CONSERVATION AND LAND USE INVESTIGATIONS

at the

Red Plains Conservation Experiment Station, Guthrie, Okla.

and the

Wheatland Conservation Experiment Station, Cherokee, Okla.

Oklahoma Agricultural Experiment Station
in cooperation with
Soil Conservation Service

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The business of every farmer is to grow as large a crop as the soil is capable of producing; but failure results eventually, regardless of the productivity of the land, unless erosion is controlled and fertility maintained (*6, 7, 8*).† Methods of controlling erosion, and of bringing eroded land back into production, have been studied over the past 17 years at the Red Plains Conservation Experiment Station near Guthrie, Oklahoma. Since 1939, similar studies for the northwestern Oklahoma wheat area have been made at the Wheatland Conservation Experiment Station near Cherokee, Oklahoma. This bulletin summarizes results obtained to date at these two stations, and discusses the implications of those results for conservation farming in Oklahoma.

The research findings at the Red Plains and Wheatland Conservation Stations are fundamental facts which help provide a basis for planning a coordinated soil conservation program for individual farms and ranches. It cannot be expected that every conservation practice proved sound by research will apply to every farm. Land differs in soil characteristics, slope, and degree of erosion. It also differs in crop-producing power and in the kinds of crops and livestock it is suited to produce. To get the most from each piece of land year after year, it must be used correctly (*19*). Before it can be used correctly the land

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† Italic numerals in parentheses refer to "Literature Cited," Page 32.

must be classified as to erosion hazard, the kind of crops it is suited to produce, and the soil conservation and fertility maintenance practices needed to keep it producing. Only then can a coordinated soil conservation program be worked out to include: (1) Sound land use; (2) the right combination of conservation practices; (3) the maintenance and improvement of soil fertility; and (4) economically sound farm management.

SOME GENERAL CONCLUSIONS

Some of the general conclusions to date from the research at Guthrie and Cherokee include:

The most effective method of controlling erosion and runoff is with thick-growing vegetation. Grass is the best type of vegetation for protective cover. Crop rotation, contour cultivation, and terraces also materially reduced runoff, thereby saving soil and moisture (See page 7).

Crop yields were increased by such conservation and fertility maintenance practices as crop rotation (See page 10), winter cover crops and phosphate fertilizer (page 12), and contour cultivation (page 16). These beneficial effects did not always appear at once but began to show up after a few years. Results at Guthrie and elsewhere suggest that, in general, severe erosion can be controlled, runoff materially reduced and crop and feed production can be maintained at about one-third higher level by wise land use and practical conservation farming.

Pastures properly fertilized and managed yielded up to two or three times as much green feed of better quality than those not fertilized (See pages 21 and 24).

Vegetation was re-established on abandoned and badly gullied areas, and the land so treated at Guthrie has produced 40 to 63 pounds of beef annually during summer grazing periods (See pages 20 and 30).

Unused, shallow, rolling scrubby-oak land at Guthrie was successfully converted into pastures by removing woody vegetation, and the amount of beef obtained compared favorably with that produced on range land of the area (See pages 27 and 30).

Loss of rainfall in runoff water has been so reduced by conservation practices that it seems fair to assume floods could be considerably reduced if complete conservation practices were applied to the entire watershed of rivers (See pages 9 and 16).

LAND CLASSIFICATION

Which of the foregoing research results will apply on a particular farm or ranch will depend upon the types of land included. In classifying land according to erosion hazard and conservation practices needed, the Soil Conservation Service (*14*) has set up the eight capability classes illustrated in Figure 1. In general, Classes I, II and III are suitable for continuous cultivation. Class I requires no special practices other than good farming. Classes II and III, however, need special practices, the intensity of which should be increased on the latter. Class IV is primarily pasture or meadow land, but under certain conditions and restrictions it can sometimes be used for cultivated crops. Classes V, VI and VII are suitable only for permanent vegetation such as grass or timber. Here too, as in the classes of land suitable for cultivation, the number of special practices and limitations increases as the class number increases. Class VIII land can safely be used only for a permanent type of vegetation which will not be harvested. Generally this land is best adapted for wild life production.

SOIL AND WATER LOSS IN RELATION TO SURFACE COVER

Results of research at the Red Plains Station (Table 1) show that during a 17-year period the soil loss from bare hard fallow land was 986 times more and the runoff water 30 times more than that from Bermuda grass (Figure 2). The plot where about 10 inches of top soil had been removed prior to measurement also lost 2.35 times more water in runoff and 1.86 times more soil than an adjacent area of surface soil. The virgin surface soil provides a favorable condition for the downward movement and absorption of water. When this layer is removed by erosion, the storage capacity is reduced. Importance of

TABLE 1.—Annual Soil and Water Losses from Various Kinds of Land Cover.[1]

Kind of Cover	Runoff Water	Soil Loss per Acre
	Percent	Tons
Bermuda grass	.88	.017
Continuous cotton	11.83	15.386
Bare hard fallow	26.00	16.764
Continuous cotton on eroded land[2]	27.76	28.580

[1] During a 17-year period (1930-46) at the Red Plains Conservation Experiment Station, Guthrie, Okla.
[2] About 10 inches of top soil removed when started in 1929.

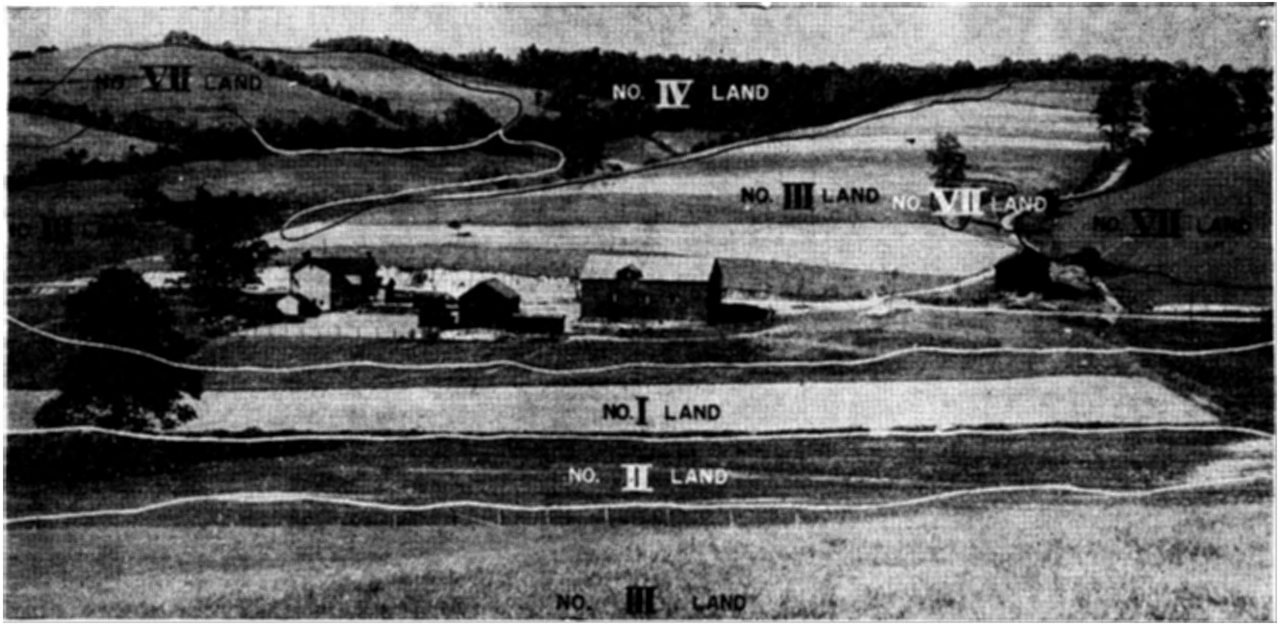

Fig. 1.—Classification of Land for Sound Use.

Conservation practices vary from farm to farm and even in different areas of the same farm, so no general plan can be laid out for application. What proves good in one section may be injurious in others. Careful study of all factors involved and accurate analysis of all aspects are necessary to work out the best conservation plan for a given farm or tract of land. For this purpose all land is classified by the Soil Conservation Service into the eight general capability classes illustrated in the above picture and further described on page 7.

checking erosion before the land becomes seriously eroded is clearly emphasized. As the soil erodes, further erosion is often accelerated.

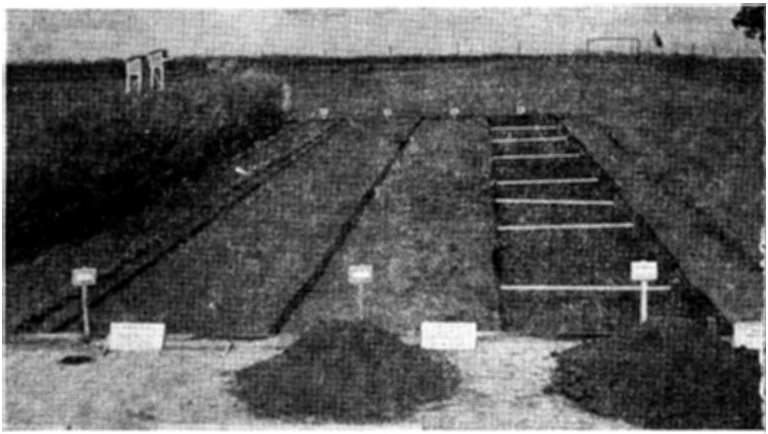

Fig. 2.—Relation of Plant Cover to Soil Erosion.

The piles of soil in front of each plot represents the average annual amount of erosion from these areas since 1930, at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma. The tons of soil removed in the runoff water from these plots are recorded in Table 1.

Severe erosion and floods result from high intensity rains (*6*) and the soil's inability to absorb water. The foregoing results, however, show that the water contributing to erosion and floods can be materially reduced by wise land use and practical conservation farming.

CONSERVATION AND LAND USE PRACTICES FOR LAND SUITABLE FOR CULTIVATION

Although thick-growing vegetation controls erosion and rebuilds soil, all the land cannot be put to grass or other permanent vegetation. Food and feed crops must be grown on cultivated land. But research shows that these cultivated fields can be protected from erosion by adequate soil conservation practices. The following pages summarize results of work at Guthrie and Cherokee which applies to erosion prevention on cultivated areas. Research on practices for areas not suitable for cultivation is summarized on page 19 ff.

Crop Rotation

A simple crop rotation on cultivated land (Figure 3) has reduced soil loss 76 percent and runoff 33 percent annually (Table 2) during 17 years at the Guthrie station. The native grass sod was destroyed and this experiment started on virgin soil in 1929. The yield of seed cotton in the rotation the first and second five-year periods was less than that on the continuous area. But during the third period it was 36.9 percent higher, and in 1945-46 it increased an average of 68.2 percent. The yield of seed cotton on the continuous area the last five years was 96 pounds per acre less than in the first five-year period, whereas on the rotation plot it was 170 pounds more (Table 3).

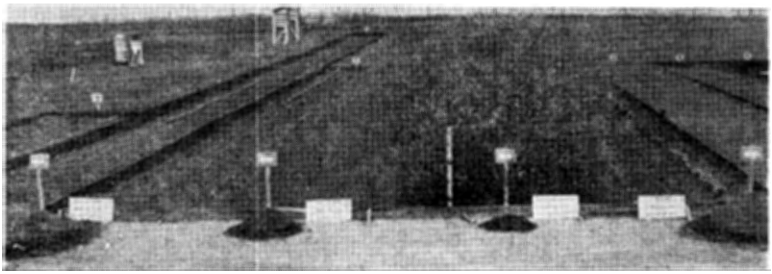

Fig. 3.—Crop Rotations Conserve Soil.

The piles of soil represent the average annual amount of erosion from the different crops in the rotation since 1930, at the Red Plains Conservation Experiment Station. Pile 1, on the left, was from continuous cotton, while Piles 2, 3 and 4 were from the respective crops of wheat, sweet clover and cotton in the rotation.

TABLE 2.—Effect of Rotation of Cotton, Wheat and Sweet Clover on Soil and Water Loss and on Yield of Cotton; Guthrie, Oklahoma.[1]

Item	1930-34	1935-39[2]	1940-44	1945-46	1930-46
Reduction in soil loss (percent)	76.8	80.1	80.3	70.0	76.3
Reduction in water loss (percent)	19.9	17.9	47.6	56.2	32.8
Gain or loss in cotton yield[3] (percent)	—10.5	—6.3	36.9	68.2	14.0

[1] This experiment was started on virgin soil in 1929.
[2] Beginning in 1940, all plots have received superphosphate at the rate of 250 pounds per acre every third year. The fertilizer was applied under the sweet clover in the rotation.
[3] Seed cotton.

TABLE 3.—Effect of a Rotation of Cotton, Wheat and Sweet Clover on Yield of Seed Cotton; Guthrie, Oklahoma.[1]

Five-year Period	Years	Annual Precipitation Inches	Pounds of Seed Cotton per Acre		
			Continuous	Rotation[2]	Gain or Loss
1	1930-34	33.39	474	429	—45
2	1935-39	26.44	510	480	—30
3	1940-44[3]	32.41	378	599	221
	1945-46	31.10	122	385	263
Average	1930-46	31.06	427	487	60

[1] Experiment was started on virgin soil.
[2] Cotton in rotation of cotton, wheat and sweet clover. The average per acre yield of wheat was 9.7 bushels and that of sweet clover, 1.59 tons.
[3] Beginning in 1940, all plots received superphosphate at the rate of 250 pounds per acre every third year. The fertilizer was applied under the sweet clover in the rotation.

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, and the length of time and season of the year 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 (Table 4) are especially valuable in conserving soil and water.

TABLE 4.—Rainfall, and Water Loss in Runoff, During Critical Months; Guthrie, Oklahoma.

	Total Annual (Inches)	Percent of Annual Total[1]		
		April, May and June	August, Sept.	April, May, June August and Sept.
Precipitation[2]	31.1	37	23	60
Runoff[2]:				
Bare hard fallow	8.17	45	30	75
Cotton—continuous	3.53	38	40	78
Rotation[3]—average	2.54	48	35	83
Bermuda grass	.26	58	23	81
Average	4.83	44	33	77

[1] Land slope 7.7 percent.
[2] Highest rainfall and runoff losses occurred during May and September.
[3] Rotation—cotton, wheat and sweet clover.

Sixty percent of the annual precipitation was received during the months of April, May, June, August and September, but an average of 77 percent of the total runoff water was lost in this period. July rainfall is usually low (*6*). Thick-growing vegetation and other conservation measures are, therefore, most useful during the spring and fall months.

Cover Crops and Fertilizer

Small grain and other winter cover crops, if properly managed, are most effective for erosion control at the time of year when most of the runoff occurs. In addition, winter cover crops increased the yield of seed cotton (Table 5). The best results were obtained when these crops received an application of fertilizer. Such crops also provide excellent early pasture.

TABLE 5.—Effect of Winter Cover Crops and Fertilizers on Yield of Seed Cotton During the Past 16 Years (1931-46) on Badly Eroded Land; Guthrie, Oklahoma.

Cover Crop	Fertilizer[1]	Yield (pounds per acre)	Percent Increase
None	None	223	
None	4-12-4	443	50
Wheat	4-12-4	521	57
Vetch	None	278	20
Vetch	0-12-4	427	48
Vetch	4-12-4	489	54
Sweet clover[2]	0-20-0	493	55

[1] Applied at a rate of 300 pounds per acre annually.
[2] Superphosphate applied at a rate of 100 pounds per acre when sweet clover was seeded. This area has been in cotton seven times during this period.

Mineral fertilizers are most important when applied to legumes. Not all crops respond equally to fertilization; therefore, it is well to consider this and apply the fertilizer mainly to the crops giving best response. Where soils are acid in nature, ground limestone may be necessary for certain crops and is a desirable soil builder. This necessitates testing the soil for its soluble phosphorus and lime content and making the necessary corrections.

Strip Cropping

The effectiveness of strip cropping depends upon the production of an adequate cover of the right kind of vegetation to offer resistance to wind and water. Native grass strips inter-

TABLE 6.—Effect of Native Grass Interspersed Between Strips of Cotton on the Conservation of Water at Guthrie, Oklahoma.[1]

Kind of Cover or Strips[2]	Percent Runoff	Crop Yield (Pounds per Acre)	
		Seed Cotton	Grass
Strips of native grass and cotton	7.7	527	3167
All cotton	13.4	520	

[1] Average of 5 years results, 1942-46.
[2] Grass, interspersed between each 22 rows of cotton, occupied about one-third of the area. All strips and cultivation are located and conducted on the contour.

spersed between strips of cotton and occupying one-third of the land area reduced runoff water loss 43 percent during the last five years on deep sloping soil (Table 6). Not all the close-growing crops are as effective as grass, but various small grains, legumes, sorghums and other hay crops can often be utilized effectively.

Vegetated Waterways

Before terraces are constructed, provision must be made for disposing of the runoff water. Broad natural vegetated (*3*) drainage ways are the most desirable for this purpose. When they are not available, the runoff must be disposed of by constructing channels (Figure 4). Various kinds of plants are being tested at Cherokee for this purpose. The results (Table 7) show that individual species respond differently under different soil conditions. Sod forming grasses were the best type of plants for water channels, as shown by studies with Bermuda grass at Guthrie and tests at the hydraulic laboratory near Stillwater (*2, 3*). Buffalo grass has also made a good cover for channels on the Cherokee station. Bunch grasses and legumes did not provide as dense a soil cover as the sod grasses. But on the Cherokee station, where the soil is deep and fertile, weeping lovegrass, switch grass and mixtures of these and other

TABLE 7.—Plants For Vegetating Broad Flat Water Channels.[1]

Grasses and Legumes[2]	Conditions For Best Use		
	Fertility	Slope Percent[3]	Growing Seasons
Sod Type[4]			
Bermuda	medium	15	1
Buffalo	high	8	2
Vine Mesquite	high	5	2 to 3
Bunch Type[5]			
Weeping Lovegrass[4, 5]	medium	5	1
Blue Grama	medium	5	2 to 3
Side-oats Grama	medium	5	2 to 3
Yellow Bluestem	medium	5	2 to 3
Mixtures[5]			
Buffalo, Blue and Side-oats Grama	medium	7	2
Switch, Weeping Lovegrass, Buffalo and Blue Grama	medium	5	2 to 3
Legume[5]			
Alfalfa	high	2	1

[1] These plants are being tested in water channels on the Conservation Experiment Stations at Guthrie and Cherokee. Other results were recorded by Elwell (10).
[2] Maximum silting moderate for bermuda grass, all others slight.
[3] Maximum slope percent based on reports by Cox and Palmer (2, 3).
[4] Soil condition (16) permeable to slowly permeable.
[5] Soil condition (16) permeable.

Fig. 4.—Vegetated Waterways.

A broad flat water channel protected by vegetation on the Wheatland Conservation Experiment Station. This kind of channel is performing satisfactorily for disposing of runoff water from terraced land. Plants used for vegetating water channels are listed in Table. 7.

grasses are giving adequate protection for outlet channels on land slope of two to three percent. In some channels on the flatter slopes at this station alfalfa is providing a satisfactory protective cover.

These studies, field observations, and hydraulic data (*3*) show that for best results vegetation in water channels should be frequently mowed or systematically grazed for maintaining a good uniform protective cover. This procedure promotes good tillering and reduces excessive turbulence in the flow of water, which aids in preventing irregular silt deposits. Therefore the success of a vegetated waterway (*10*) depends upon proper design of channel, condition of soil, selection and establishment of plants, and method of maintenance.

Moisture Conservation for Wheat Production

The effectiveness of different methods of tillage, contour cultivation, and terraces in conserving moisture for wheat production is being studied on the Wheatland Conservation Experiment Station. Different methods of continuous tillage are studied on 48 plots, and rotation of tillage methods is studied on 9 small natural watersheds.* All plot and watershed treatments are in triplicate.

Effect of tillage methods: To date, the highest average yield of wheat from the continuous tillage tests on the plots has been (Table 8) produced on the plowed land and the lowest on the

* Information on the methods used in these studies is available upon request from the Project Supervisor, Red Plains Conservation Experiment Station, Guthrie, Oklahoma.

TABLE 8.—Effect of Different Methods of Continuous Tillage on Yields of Wheat; Cherokee, Oklahoma.

Method of Tillage	Yield of Wheat per Acre[1]	
	Grain (Bushels)	Straw (Tons)
Stubble mulch	15.4	1.23
Plowed	19.3	1.51
Listed	18.8	1.45
Basin listed	18.7	1.45

[1] Five years 1942-46. Precipitation average 25.7 inches.

stubble mulch plots. The average yield from the listed and basin listed land has been the same and only slightly less than that from plowed land. The mulched plots have consistently contained a heavy growth of cheat and weeds, and the wheat plants were attacked by an infestation of foot rot in 1944, 1945 and 1946. During 1943 some straw worm damage was also observed on the mulched plots.

The highest average yield to date on the watersheds has been produced on the one-way plowed land and the lowest on the stubble mulch areas (Table 9). The annual water loss in

TABLE 9.—Effect of Different Methods of Rotated Tillage on Wheat Yields and Runoff Water; Cherokee, Oklahoma.[1]

Method of Tillage[2]	Yield of Wheat per Acre[3]		Percent Runoff[4]
	Grain (Bushels)	Straw (Tons)	
Basin listed	18.3	1.47	9.2
One-way plowed	19.3	1.47	12.1
Stubble mulch	17.4	1.36	9.2

[1] For crop year (July 1 to June 30).
[2] Cultivated on contour.
[3] Average of five years 1942-46.
[4] Average of four years 1943-46.

runoff from the watersheds was the highest from the one-way plowed land.

Stubble mulch machinery: The introduction of stubble mulch culture for small grain and other crops created a definite need for better adapted tools. Various kinds have been tried at the Cherokee station (*5*), including the rod-weeder, plows without moldboards, blades and sweeps of different types, and the one-way disk plow. The present thinking seems to be that different kinds of tools may need to be made for different soil and crop conditions. From this work and other reports (*1*, *9*) it appears that the type of tools needed for stubble mulch in general, however, should have the following specifications:

1. Strong, heavy and durable.

2. Easy to adjust and repair.

3. Till rather smoothly, but cultivate the soil sufficiently to cover seed and kill weeds.

4. Sufficient clearance so that straw will pass through properly.

Another possible opportunity might be to modify the disk of the one-way plow so that it will not completely turn or cover the straw. This might be done by taking part of the cup out of the present disk.

Contour cultivation and terraces: The effect of contour cultivation and terraces on the conservation of runoff water and crop yields is also being measured at Cherokee. The results given in Table 10 show that where all cultivation was conducted with the slope the lowest amount of runoff was from the mulch plots and the highest from the listed. During heavy rains the dams in the furrows of the plots basin listed with the slope often broke (Figure 5) and this may account for the runoff being higher from these plots than that from the plowed land. But both listing and basin listing greatly reduced runoff water losses when listing followed the contour. In fact during the last five years contour cultivation reduced the average amount of runoff from the four methods of tillage 22.7 percent. Even though this is an outstanding saving of moisture, observations on the watersheds show that contour cultivation alone is not sufficient to control erosion on land slopes over 1.5 percent. On steeper slopes, a combination of terraces and contour cultivation is needed. How terraces help hold

TABLE 10.—Effect of Tillage Method, Contour Cultivation and Terraces on Runoff Water from Deep, Permeable Soil; Cherokee, Oklahoma.[1]

Method of Tillage	Percentage of Rainfall Lost in Runoff			Percentage of Runoff Saved by:	
	With Slope	Contour	Terraces[2] and Contour	Contouring	Terracing and Contouring
Stubble mulch	12.9	11.9	7.6	7.7	41.1
Plowed	13.8	12.6	8.2	8.7	40.6
Listed	15.2	10.3	8.9	32.2	41.4
Basin listed	14.5	8.8	7.8	39.3	46.2
Average	14.1	10.9	8.1	22.7	42.5

[1] Results for crop year (July 1 to June 30). Five-year average 1942-46. Average annual rainfall 25.70 inches.
[2] Short level terraces with one end open.

Fig. 5.—These Basin Lister Dams Broke Where Furrows Ran Up and Down the Hill.

High intensity rains wash out dams in basin listed furrows which run up and down the slope. Water loss in runoff was higher from those plots than that from plowed land (Table 4). But both listing and basin listing greatly reduced runoff water losses when the lister followed the contour.

water is illustrated by the fact that in this test the combination of terraces and contour cultivation conserved an average of 42.5 percent more water than land cultivated with the slope, as compared to the 22.7 percent saved by contour cultivation alone.

The amount of soil lost in the runoff water has not been recorded from studies at Cherokee. But results at the Guthrie station (Table 11) show that terraces also greatly reduced soil

TABLE 11.—Annual Soil Loss in Runoff Water from Terraced and Unterraced Shallow Soil; Guthrie, Oklahoma.[1]

Kind of Land Treatment	Land Slope (Percent)	Soil Loss per Acre (Tons)
Unterraced	5.13	83.72
Terrace grade 4 in.	4.41	5.92
Terrace grade 2 in.	4.72	3.17
Level terrace	5.51	1.33

[1] Average of eight years 1930-38. Data compiled from Tables 29 and 31 of report of Red Plains Conservation Experiment Station (6).

losses and prevented severe erosion. Although open-end level terraces conserved more soil than graded terraces, they cannot be recommended for the impermeable soils or for clay soils on the Guthrie station (*6*) because of the reduction in crop yields by excess moisture. 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 soil with compact subsoil and low infiltration rate. On the Cherokee station, however, where the soil is deep and permeable, level open-end terraces are performing satisfactorily.

The first and second year after the terraces were built at Cherokee, the yield of wheat on the terraced and contour cultivated plots was less than that from those cultivated with the slope (Table 12). But beginning with the third year, apparently

TABLE 12.—Effect of Contour Cultivation and Terraces on Wheat Yields at Cherokee, Oklahoma.[1]

Year	Wheat Yields (Bushels per Acre)			Difference in Yield (Bushels per Acre) Due to:		Precipitation[3]	
	Cultivated With Slope	Cultivated on Contour	Terraced and Cultivated on Contour[2]	Cultivating on Contour	Terracing and Cultivating on Contour	Total Annual Inches	Departure from Average Inches
1942	16.0	15.5	14.1	—0.5	—1.9	30.0	+4.4
1943	9.2	9.9	8.0	0.7	—1.2	20.3	—5.6
1944	17.7	19.2	19.4	1.5	1.7	20.4	—5.5
1945	23.2	24.6	24.5	1.4	1.3	34.3	+8.6
1946	21.0	24.0	23.8	3.0	2.8	23.7	—2.1
Av.	17.4	18.6	18.0	1.2	0.6	25.7	—0.2

[1] Data compiled from averages of stubble mulch, plowed, listed and basin listed plots.
[2] Short level terraces one end open.
[3] Based on Weather Bureau record in Cherokee, Oklahoma, since 1915.

after nature had time to adjust soil conditions in the disturbed portion of the ridges and channel, the yields have been higher on the terraced and contour cultivated plots. Although the rainfall for the 1945 crop year was well distributed and 8.6 inches above normal, terraces and contour cultivation increased the yield an average of 1.3 bushels per acre. With the exception of the first year, contour cultivation alone also increased crop yields.

Water spreading: Another study under way at Cherokee involves the conservation value of collecting runoff water from higher sloping land and spreading it onto lower, more level, deep permeable soil. This experiment was started in the summer of 1944 by systematically designing and constructing level terraces on intervals of one foot in a "syrup pan" (spread and spill) type of arrangement. This forces the water (Figure 6) to completely cross the field in the interval between each terrace. As it moves slowly back and forth over such a large

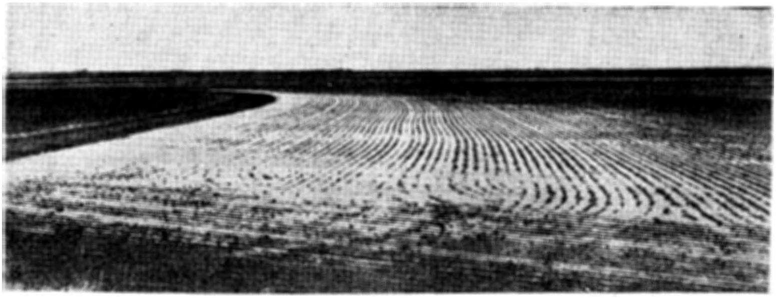

Fig. 6.—Water Spreading.

The conservation value of collecting runoff water from higher sloping land and spreading it onto lower, more level, deep permeable soil is being studied at the Wheatland Conservation Experiment Station, Cherokee, Oklahoma. The water spreading is done by systematically designed level terraces in "syrup pan" type of arrangement.

surface area, much of the surplus is absorbed by the soil and retained for plant use.

The area occupied by the terraces has been completely flooded seven times since the experiment was started. This method of spreading and conserving the excess water prevented it from collecting in a pond that formerly developed in the northwest corner of the station.

The "syrup pan" (spread and spill) terrace, therefore, may serve two every important purposes on the valuable wheat and alfalfa land typical of northwestern Oklahoma. In many places it has possibilities of providing the most desirable outlet for the excess runoff. And on other areas it may also be used advantageously to prevent the excess water from accumulating in ponds and destroying the crops.

CONSERVATION AND LAND USE PRACTICES FOR LAND NOT SUITABLE FOR CULTIVATION

The shallow, sloping, highly erodible soils, as well as others unsuited for cultivation, are more stable and useful when put to permanent vegetation and used for livestock or woodland production. The most effective method of controlling erosion and runoff in tests at Guthrie was the use of thick-growing vegetation (Table 13). The dense cover protects the soil by forming a carpet readily permeable to water. Grass and other permanent vegetation greatly reduce runoff water even from eroded shallow regrassed land. The amount of runoff from such land was 39 percent less than that from cultivated terraced land. Native vegetation, however, reduced the runoff water loss 94 percent.

Revegetation of Eroded Land

Many additional cattle could be supplied with pasturage if the millions of acres of idle, eroded, and unused land in Oklahoma were revegetated and developed. Grass, as a whole,

TABLE 13.—Amount of Runoff Water from Different Kinds of Plant Cover at Guthrie, Oklahoma.[1]

	Average Runoff[2] (Percent)
Cultivated terraced land	18.74
Eroded regrassed land	11.39
Native grass and woodland	1.18

[1] Located on rolling, mainly shallow land.
[2] Average of 5 years (1942-46) on eroded regrassed areas and 7 years (1940-46) for other areas. Average total annual precipitation, 31.86 inches. Average annual precipitation compiled by Weather Bureau in Guthrie, Oklahoma, since 1898 is 32.50 inches.

re-establishes itself slowly under natural conditions on eroded land, but this process can be greatly accelerated by working with nature. There are several methods of establishment, but the kind of vegetation and method of establishment varies with soil and climatic conditions.

The major problems to be overcome in regrassing eroded land are low fertility, poor physical condition of the soil, low available moisture, and poor biological activity. If the low fertility is due to minerals, they must be supplied by the addition of limestone and commercial fertilizers. The nitrogen may be obtained by growing legumes or by supplying commercial fertilizers. Sweet clover and other plants supply organic matter or food for a new life of soil organisms to improve biological activity. This is essential for a good seedbed for native grass. Under native vegetation, there is considerable biological activity. This may be observed from the decay of residue, insects, worms and other forms of life. Eroded, abandoned land has lost most of its organic matter. As a result, there is little or no biological life to start rebuilding fertility and improving the physical condition (*12*).

In addition to these factors, grasses are greatly influenced by climatic conditions. Studies made in Nebraska (*15*) show that blue grama (*Bouteloua gracilis*) was the most drought resistant native grass. Other grasses occur in the following order: buffalo (*Buchloe dactyloides*), black grama (*Bouteloua hirsuta*), drop seed (*Sporobolus asper*), side-oats grama (*Bouteloua curtipendula*), little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon *furcatus*), switch (*Pancium virgatum*) and Indian (*Sorghastrum nutans*). Due to the frequent droughts that occur in Oklahoma, a mixture of both tall and short grasses is usually recommended for reseeding eroded land.

Plants for revegetation: New plants showing considerable promise for revegetation purposes are weeping lovegrass and the King Ranch strain of *Andropogon ischaemum* (sometimes called yellow bluestem).

TABLE 14.—Hay Yields of Two Important Grasses.[1]

Kind of Grass	Yield (Pounds per Acre)[2]
Weeping lovegrass (**Eragrostis curvula**)	5009
Little bluestem (**Andropogon scoparius**)	2417

[1] Average yield, 6-year period 1941-46 at Red Plains Conservation Experiment Station, Guthrie, Oklahoma.
[2] Determined by rod row samples, and represent oven dry weight.

Weeping lovegrass has produced over twice as much hay (Table 14) as little bluestem at the Guthrie station. It has completely controlled weeds or other undesirable competing plants on poor, eroded soil. It is also a good seed producer and easy to establish (*18*). It makes a vigorous growth on various soil conditions and has excellent value for erosion control purposes. As other new plants are found, they will be given further tests and their full uses determined.

TABLE 15.—Effect of Fertilizer on the Yield of Grass; Guthrie, Oklahoma.

Kind of Fertilizer[1]	Pounds of Fertilizer Applied per Acre	Pounds of Hay per Acre[2]	
		Weeping Lovegrass on Severely Eroded Soils[3]	Native Grass on Virgin Soil[4]
4-12-4	200	713	2701
4-12-0	170	954	2191
0-12-4	136	771	2388
4-0-0	50	996	2897
0-12-0	120	444	2335
0-0-4	16	681	2096
Manure	4000	927	1914
Manure) 0-12-0)	4000) 120)	905	2686
Check	None	379	2236

[1] Each kind of fertilizer was applied on the surface of the soil in the spring of 1945 and again in the spring of 1946, in triplicate on small plots.
[2] The results gives two average yields of hay (1945-46).
[3] Weeping lovegrass seeded broadcast in July, 1944.
[4] This area was cleared of scrubby oak in 1934 and has been used for pasture or meadows.

Fertilization of Grass: The effect of fertilizers on growth of grass was tested at Guthrie in 1945 and 1946 (Table 15).

Although the data represent only two years, they indicate that fertilizer is needed for grass production on eroded soils in central Oklahoma before sufficient vegetation can be grown to control erosion. Certain kinds of fertilizers may also be profitable for native grass production even on virgin soils. Fertilization will assist in developing a mulch cover for erosion.

In earlier studies on severely sheet eroded soils at Guthrie, sweet clover lightly fertilized (*6*) also gave good results. Where the seed was planted in shallow furrows on the contour, a light application of rock phosphate and lime increased the yield of the second year's growth of the clover over three times. The yield was also increased by superphosphate. The higher production on the contour listed area definitely shows the value of moisture conservation. The full value of the fertilizer application is not obtained unless it is applied in combination with the best possible soil and water saving practices. The sweet clover reseeded and produced a good forage growth on the fertilized area for several years. When fertilizing, it sometimes may be desirable to make an application sufficient to take care of the plant needs for several years, instead of light applications annually.

Methods of seeding: If the land to be revegetated is seriously gullied (Figure 7) or sheet eroded, special treatment will be necessary. In some areas, it may be necessary to divert the runoff water from the original channels by installing low-cost contour furrows or ridges between and above the sources of the gullies. After runoff has been diverted, satisfactory results (Table 16) have then been obtained by installing vegetative barriers of brush and crop residue, plowing down the gully bank, (Figure 7) applying a light application of fertilizer and lime when needed, and introducing legumes. After the legumes are established, grasses may be introduced. Where such procedure was followed, the density of vegetation in treated

TABLE 16.—Density of Vegetation on Treated and Untreated Gullies; Guthrie, Oklahoma.

Treatment of Gullies	Percent Density of Vegetation		
	Perennial Grasses	Annual Weeds and Grasses	Total
Untreated	2.29	0.16	2.45
Treated[1]	5.95	2.04	7.99

[1] Gully banks plowed down, light applications of lime and superphosphate applied and sweet clover planted, which was followed the third year by a seed-hay planting of native grass.

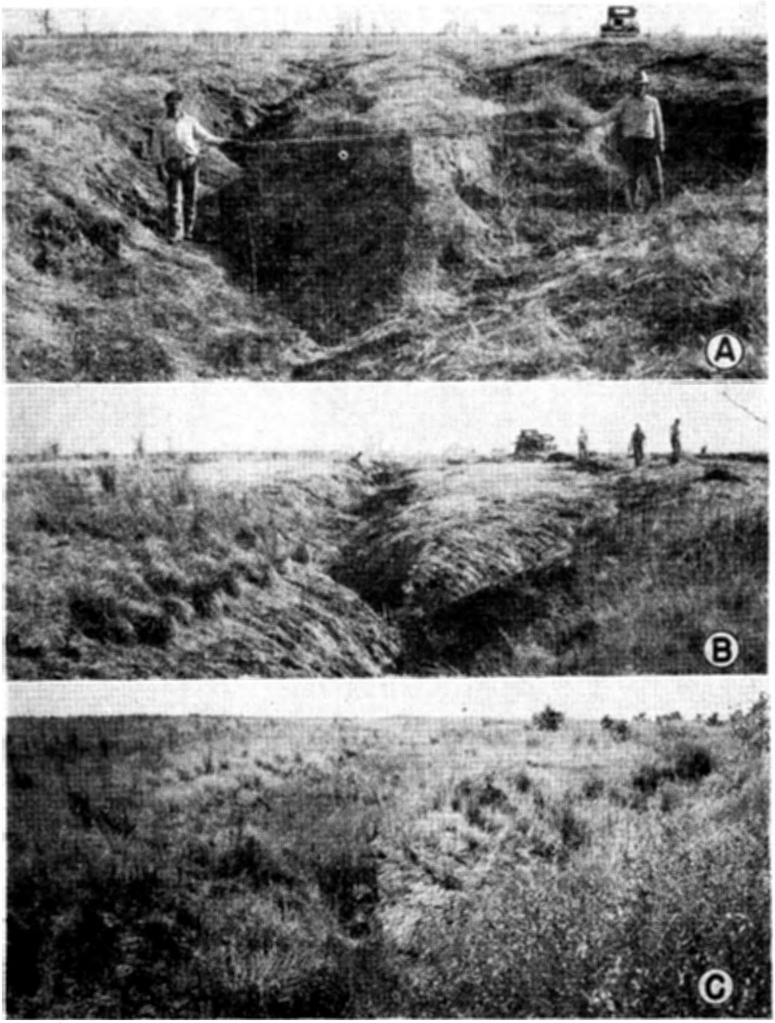

Fig. 7.—Gully Control.

These gully control studies are being conducted on the Red Plains Conservation Experiment Station. (A) A gully before the banks were sloped and prepared for vegetation. (B) The same gully after the banks had been sloped and prepared for constructing vegetative dams, planting legumes and applying a seed-hay mulch of native grass. (C) The same gully two years after the establishment of sweet clover and other vegetation. The results in Table 17 show that the density of the vegetation in the treated gullies was over three times greater than in the untreated.

gullies was over three times greater than in untreated ones (Figure 7).

Introduced Grasses—Bermuda grass and other introduced grasses do quite well on medium to high fertility soils in the more humid areas. But revegetation can be greatly accelerated by the use of legumes and light applications of lime and mineral fertilizer. Results from field trials in the soil conservation districts show that proper fertilization and pasture treatment have doubled (*20*) and, in some cases, increased up to four times the yields of pastures in eastern Oklahoma. One of the most common methods of establishing Bermuda grass is the planting of root sprigs or sod, but it has been seeded in soil conservation districts in the extreme southeastern part of Oklahoma (*17*). Other grasses, however, are giving good results and, if found desirable, may also be established.

Native Grasses—Due to the arid conditions prevailing in much of central and western Oklahoma, native grass in general seems to be best adapted to this area. There are several methods of establishing native grasses, but satisfactory results have been obtained by applying mulches of mature hay containing seed or planting in a dead stubble.

Seed-hay Method—The seed-hay method has produced better stands and sods than other methods of seeding native grasses on badly eroded land (Table 17). This method of seeding produced a density of grass which was 2.5 times as great as that

TABLE 17.—Effect of Different Methods of Seeding on the Density of Little Bluestem Grass.

Method of Seeding[2]	Density of Stand[1]
	Percent
Seed-hay[3]	9.56
Threshed seed	3.43
Virgin native grass[4]	7.61

[1] Determined by line transect method the third year after seeding.
[2] Amount of seed applied per acre was the same for both methods.
[3] The hay and other mulch used amount to 1500 pounds per acre.
[4] Includes all palatable perennial native grasses.

from threshed seed. By the end of the second growing season, the density on the seed-hay area was about the same as that of virgin native grass. Although the seed-hay method of regrassing land is proving to be very satisfactory, (Figure 8) it is probably best adapted for severely eroded and gullied land and for seeding bare areas in pastures. Usually 1,500 to 2,000 pounds of hay per acre will give satisfactory results.

Fig. 8.—Seed-Hay.

The seed-hay method of regrassing land adds organic matter and seed to bare soil between tufts of native grass. This retards ercsion and thereby accelerates the process of plant succession.

Stubble and Hay Method—The most consistently successful method to use in regrassing cultivated lands in the drier portion of Oklahoma (*13*) consists of drilling a mixture of adapted grasses, principally native species in the spring, in the protective stubble and hay residue left by a previous crop of cane (sorgo), Sudan grass or other sorghum. June is usually the safest month to drill the preparatory crop and insure maximum production. Earlier plantings are necessary, however, in chinch bug infested areas; and later plantings are desirable elsewhere when moisture conditions are favorable. Whenever the cover crop begins to produce seed stalks, it should be mowed at a stubble height of about 6 to 10 inches and most of the hay left on the land to insure maximum protection to the seedbed the following spring. If the cover crop is allowed to mature seed, it often volunteers the following year and competes seriously with the grass seedlings for moisture and plant food.

The second most successful method consists of drilling the grasses in a high, dense stubble of cane, Sudan or sorghum from which the hay has been removed. This method provides less protection to the seedling grasses but affords some return from the preparatory crop. It is, therefore, a practical and satisfactory method to use on special sites where soil blowing is less serious or where the slope of the land is such that severe washing is not a problem.

Management after revegetation: After the grass has been established, the most logical approach for improving and conserving it is intelligent management. Fall and winter mowing of poor stands develops a mulch, saves seed which otherwise would blow away, supplies organic matter, and affords protection to the young seedlings. Spring mowing for weed control has also been quite beneficial in maintaining a good stand. An ideal period for this mowing is about the time the weeds begin to bloom. Light to moderate grazing, depending upon moisture conditions, aids in increasing the stand on reclaimed eroded pastures. Adjustment of grazing periods to permit the grass to produce seed is also helpful in improving and maintaining a cover.

Pastures sometimes become sod bound and occasional light disking is beneficial. The yield of Bermuda grass hay was increased 22 percent (Table 18), and that of native grass 5

TABLE 18.—Yield of Hay from Cultivated Grass.[1]
(Pounds of Hay per Acre)

	Bermuda Grass	Native Grass[2]
Untreated	961	1922
Disked[3]	1172	2018
Increase in yield	211	96

[1] Average of 6 years of results, 1941-46.
[2] Mixture of little and big bluestem and Indian grass.
[3] Disked lightly every other year in March.

percent, by disking the sod lightly every other year in March at the Guthrie station.

Fire Prevention—Another essential management practice is fire prevention. A burned area lost an average of 27 times more soil and 32 times more water in runoff (Table 19) than

TABLE 19.—Effect of Burning Native Vegetation, Guthrie, Oklahoma.

Increased (16-year average)	
Soil loss	27 times
Water loss	32 times
Decreased (14-year average)	
Hay yields	45 percent

an adjacent undisturbed woodland area during a 16-year period at the Guthrie station. Continuous burning of native grass has also decreased the production of hay 45 percent.

Fire destroys plant seeds and the valuable layer of litter and organic matter underneath the grass. Fire also releases into the air the nitrogen (*12*) contained in the vegetation which is burned. Because the amount of vegetation varies, the exact quantity of nitrogen lost by the soil when a particular area burns is difficult to calculate. To get a general idea, however, the amount of nitrogen in 2,000 pounds of forage, based on the analysis of a large number of grasses in Oklahoma, would be about 17 pounds per acre.

Row cultivation for grass production: The effect of row cultivation on seed and hay production of grass has been studied at the Guthrie station since 1939. The results are given in Table 20. In general, the broadcast areas have produced the

TABLE 20.—Effect of Cultivation on Seed and Hay Production of Grass; Guthrie, Oklahoma.[1]

Method of Planting	Weeping Lovegrass	Little Bluestem	Side-oats Grama	Average
Hay Yield (Pounds per Acre)[2]				
Broadcast	5009	2417	1195	2874
21-in. rows	4535	2658	953	2751
42-in. rows	4250	2329	816	2465
Seed Yield (Pounds per Acre)[3]				
Broadcast	57	30	27	38
21-in. rows	50	89	55	65
42-in. rows	66	113	49	76

[1] All row plantings were cultivated twice with sweeps during the growing season.
[2] Average of 6 years
[3] Average of 5 years.

most hay and the row plantings the most seed. In fact, the 42-inch rows produced an average of two times more seed than the broadcast strips. The quality of the seed produced was also considerably higher. From these results, it appears that light row cultivation might be beneficial for grass seed production.

Removing Woody Vegetation

In addition to the idle, eroded and abandoned land, Oklahoma has a large acreage of mixed native grass and scrubby, woody vegetation (Figure 9). Much of the land of this type is being only partially used. The grass is too sparse for pasture and the timber is of little value except occasionally for posts or fire wood. The use of such land can be improved, however, by removing the trees and brush. The success depends upon the kind of treatment and management it receives.

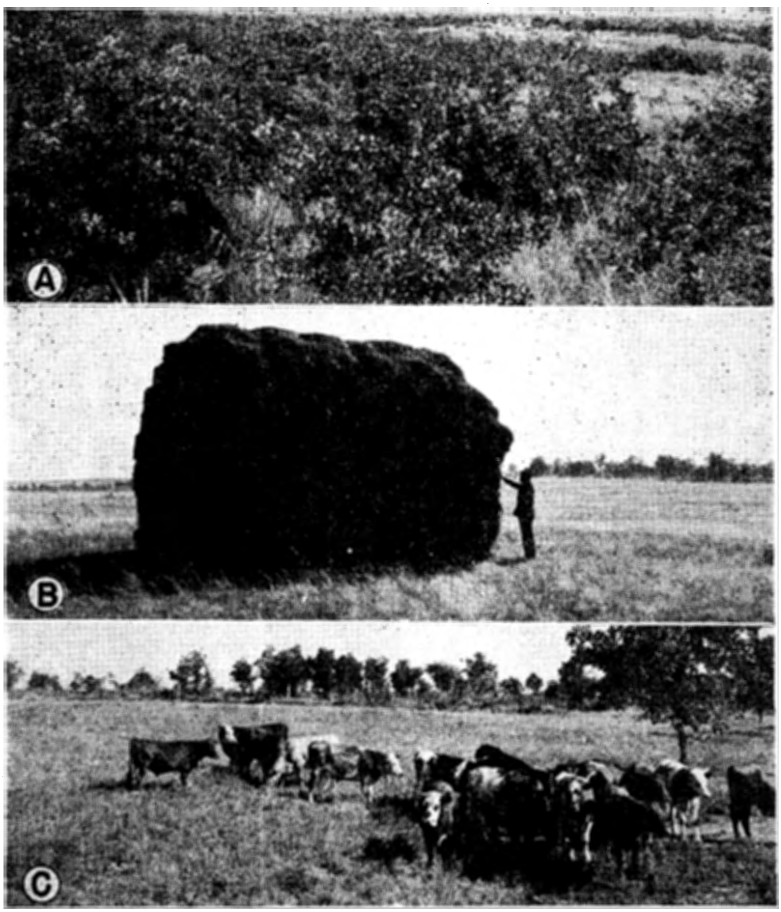

Fig. 9.—Pastures and Meadows Out of Brushland.

Development of pasture and meadow from brushy land is being studied at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma. (A) The original cover of black-jack and scrubby oak that blanketed the land. (B) After the trees and brush were removed the grass soon spread and within three years developed a good cover. The first year after clearing, this land produced about one-half of a ton of hay per acre, the second slightly more, and the third about a ton. (C) Beginning with the third or fourth season after clearing this land may be used for pasture. The cattle harvest grass and produce beef and the grass protects the soil. The productive capacity of these pastures and meadows was increased about five times by this type of development and management.

TABLE 21.—Effect of Shade from Scrubby Oak Trees and Brush on Native Grass Production.

Percent of Land Shaded	Grass Densities[1] (Percent)
None[2]	15.5
20	12.0
60	6.3
90	3.0

[1] Determined by line transect method.
[2] Fully cleared virgin land.

Effect on grass production: Surveys (Table 21) show that grass production was definitely limited by shade from trees and brush. The average yield of grass on fully cleared virgin land was five times that found on land 90 percent shaded.

The original grass cover is more dense on gently sloping soil where small amounts of shade from woody vegetation exist. Therefore, full grass production will be obtained more rapidly and erosion more completely controlled if clearing is limited to areas having only light or medium brush cover. In tests at Guthrie, the grass soon spread after the trees were removed (Figure 9), and within three years the stand of grass was equal to that of virgin meadow. Blackjack and white oak sprouts have been controlled by spring mowing. Those remaining (Table 22) after several years of mowing are largely running

TABLE 22.—Percentage of Original Oak Sprouts Remaining on the Land After Clearing and Spring Mowing; Guthrie, Oklahoma.

Number of Years Mowed[1]	Percent Remaining in 1945
10	8.5
8	11.1
2	44.7
Unmowed	58.3

[1] Light density brush before clearing (approximately 22,200 shrubs per acre, 2 inches or less in diameter at 1 foot above ground level).

oak. Consistent annual mowing gradually reduces sprout growth, and after 10 years the small quantity left offers little competition to the grass.

During August of 1943, another woodland pasture was cleared on the Guthrie station. The density of the brush and trees was determined before clearing operations began. The sprouts on this area were mowed in May each year. This method of mowing has controlled sprout growth sufficiently to allow a good stand of native grass to develop. In addition this pasture produced an average of 63 pounds of beef per acre (Table 23) during 120 days of summer grazing.

TABLE 23.—Use of Shallow Soil for Livestock Production, Guthrie, Oklahoma.[1]

Kind of Soil	Beef Produced per Acre (Pounds)	Yield of Hay per Acre (Tons)
Regrassed, eroded	40	.60
Cleared virgin	63	1.00
Regrassed, cultivated	43	

[1] Three-year average 1944-46.

Machines for removing trees and brush: Due to the possibilities of better land use created by removing scrubby trees and brush from pastures or grassland, several kinds of machines have been designed for cutting such vegetation. Five kinds of machines have been tried at the Guthrie station. They are the power mowing machine, tractor saws, small portable saws, power brush beater, and brush buck rakes. All five give satisfactory results when used on material within the limits for which they are best suited. The requirements and uses of each type of machine are described in a publication by Cox (*4*).

Costs of land clearing depend upon several factors, studies at Guthrie show. Important among the factors affecting cost of clearing are skill of machine operators, density and type of growth, type of soil, and unevenness of soil surface. Much of the expense of removing brush and trees can be offset by the increase in grass production. The immediate cost can also be reduced if the larger trees are used or sold for posts, firewood, or other use.

Chemicals for brush control: Studies of chemicals for brush control were started in 1945, and only preliminary information has been obtained as yet (*11*). Among the chemicals being tried at the Guthrie station are Ammate (ammonium sulfamate) and 2,4-D (dichlorophenoxyacetic acid). Results of these studies will be reported as soon as definite recommendations can be made.

Beef Production on Regrassed and Cleared Land

Much of the establishment and improvement of pastures on unused land is practical for the average landowner or occupier. Pastures on idle, eroded or scrubby woodland may be maintained by keeping out fires, conservative use, and eliminating undesirable species with the mowing machine. These practices will assist in the development of a mulch cover for erosion and flood control. Thus, through proper management, much of the shallow scrubby oak and unused land (Table 23) can be converted into useful pastures and meadows, and if grazed conservatively, satisfactory returns obtained. During the last three years, summer grazing experiments with yearling steers on eroded land at the Guthrie station (Figure 9) produced an average of 40 pounds of beef per acre, while that for the cleared virgin land was 63 pounds. The amount of beef obtained compared favorably to that produced on the range land of the area. Livestock makes grassland and other forage crops useful and restores to the soil some of the life-giving elements used by growing plants. Soil conservation and balanced farming are being accompanied logically and profitably by sound development of the livestock industry.

The yield and quantity of hay was also much higher on the virgin land than on the eroded areas.

LITERATURE CITED

1. Ackerman, F. G. and Ebersole, J. C., "Prerequisites of a Sweep Stubble-Mulch Tillage Implement for the Southern High Plains." *Amer. Soc. Agr. Eng.* 26:249-250, 1945.
2. Cox, Maurice B., *Tests On Vegetated Waterways.* Okla. Exp. Sta. Tech. Bul. T-15, 1942.
3. Cox, Maurice B. and Palmer, Vernon J., *Results of Tests on Vegetated Waterways* (In process of publication as Okla. Exp. Sta. Tech. Bul.)
4. Cox, Maurice B., *Brush and Tree Removing Machines.* Okla. Agr. Exp. Sta. Bul. 1947. Okla. Exp. Sta. Bul. B-310, 1947.
5. Cox, Maurice B., "Mulch Culture Tillage and Draft Requirements for Tillage Machinery." *Amer. Soc. Agr. Eng.* 25:175-176, 1944.
6. Daniel, Harley A., Elwell, Harry M. and Cox, Maurice B., *Investigations in Erosion Control and Reclamation of Eroded Land at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma*: 1930-40. U.S.D.A. Tech. Bul. 837, 1943.
7. Daniel, Harley A. and Finnell, H. H., *Climatic Conditions and Suggested Cropping Systems for Northwestern Oklahoma.* Okla.. Agr. Exp. Sta. Cir. 83, 1939.
8. Daniel, Harley A., Elwell, Harry M. and Murphy, H. F., *Conservation and Better Land Use for Oklahoma.* Okla. Agr. Exp. Sta. Bul. B-257, 1942.
9. Duley, F. L. and Russel, J. C., "Machinery Requirements for Farming Through Crop Residues." *Amer. Soc. Agr. Eng.* Vol. 23, No. 2, February 1942.
10. Elwell, Harry M., "Vegetation for Water Channels." *Oklahoma Crops and Soils*, 1947. Ms. in preparation for Okla. Agr. Exp. Sta. Bul. (1947).
11. Elwell, Harry M., "Preliminary Report of Chemicals for Brush Control." *Oklahoma Crops and Soils*, 1947. Ms. in preparation for Okla. Agr. Exp. Sta. Bul. (1947).
12. Elwell, Harry M., Daniel, Harley A. and Fenton, F. A., *The Effects of Burning Pasture and Woodland Vegetation.* Okla. Agr. Exp. Sta. Bul. B-247, 1941.
13. Finnell, H. H., *Review of Revegetation Work in the Southern Great Plains.* The Revegetation And Stubble Mulch Sub-committee of the Southern Great Plains Agricultural Council, Amarillo, Texas, January 10, 1945.
14. Hackinsmith, R. D. and Steele, J. G., *Classifying Land for Conservation Farming.* U.S.D.A. Farmers Bul. 1853, 1943.
15. Mueller, Irene M. and Weaver, J. E., "Relative Drought Resistance of Seedlings of Dominant Prairie Grasses." *Ecology*, October 1942, Vol. 23, Pages 387-398.
16. Orban, C. L., *Proceedings for Making Utilization of Soil Conservation Survey* 6, July 5, 1943.
17. Sittle, Clarence W., *Establishing Bermuda Grass From Seed.* Okla. Agr. Exp. Sta. Bul. B-295, Pages 85-90, 1946.
18. Staten, Hi W. and Elwell, Harry M., *Weeping Lovegrass in Oklahoma.* Okla. Agr. Exp. Sta. Bul. 281, 1944.
19. State Committee, *Looking Forward in Oklahoma Agriculture.* Okla. Agr. Exp. Sta. Bul. B-299, 1946.
20. Tucker, E. A., "Simple Conservation Practices are Weapons of War." *Okla. Current Farm Economics*, Vol. 15, No. 6, December 1942.