.270	7.780	3.785	5.26	22.04	12.52	5.55	88.04	28.89
	Groups of rains for the period:													
	High-intensity rains:													
1	36.3 feet					.086	2.644	.866	5.21	86.97	34.78	.30	17.54	3.74
3	72.6 feet	21	1.20	5.76	2.49	.059	2.489	.805	3.55	62.70	32.33	.08	29.58	5.09
2	145.2 feet					.036	2.593	.853	2.19	65.30	34.26	.10	43.09	8.50
	Moderate-intensity rains:													
1	36.3 feet					.000	1.987	.337	.00	65.21	22.31	.00	4.89	.93
3	72.6 feet	20	.52	4.15	1.51	.000	1.641	.377	.00	66.93	24.97	.00	8.20	1.67
2	145.2 feet					.000	1.685	.411	.00	68.34	27.22	.00	15.92	3.41
	Low-intensity rains:													
1	36.3 feet					.000	1.318	.117	.00	59.34	13.00	.00	2.24	.22
3	72.6 feet	31	.36	4.12	.90	.000	1.515	.145	.00	50.12	16.11	.00	3.42	.28
2	145.2 feet					.000	1.578	.165	.00	47.57	18.33	.00	4.02	.52

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] All plots are on Stephensville (originally classified as Vernon) fine sandy loam planted continuously to cotton; 6 feet wide; and have a uniform slope of 7.7-percent.

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TABLE 28.—*Runoff and soil loss in runoff from terraces with various spacings by classified groups of rains*[1] *for the 8-year period 1931–38*

Terrace number[2] and spacing, and rainfall group	Size of area	Land slope	Rainfall				Runoff						Soil loss in runoff per acre		
			Rains	Amount			Amount			Percent of rainfall					
				Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
	Acres	*Percent*	*Number*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
Annual for the period:															
1- and 6-A, 2-foot	0.58	5.47					1.84	9.98	6.45	6.77	32.94	22.30	1.06	11.23	3.53
2- and 5-A, 3.5 foot	.96	5.61	55	19.55	36.61	28.93	2.11	9.22	6.27	7.77	29.53	21.67	1.07	9.19	4.05
3- and 4-A, 5-foot	1.36	5.52					1.56	7.55	5.23	5.72	25.32	18.08	.69	10.96	4.59
Groups of rains for the period:															
High-intensity rains:															
1- and 6-A, 2-foot	.58	5.47					.33	3.05	1.49	7.95	86.70	51.21	.05	1.66	.68
2- and 5-A, 3.5 foot	.96	5.61	10	1.69	4.15	2.80	.34	2.62	1.27	10.84	85.34	45.36	.05	3.31	.71
3- and 4-A, 5-foot	1.36	5.52					.28	2.27	1.14	7.47	66.50	40.72	.07	3.56	.89
Moderate-intensity rains:															
1- and 6-A, 2-foot	.58	5.47					.28	2.32	1.03	19.05	88.66	52.30	.10	4.86	.54
2- and 5-A, 3.5 foot	.96	5.61	20	.74	4.97	1.96	.32	2.46	1.06	21.77	85.58	54.08	.06	3.01	.63
3- and 4-A, 5-foot	1.36	5.52					.21	2.11	.83	7.22	72.50	42.40	.04	2.63	.65
Low-intensity rains:															
1- and 6-A, 2-foot	.58	5.47					.20	.71	.47	17.24	79.17	45.15	.01	.72	.13
2- and 5-A, 3.5-foot	.96	5.61	5	.72	1.35	1.03	.21	.53	.44	15.56	73.61	42.24	.02	1.10	.28
3- and 4-A, 5-foot	1.36	5.52					.12	.51	.34	8.89	70.83	33.01	.02	1.53	.31

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] Terraces of 4-inch grade, 700 feet long, on virgin Chickasha (originally classified as Kirkland) and Stephensville (originally classified as Vernon) fine sandy loam, and in a rotation of cotton, oats, and corn or darso.

TABLE 29.—*Runoff and soil loss in runoff from terraces of various constant grades by classified groups of rains*[1] *for the 8-year period 1931–38*

Terrace No.[2] and grade, and rainfall group	Vertical interval	Size of area	Land slope	Rainfall: Rains	Rainfall: Amount: Low	Rainfall: Amount: High	Rainfall: Amount: Average	Rainfall: Duration: Low	Rainfall: Duration: High	Rainfall: Duration: Average	Runoff: Amount: Low	Runoff: Amount: High	Runoff: Amount: Average	Runoff: Percent of rainfall: Low	Runoff: Percent of rainfall: High	Runoff: Percent of rainfall: Average	Soil loss in runoff per acre: Low	Soil loss in runoff per acre: High	Soil loss in runoff per acre: Average
	Ft.	*Acres*	*Pct.*	*No.*	*In.*	*In.*	*In.*	*Min.*	*Min.*	*Min.*	*In.*	*In.*	*In.*	*Pct.*	*Pct.*	*Pct.*	*Tons*	*Tons*	*Tons*
Annual for the period:																			
3-C, 6-inch	3.51	2.85	4.33		19.58	36.20	28.91	......	......	......	2.34	9.09	6.46	19.63	28.40	22.35	2.84	15.50	9.30
4-C, 4-inch	3.47	2.77	4.41		19.58	36.20	28.80	......	......	......	2.82	9.61	6.36	10.36	26.55	22.08	1.43	13.85	5.92
5-C, 2-inch	3.43	2.58	4.72	56	19.58	36.20	28.81	......	......	......	2.82	8.59	6.04	10.39	25.67	20.96	.63	7.27	3.17
6-C, Level open-end	3.27	2.06	5.51		19.58	36.20	28.80	......	......	......	1.48	9.99	5.16	6.55	36.75	17.92	.18	4.06	1.33
6-E, Level open-end[3]	4.00	1.22	4.56		20.74	34.40	28.65	......	......	......	.95	9.60	5.74	3.20	29.52	20.03	.31	4.15	2.61
Groups of rains for the period:																			
High-intensity rains:																			
3-C, 6-inch	3.51	2.85	4.33					152	733	390	.59	2.56	1.24	16.39	71.48	44.44	.15	4.72	1.81
4-C, 4-inch	3.47	2.77	4.41					210	728	393	.49	2.28	1.26	12.77	75.00	45.16	.13	2.64	1.24
5-C, 2-inch	3.43	2.58	4.72	10	1.61	4.22	2.79	243	658	391	.58	2.66	1.32	16.87	73.24	47.31	.09	2.58	.86
6-C, Level open-end	3.27	2.06	5.51					298	732	554	.16	2.33	1.08	7.95	79.23	38.71	.02	1.52	.39
6-E, Level open-end[3]	4.00	1.22	4.56	8	1.61	4.22	2.76	211	912	463	.30	2.85	1.15	11.03	67.54	41.67	.18	.68	.44
Moderate-intensity rains:																			
3-C, 6-inch	3.51	2.85	4.33					96	1,365	582	.02	1.77	1.01	2.13	80.49	51.01	.04	4.62	1.39
4-C, 4-inch	3.47	2.77	4.41					24	1,650	542	.02	1.99	.98	2.13	76.15	49.49	.02	3.26	.99
5-C, 2-inch	3.43	2.58	4.72	20	.72	4.57	1.98	164	1,390	646	.01	2.04	.94	1.06	75.23	47.47	.01	1.57	.44
6-C, Level open-end	3.27	2.06	5.51					19	2,081	762	.002	1.33	.65	.21	88.07	32.83	.00	.56	.17
6-E, Level open-end[3]	4.00	1.22	4.56	17	.94	4.57	2.12	226	1,952	755	.24	2.19	1.07	23.77	88.80	50.47	.13	2.26	.60
Low-intensity rains:																			
3-C, 6-inch	3.51	2.85	4.33					180	338	272	.32	.42	.36	25.20	60.00	34.29	.05	1.54	.43
4-C, 4-inch	3.47	2.77	4.41					184	385	291	.21	.43	.35	19.63	58.57	33.33	.04	1.44	.38
5-C, 2-inch	3.43	2.58	4.72	5	.70	1.38	1.05	358	590	458	.28	.60	.40	25.20	55.71	38.10	.02	.42	.16
6-C, Level open-end	3.27	2.06	5.51					331	1,069	646	.06	.36	.20	5.61	45.71	19.05	.00	.13	.05
6-E, Level open-end[3]	4.00	1.22	4.56					272	530	352	.15	.49	.34	10.89	70.00	32.38	.00	.59	.15

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.

[2] The C terraces were on Zaneis (originally classified as Vernon) and Chickasha (originally classified as Kirkland) fine sandy loam, 1,000 feet of which was virgin soil and 500 feet cultivated slightly sheet-eroded soil. Rotation: Cotton, oats, and corn or darso.

[3] 6-E was 648 feet long on badly eroded Chickasha, Zaneis, and Stephensville (originally classified as Vernon) soil, and planted in a rotation of cotton and cowpeas; the cowpeas were turned under as a green manure.

TABLE 30.—*Runoff and soil loss in runoff from long terraces of variable grade on virgin and eroded soil by classified groups of rains*[1] *for the 8-year period 1931–38*

Terrace No.[2] and grade, and rainfall group	Length	Soil condition	Vertical interval	Size of area	Land slope	Rainfall				Runoff						Soil loss in runoff per acre		
						Rains	Amount			Amount			Percent of rainfall					
							Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
Annual for the period:	*Ft.*		*Ft.*	*Acres*	*Pct.*	*No.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Pct.*	*Pct.*	*Pct.*	*Tons*	*Tons*	*Tons*
2–B, 0- to 4-inch	2,536	Eroded	3.99	5.99	2.79	55	19.58	36.20	28.87	3.34	12.34	7.88	12.28	36.63	27.29	2.57	11.49	8.51
1–C, 0- to 4-inch	2,350	Virgin	3.91	6.16	3.54		19.58	36.20	28.86	2.49	7.46	4.85	10.55	20.61	16.81	1.95	8.75	5.42
Average	2,443					55			28.87			6.37			22.06			6.97
3–B, 0- to 6-inch	2,856	Eroded	3.45	5.67	3.70	55	19.58	36.20	28.93	2.08	11.12	7.75	7.64	38.15	26.79	3.37	15.20	9.78
2–C, 0- to 6-inch	2,525	Virgin	2.93	4.37	3.66		19.58	36.20	29.19	3.79	7.91	5.49	13.51	25.36	18.81	2.05	7.88	6.00
Average	2,690					55			29.06			6.62			22.78			7.89
Groups of rains for the period:																		
High intensity rains:																		
2–B, 0- to 4-inch	2,536	Eroded	3.99	5.99	2.79	10	1.61	4.22	2.79	.32	3.35	1.36	12.20	79.40	48.75	.31	3.31	1.56
1–C, 0- to 4-inch	2,350	Virgin	3.91	6.16	3.54					.16	2.02	.88	6.10	32.00	31.54	.25	2.71	1.13
Average	2,443					10			2.79			1.12			40.14			1.35
3–B, 0- to 6-inch	2,856	Eroded	3.45	5.67	3.70	10	1.61	4.22	2.79	.41	2.76	1.27	15.60	67.00	45.52	.51	2.74	1.61
2–C, 0- to 6-inch	2,525	Virgin	2.93	4.37	3.66					.25	2.10	.98	9.50	60.00	35.13	.18	2.29	1.14
Average	2,690					10			2.79			1.13			40.33			1.38
Moderate intensity rains:																		
2–B, 0- to 4-inch	2,536	Eroded	3.99	5.99	2.79	20	.72	4.57	1.98	.27	2.17	1.10	29.10	91.90	55.56	.33	2.52	1.18
1–C, 0- to 4-inch	2,350	Virgin	3.91	6.16	3.54					.23	1.13	.68	16.10	61.40	34.34	.23	2.54	.78
Average	2,443					20			1.98			.89			44.99			.98

3-B, 0- to 6-inch	2,856	Eroded	3.45	5.67	3.70	20	.72	4.57	1.98	.33	2.01	1.13	30.80	94.10	57.07	.37	4.35	1.53
2-C, 0- to 6-inch	2,525	Virgin	2.93	4.37	3.66					.17	1.98	.77	8.40	71.20	38.89	.21	3.85	.95
Average	2,690					20			1.98			.95			47.98			1.24
Low intensity rains:																		
2-B, 0- to 4-inch	2,536	Eroded	3.99	5.99	2.79	5	.70	1.38	1.05	.03	.67	.43	2.00	63.00	40.95	.01	1.70	.62
1-C, 0- to 4-inch	2,350	Virgin	3.91	6.16	3.54					.00	.32	.20	.00	29.60	19.05	.00	1.29	.44
Average	2,443					5			1.05			.32			30.00			.53
3-B, 0- to 6-inch	2,856	Eroded	3.45	5.67	3.70	5	.70	1.38	1.05	.04	.65	.41	3.00	89.00	39.05	.02	2.15	.71
2-C, 0- to 6-inch	2,525	Virgin	2.93	4.37	3.66					.00	.53	.31	.00	65.50	29.52	.00	1.06	.32
Average	2,690					5			1.05			.36			34.29			.52

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] All terraces on Chickasha (originally classified as Kirkland) and Zaneis (originally classified as Vernon) fine sandy loam and in a rotation of cotton, oats, and corn or darso.

TABLE 31.—*Runoff and soil loss in runoff from terraced and unterraced watersheds by classified groups of rains* [1] *for the 9-year period 1930–38*

Watershed designation and rainfall group	Size of area	Land slope	Rainfall							Runoff						Soil loss in runoff per acre		
			Rains	Amount			Duration			Amount			Percent of rainfall					
				Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
	Acres	*Percent*	*No.*	*In.*	*In.*	*In.*	*Min.*	*Min.*	*Min.*	*In.*	*In.*	*In.*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
Annual for the period:																		
Plot 13, Unterraced [2]	3.23	5.13	54	19.76	34.40	28.53	-----	-----	-----	3.72	11.15	7.11	14.05	37.57	24.02	37.78	124.30	83.72
Plot 15-A, Level open-end terraces [3]	3.13	3.42	55	20.74	34.40	28.47	-----	-----	-----	2.15	7.16	4.10	7.91	24.10	14.40	.41	15.60	4.43
Ravine A, Graded terraces [4]	35.00	4.94	56	19.76	34.40	28.67	-----	-----	-----	2.89	9.65	5.99	12.41	32.48	20.89	-----	-----	-----
Groups of rains for the period:																		
High-intensity rains:																		
Plot 13, Unterraced	3.23	5.13					112	346	198	.42	3.08	1.24	14.22	94.37	44.44	7.63	23.20	16.81
Plot 15-A, Level open-end terraces	3.13	3.42	10	1.61	4.22	2.79	117	980	446	.26	3.01	1.07	9.93	78.87	38.35	.07	5.05	1.27
Ravine A, Graded terraces	35.00	4.94					334	958	521	.33	2.98	1.23	12.13	70.62	44.09	-----	-----	-----
Moderate-intensity rains:																		
Plot 13, Unterraced	3.23	5.13					105	1,046	395	.39	1.46	.92	24.22	99.31	46.46	3.33	30.15	11.59
Plot 15-A, Level open-end terraces	3.13	3.42	20	.72	4.57	1.98	155	1,525	582	.04	1.45	.68	3.28	56.25	34.34	.003	2.84	.47
Ravine A, Graded terraces	35.00	4.94					243	1,060	643	.30	1.60	.86	24.59	65.76	43.43	-----	-----	-----
Low-intensity rains:																		
Plot 13, Unterraced	3.23	5.13					80	379	174	.11	.51	.32	8.66	59.26	30.48	.44	9.39	2.78
Plot 15-A, Level open-end terraces	3.13	3.42	5	.70	1.38	1.05	153	388	280	.02	.29	.17	1.45	35.80	16.19	.21	.01	.07
Ravine A, Graded terraces	35.00	4.94					210	662	399	.05	.34	.26	3.94	47.14	24.76	-----	-----	-----

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.

[2] Plot 13 was on badly eroded Chickasha (originally classified as Kirkland), Zaneis, and Stephensville (originally classified as Vernon) fine sandy loam in a rotation of cotton and cowpeas.

[3] Plot 15-A was on badly eroded Chickasha (originally classified as Kirkland), Zaneis, and Stephensville (originally classified as Vernon) fine sandy loam in a rotation of cotton and cowpeas. The terraces of this plot were 400 to 522 feet long, with vertical spacings, from 2 to 2.5 feet.

[4] Ravine A included the variable grade terraces of fields B and E (fig. 2) on badly eroded Chickasha (originally classified as Kirkland) and Zaneis fine sandy loam and in cultivated crops. Soil loss was not measured from this watershed.

TABLE 32.—*Average annual crop yields from terraced and unterraced land for the 8-year period 1931–38*

Area designation	Size of area	Land slope	Vertical interval	Grade per 100 feet	Length of terrace	Soil condition	Crop yield per acre: Ridge			Channel			Interval			Total[1]		
							Seed cotton	Oats	Corn or darso	Seed cotton	Oats	Corn or darso	Seed cotton	Oats	Corn or darso	Seed cotton	Oats	Corn or darso
	Acres	*Pct.*	*Ft.*	*In.*	*Ft.*		*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Field A:[2]																		
Terrace 1- and 6-A	0.58	5.47	2.00	4	700	Virgin	698	600	296	301	312	131	162	287	39	490	294	200
Terrace 2- and 5-A	.96	5.61	3.50	4	700	do	818	657	413	554	591	214	297	592	107	517	382	228
Terrace 3- and 4-A	1.36	5.52	5.00	4	700	do	925	703	366	631	592	280	469	693	158	587	546	224
Field C:[3]																		
Terrace 3-C	2.85	4.33	3.51	6	1,500	Virgin and cultivated[4]	731	390	257	418	432	198	444	350	144	510	419	175
Terrace 4-C	2.77	4.41	3.47	4	1,500	do.[4]	723	470	392	453	504	346	430	441	282	513	505	315
Terrace 5-C	2.58	4.72	3.43	2	1,500	do.[4]	780	469	411	558	773	427	458	399	300	557	531	350
Terrace 6-C	2.06	5.51	3.27	Level	1,500	do.[4]	650	364	388	357	448	457	346	190	250	449	419	336
Plot C-1, unterraced	1.51	4.00				Virgin										527	638	211
Field B:[5]																		
Terrace 2-B	5.99	2.79	3.99	0–4	2,536	Eroded	224	000	453	191	000	399	191	000	481	342	000	465
Terrace 1-C	6.16	3.54	3.91	0–4	2,350	Virgin	396		961	347		928	281		771	453	361	820
Terrace 3-B	5.67	3.70	3.45	0–6	2,856	Eroded	234	000	498	185	000	386	107	000	361	248	000	379
Terrace 2-C	4.37	3.66	2.93	0–6	2,525	Virgin	318		1,019	320		753	249		824	417	370	865
Field E:[6]																		
Terrace 6-E, open-end	1.22	4.56	4.00	Level	648	Badly eroded	417			166			192			273		
Plot 14, closed-end terraces	1.23	4.49	2–3.5	do	100	do	408			106			184			245		
Plot 15–A, open-end terraces	3.13	3.42	2–3.5	do	460–522	do	446			179			200			251		
Plot 13, unterraced	3.23	5.13				do										394		
Plot G:[7]																		
Plot G, closed-end terraces	.82	5.00	2–3.5	Level	101–196	Virgin	610			362			388			579		
Plot G-1, unterraced	1.40	1.50				do										569		

[1] These totals include 1931 yields which are not included in the ridge, channel, and interval averages initiated in 1932.

[2] Field A was on Chickasha (originally classified as Kirkland) and Stephensville (originally classified as Vernon) fine sandy loam. Crops were grown as follows: Cotton, 1935, 1938; oats, 1932, 1934, 1937; corn, 1931, 1933; darso was planted in 1936 but failed.

[3] Field C was on Chickasha (originally classified as Kirkland) and Zaneis (originally classified as Vernon) fine sandy loam. Crops were grown as follows: Cotton, 1932, 1935, 1938; oats, 1931, 1934, 1937; corn, 1933; darso was planted in 1936 but failed.

[4] About two-thirds of the terrace was on virgin soil and one-third on soil that had been cultivated and was slightly sheet eroded.

[5] Field B was on Chickasha and Zaneis fine sandy loam. Crops were grown as follows: Cotton, 1931, 1934, 1937; oats, 1933, 1936 (both the 1933 and 1936 crops failed on eroded soil; the 1936 crop produced a small yield on virgin soil, which is reported as a total yield); corn, 1932; darso, 1935, 1938.

[6] Field E was on Chickasha, Stephensville, and Zaneis fine sandy loam. Crops were grown as follows: Cotton, 1932, 1934, 1936, 1938; cowpeas, 1931, 1933, 1935, 1937; the cowpeas were turned under as green manure.

[7] The plots were on Stephensville and Chickasha fine sandy loam. Crops were grown as follows: Cotton, 1932, 1934, 1936, 1938; cowpeas, 1931, 1933, 1935, 1937; the cowpeas were turned under as green manure.

TABLE 33.—*Crop yields from terrace ridges, channels, and intervals from Field A for the 8-year period 1931–38* [1]

Year and description of area [3]	Kind of crop	Crop yield per acre [2] with vertical interval of—								
		2.0 feet			3.5 feet			5.0 feet		
		Terrace 1–A	Terrace 6–A	Average	Terrace 2–A	Terrace 5–A	Average	Terrace 3–A	Terrace 4–A	Average
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1931:										
Ridge	Corn	------	------	------	------	------	------	------	------	------
Channel	do	------	------	------	------	------	------	------	------	------
Interval	do	------	------	------	------	------	------	------	------	------
Total		525.0	441.0	483.0	427.0	392.0	409.5	399.0	378.0	388.5
1932:										
Ridge	Oats	752.0	960.0	856.0	803.5	945.9	874.7	779.5	1,106.2	922.9
Channel	do	398.4	367.4	382.9	700.8	639.4	670.1	544.0	587.8	565.9
Interval	do	560.0	289.3	424.7	808.6	898.6	853.6	1,037.8	808.3	923.1
Total		207.6	313.6	260.6	505.6	208.0	356.8	672.0	656.0	664.0
1933:										
Ridge	Corn	405.0	186.9	296.0	495.3	330.2	412.8	414.3	317.8	366.1
Channel	do	211.2	49.7	130.5	329.2	99.4	214.3	260.9	298.1	279.5
Interval	do	64.8	12.8	38.8	179.1	34.3	106.7	188.2	127.0	157.6
Total		273.0	126.0	199.5	308.0	147.0	227.5	252.0	196.0	224.0
1934:										
Ridge	Oats	253.1	434.6	343.9	373.8	503.1	438.5	378.5	587.2	482.9
Channel	do	295.0	186.3	240.5	571.4	450.3	501.9	462.7	770.2	616.5
Interval	do	92.6	198.7	145.7	320.1	339.0	329.6	511.1	415.5	463.3
Total		233.6	329.6	281.6	403.2	416.0	409.6	473.6	499.2	486.4
1935:										
Ridge	Cotton	525.1	341.3	433.2	531.3	479.9	505.6	686.3	615.4	650.9
Channel	do	304.6	90.3	197.5	428.8	233.2	331.0	425.7	307.7	366.7
Interval	do	94.5	50.8	72.7	265.2	108.4	186.8	308.2	254.1	281.2
Total		386.1	288.7	307.4	378.1	259.9	319.0	409.9	347.1	378.5
1936:										
Ridge	Darso	------	------	------	------	------	------	------	------	------
Channel	do	------	------	------	------	------	------	------	------	------
Interval	do	------	------	------	------	------	------	------	------	------
Total		0	0	0	0	0	0	0	0	0
1937:										
Ridge	Oats	------	------	------	------	------	------	------	------	------
Channel	do	------	------	------	------	------	------	------	------	------
Interval	do	------	------	------	------	------	------	------	------	------
Total		347.5	333.1	340.3	385.3	369.6	377.5	478.4	499.2	488.8

1938:										
Ridge	Cotton	928.3	996.9	962.6	1,074.8	1,183.8	1,120.3	1,261.7	1,134.0	1,197.9
Channel	do	490.7	316.8	403.8	875.8	677.0	776.4	944.1	844.7	894.4
Interval	do	250.0	0	250.0	525.6	287.7	406.7	738.3	573.4	655.9
Total		683.8	662.5	673.2	759.6	663.5	714.1	883.1	704.3	793.7
		Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Size of area		0.59	0.56	0.58	0.99	0.92	0.96	1.38	1.34	1.36
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Land slope		5.47	5.47	5.47	5.61	5.61	5.61	5.52	5.52	5.52

[1] Field A was located on virgin Chickasha (Kirkland) and Stephensville (Vernon) soils.
[2] Seed cotton.
[3] All terraces were 700 feet long and had a constant grade of 4 inches per 100 feet.

TABLE 34.—*Crop yields from terrace ridges, channels, and intervals from Field B for the 8-year period 1931–38* [1]

Year and description of area [3]	Kind of crop	Crop yield per acre [2] according to grade per 100 feet				
		Eroded soil			Virgin soil	
		Terrace 2-B, 0-4 inches [4]	Terrace 3-B, 0-5 inches [4]	Terrace 4-B, 3 inches [4]	Terrace 1-C, 0-4 inches [4]	Terrace 2-C, 0-6 inches [4]
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1931:						
Ridge	Cotton					
Channel	do					
Interval	do					
Total	do	680.0	454.0	585.0	742.0	700.0
1932:						
Ridge	Corn	422.6	635.2	1,085.3	1,481.0	1,510.8
Channel	do	183.8	234.8	688.8	1,192.9	662.1
Interval	do	475.6	393.7	757.8	1,088.9	947.8
Total	do	429.1	436.1	827.4	1,109.7	1,056.3
1933:						
Ridge	Oats					
Channel	do					
Interval	do					
Total	do	0	0	0	0	0
1934:						
Ridge	Cotton	147.8	131.6	106.6	253.5	187.2
Channel	do	104.8	109.0	139.0	231.9	206.9
Interval	do	117.7	65.6	114.4	194.7	151.9
Total	do	122.7	85.9	117.1	208.7	168.2
1935:						
Ridge	Darso	500.4	348.8	362.8	583.9	474.6
Channel	do	515.5	533.5	657.1	830.2	853.5
Interval	do	373.6	250.5	329.7	524.6	546.5
Total	do	415.5	240.8	370.1	562.8	567.8
1936:						
Ridge	Oats					
Channel	do					
Interval	do					
Total	do	0	0	0	360.6	369.9
1937:						
Ridge	Cotton	300.3	334.9	285.7	536.6	443.2
Channel	do	276.6	260.7	293.8	462.0	431.9
Interval	do	203.8	148.1	240.5	367.3	345.3
Total	do	272.9	204.3	252.3	406.6	383.1
1938:						
Ridge	Darso	436.7	510.5	957.8	819.3	1,071.6
Channel	do	496.9	389.6	545.6	761.4	743.5
Interval	do	574.1	438.6	529.5	698.6	977.7
Total	do	550.5	449.7	571.8	726.3	971.6
		Acres	*Acres*	*Acres*	*Acres*	*Acres*
Size of area		5.99	5.67	4.70	6.16	4.37
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Land slope		2.79	3.70	4.21	3.54	3.66
		Feet	*Feet*	*Feet*	*Feet*	*Feet*
Vertical interval of terrace		3.99	3.45	3.98	3.91	2.93

[1] Field B was located on Zaneis (Vernon) and Chickasha (Kirkland) soil.
[2] Seed cotton.
[3] Length of terraces were: 2-B, 2,536 feet; 3-B, 2,536 feet; 4-B, 2,885 feet; 1-C, 2,350 feet; and 2-C, 2,525 feet.
[4] Grade per 100 feet—terraces with variable grade.

TABLE 35.—*Crop yields from terrace ridges, channels, and intervals from Field C for the 8-year period 1931–38* [1]

Year and description of area [3]	Kind of crop	Crop yield per acre [2] according to grade per 100 feet			
		Terrace 3-C, 6 inches [4]	Terrace 4-C, 4 inches [4]	Terrace 5-C, 2 inches [4]	Terrace 6-C, level
		Pounds	*Pounds*	*Pounds*	*Pounds*
1931:					
Ridge	Oats				
Channel	do				
Interval	do				
Total	do	672.0	736.0	819.2	729.6
1932:					
Ridge	Cotton	724.2	812.8	822.9	699.6
Channel	do	494.2	532.0	720.9	343.0
Interval	do	533.3	524.5	587.6	403.1
Total	do	574.7	597.1	668.2	492.3
1933:					
Ridge	Corn	256.0	391.0	410.7	387.5
Channel	do	197.7	346.0	427.3	450.6
Interval	do	144.2	282.1	290.9	259.0
Total	do	175.0	315.0	350.0	336.0
1934:					
Ridge	Oats	390.4	469.5	465.8	364.3
Channel	do	431.7	504.4	773.3	447.7
Interval	do	350.4	441.4	398.8	189.9
Total	do	371.2	457.6	407.2	291.2
1935:					
Ridge	Cotton	363.0	422.9	397.3	316.0
Channel	do	110.7	153.0	130.6	76.0
Interval	do	155.2	207.0	153.2	103.1
Total	do	209.1	254.0	215.4	169.8
1936:					
Ridge	Darso				
Channel	do				
Interval	do				
Total	do	0	0	0	0
1937:					
Ridge	Oats				
Channel	do				
Interval	do				
Total	do	213.8	319.7	306.2	237.1
1938:					
Ridge	Cotton	1,107.4	1,021.8	1,119.0	933.2
Channel	do	648.3	674.4	822.7	651.2
Interval	do	643.4	558.4	633.5	531.7
Total	do	756.1	688.1	788.4	685.9
		Acres	*Acres*	*Acres*	*Acres*
Size of area		2.85	2.77	2.58	2.06
		Percent	*Percent*	*Percent*	*Percent*
Land slope		4.33	4.41	4.72	5.51

[1] Field C was located on Zaneis (Vernon) and Chickasha (Kirkland) soil.
[2] Seed cotton.
[3] All terraces were 1,500 feet long with a vertical spacing of 3.5 feet and 1,000 feet of the area was virgin soil and the other slightly eroded in 1930.
[4] Grade per 100 feet.

TABLE 36.—*Soil and water losses from control plots on surface and desurfaced Stephensville (Vernon) fine sandy loam by classified groups of rains* [1] *for the 11-year period 1930–40*

Rainfall group, plot number,[2] soil condition, and crop	Rains	Rainfall: Amount: Low	Rainfall: Amount: High	Rainfall: Amount: Average	Water loss: Amount: Low	Water loss: Amount: High	Water loss: Amount: Average	Water loss: Percent of rainfall: Low	Water loss: Percent of rainfall: High	Water loss: Percent of rainfall: Average	Soil loss per acre: Low	Soil loss per acre: High	Soil loss per acre: Average
	Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*	*Percent*	*Percent*	*Tons*	*Tons*	*Tons*
Annual for the period:													
3, Virgin surface soil, continuous cotton [3]					0.920	6.930	3.430	3.81	19.63	21.35	0.35	68.52	16.47
9, Desurfaced soil,[4] continuous cotton [5]	57	21.45	37.40	30.22	2.972	12.070	7.521	12.58	34.29	24.89	9.91	50.95	27.53
8, Virgin surface soil, bare hard fallow					4.578	11.520	8.180	19.30	32.63	27.10	6.33	40.95	21.86
Groups of rains for the period:													
High-intensity rains:													
3, Virgin surface soil, continuous cotton [3]					.059	2.489	.805	3.55	62.70	32.33	.08	29.58	5.09
9, Desurfaced soil,[4] continuous cotton [5]	21	1.20	5.76	2.49	.318	3.681	1.300	10.19	92.71	52.21	1.00	22.36	7.44
8, Virgin surface soil, bare hard fallow					.591	2.831	1.348	30.83	86.25	54.14	1.16	20.10	4.90
Moderate-intensity rains:													
3, Virgin surface soil, continuous cotton [3]					.000	1.641	.377	.00	66.93	24.07	.00	8.20	1.67
9, Desurfaced soil,[4] continuous cotton [5]	29	.52	4.15	1.51	.000	2.634	.782	.00	85.60	51.79	.00	10.04	2.80
8, Virgin surface soil, bare hard fallow					.125	1.953	.704	5.03	79.56	46.62	.00	4.88	1.54
Low-intensity rains:													
3, Virgin surface soil, continuous cotton [3]					.000	1.515	.145	.00	50.12	16.11	.00	3.42	.28
9, Desurfaced soil,[4] continuous cotton [5]	31	.36	4.12	.90	.000	2.073	.268	.00	83.10	29.78	.00	3.50	.53
8, Virgin surface soil, bare hard fallow					.000	1.992	.287	.00	92.47	31.88	.00	1.58	.42

[1] The rains are grouped into high-, moderate-, and low-intensity rains on the basis of 30-minute intensities of 2 or more inches, 1 to 2 inches, and 0.5 to 1 inch per hour.
[2] Plots of 1/100-acre on a 7.7-percent slope.
[3] Planted parallel with slope. Average yield of seed cotton, 506 pounds.
[4] Desurfaced to a depth of 10 inches.
[5] Planted parallel with slope. Average yield of seed cotton, 307 pounds.

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