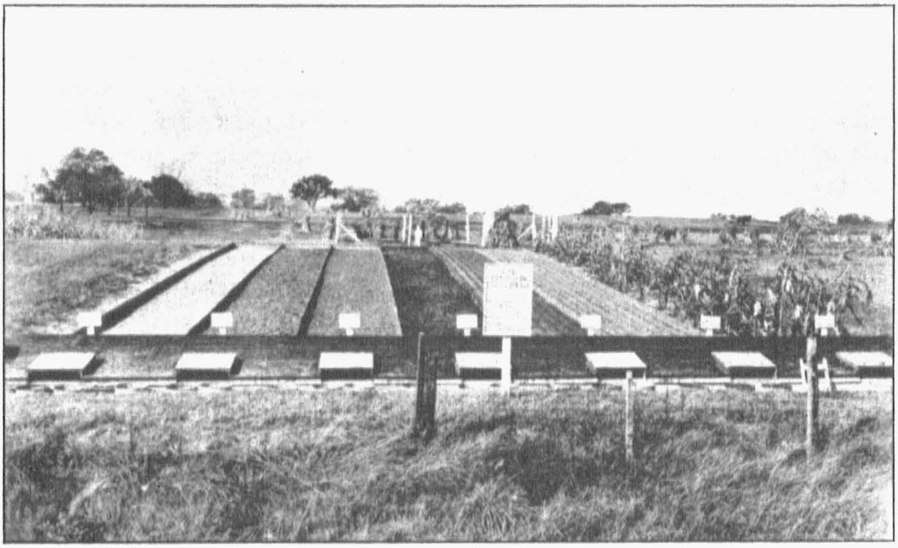
# CROPPING SYSTEMS
# for Soil Conservation

By DWIGHT D. SMITH, DARNELL M. WHITT and MERRITT F. MILLER



The first plots for the study and measurement of erosion as affected by cropping at the Missouri Agricultural Experiment Station dating from 1917.

**UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE**

**AGRICULTURAL EXPERIMENT STATION**

J. H. LONGWELL, *Director*

**SEPTEMBER, 1948 BULLETIN 518**

# Foreword

The pioneer study of soil erosion initiated thirty-five years ago at the University of Missouri by M. F. Miller and F. L. Duley demonstrated wide differences in the erosion of the soil growing different crops. While the crop was emphasized as mechanical cover, the effect on the soil in connection with it, that is, modifying the soil structure, was an outstanding result of their study. They demonstrated effects on the soil by red clover that reduced the erosion under the following corn crop far below that occurring under corn following corn. This early work showed that the crop was indirectly a factor in that it—along with the treatments of the soil for growing it—may modify the condition of the soil, which is the major factor in its erosion.

The recent emphasis on conservation in general, and on soil conservation in particular, is the delayed recognition of the great cardinal principle that, in nature, the many component parts are dependent one on the other and reinforce each other. According as the soils are deeper, more granular, and more fertile, they are less erosive. Their openness encourages infiltration of the water, and their stability of granulation resists dispersion by the falling rain and removal by the running water. These better soils grow more vegetation for more cover which in turn puts more organic matter into the soils to reduce erosion when they are delivering greater agricultural output.

However, such reinforcement of the crops by the soil and of the soil by the crops is not possible under cultivation unless provision of the necessary fertility and return to the soil of its own organic matter creations are parts of the soil management. The choice then of a particular cropping system for soil conservation is first, an opportunity to arrange for protective vegetative cover during the maximum time, and second, an opportunity to introduce the lime and other fertilizers for building up the organic matter in the soil. By such reinforcement of nature, the body of the soil will be strengthened to make it more able to save itself from erosion. At the same time the economics of production will be improved. Whatever the cropping system, its service in soil conservation will depend much on what we help it do through the effects on the soil itself.

The research in soil conservation going forward cooperatively between the Missouri Agricultural Experiment Station, and the Soil Conservation Service Research, U. S. D. A., has given the opportunity to study many cropping systems, the condition of the soil under them, and the measured erosion resulting from each. The data from these studies on two major soil areas in Missouri, going back for almost twenty years, have been the bases for the experiences and recommendations reported in this publication

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# CROPPING SYSTEMS for Soil Conservation

By DWIGHT D. SMITH,[1] DARNELL M. WHITT[2] and MERRITT F. MILLER[3]

Three acres of cropland are now considered necessary to provide each American with an adequate diet and clothing. Today that amount is available, but our population continues to increase. Only small additions can be made to our crop area by drainage, irrigation, and clearing. Lands that have been subjected to wastage through erosion under outmoded methods of farming must continue to produce. Conservation farming methods must be applied to these areas to increase their fertility and physical capacities for greater production.

Agricultural research has developed methods of conservation farming that will prevent destructive erosion and permit the economical maintenance of soil productivity. Widespread application of these methods would make possible a greater total agricultural production. The benefits of improved soil treatments or better crop varieties would then be used for increasing the production instead of merely offsetting the loss of it resulting from accelerated erosion. The upland farmer would no longer be compelled to increase his crop acres periodically to maintain a given level of production of grain or livestock.

## LOSS OF SURFACE SOIL REDUCES CROP YIELDS

Declining production accompanies excessive erosion simply because the subsoil does not have the fertility and physical conditions to produce high crop yields. Corn yields have been secured for different depths of surface soil on three soils in Missouri. They show a decrease of 4 bushels in yield per acre, as an average, for the loss of an inch of surface soil. Average acre yields for different depths of surface soil are shown in Figure 1. With soybeans, the decrease in yield averaged 1.6 bushels per inch of surface soil lost. Similar declines in yield were observed with small grain and hay. Recent research has shown that production losses would be appreciably greater if quality, or the value of the products as feed in animal growth, were considered, along with the yield in bushels per acre.

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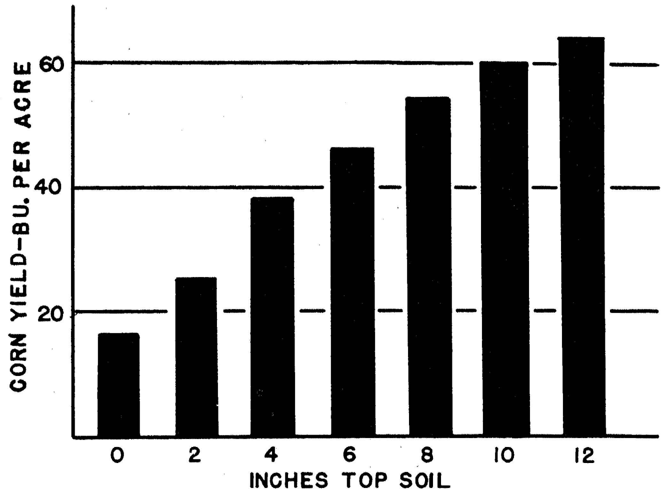


Figure 1.—Effect of depth of surface soil on yield of corn. Averages for Shelby, Grundy and Putnam soils, 1940-44.

## EROSION CAN BE CONTROLLED

The most effective and practical means of erosion control yet developed for growing cultivated crops consist of a combination water and crop-soil management system. The water management phase commonly includes terracing, contour farming, sod outlet channels, and main drainageway control with structures and grass. The crop-soil management phase includes cropping systems and soil fertility treatments. The cropping systems are combinations of the cultivated crops with small grains, legumes, and grasses. These crops are arranged in sequences that provide a maximum of soil cover and also condition the soil to resist erosion under the cultivated crop. Soil fertility treatments that will enable crops to grow vigorously for erosion control and to produce high acre yields are an essential part of this phase.

The problems of erosion control found in the Shelby soil area of Northwest Missouri are typical of most areas in which erosion is a menace. The slopes are moderately steep, the subsoil moderately tight, and the natural fertility moderately high. Some of the earliest research on erosion control was carried out on this soil. From data secured by these studies, it is possible to show how effective the conservation practices may be, both individually and in combination. Some of these effects are shown in Figure 2.

The old straight-row method of cropping, with corn year after year or with corn and oats in alternate years, has resulted in extremely high rates of erosion. These erosion losses progress so rapidly on the field of average Shelby soil that the plow layer of surface soil is washed away in 10 to 20 years. By adding a year of grass and legume mixture to the corn and oats combination, the life of the plow layer is more than trebled by being extended to 50 or 60 years. Contour farming reduces soil loss and extends the life of this layer still further. Only by combining several practices—a soil conserving rotation with adequate soil treatments, contour farming, and terracing—has it been

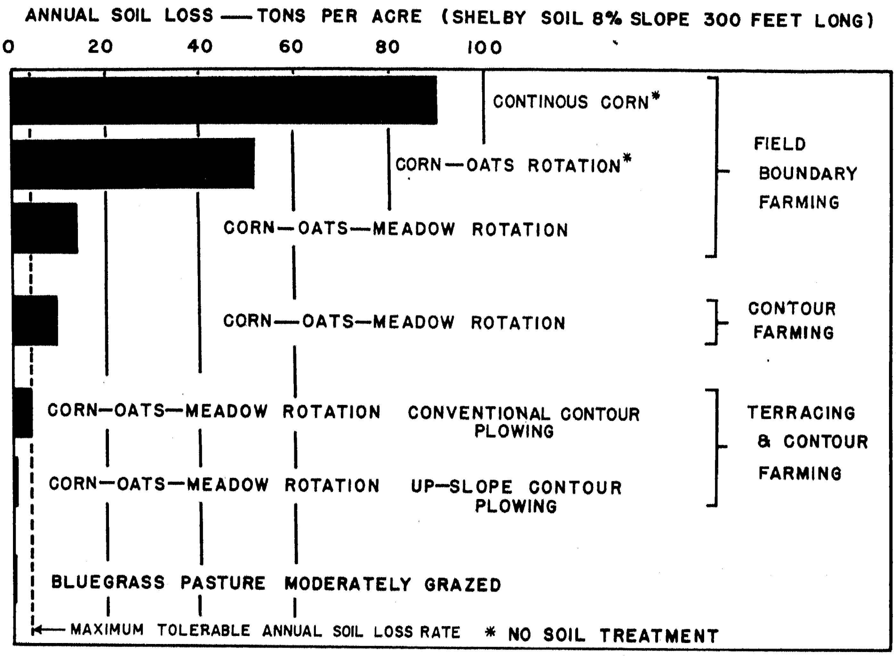


Figure 2.—Effect of the conservation practices on erosion. Shelby soil of average slopes.

possible to reduce the annual soil loss to a tolerable amount. Research studies have shown that 4 tons per acre annually is the maximum tolerable rate of soil loss on the Shelby. If this is not exceeded, the fertility level can be maintained economically. On some soils of the state the maximum tolerable rate is only 2 tons.

This publication deals with the crop-soil phase of soil conservation for the growing of grain and row crops on sloping land suitable for cultivation. It is intended as a guide for the selection and safe use of such cropping systems when they are a required part of a balanced farming plan. In general, the suggestions are applicable to soils of Classes I, II, III, and IV.

CLASS I. Superior crop land. High fertility. No special erosion or other management problems. Grows legumes without soil treatment.

CLASS II. Good crop land. Suitable for intertilled crops, but usually requires some soil treatment, protection from erosion, or both, to maintain productivity.

CLASS III. Average crop land. Less desirable than Class II land, especially for intertilled crops, because of lower fertility, more erosion, or some unfavorable soil feature. Requires regular fertility treatment or erosion control, or both, to maintain productivity.

CLASS IV. Inferior crop land. Too low in fertility or too susceptible to erosion, or both, for intertilled crops or frequent cultivation. Suited best to small grain, legume and grass rotations.

## CROPPING METHODS CAN REDUCE EROSION

Observations by farmers led to the conclusion many years ago that relatively large amounts of soil are washed from the field when it is in row crops. Likewise, the value of sod was appreciated in the early days when virgin land was available on which to extend the corn acreage. Only within the last 30 years, however, have controlled measurements been made to study these various erosion losses. Missouri has been intensely interested in this problem, and studies have been made at three locations within the state.

**Investigations.**—The Missouri Agricultural Experiment Station began a series of studies in 1917 to determine the influence of cropping systems on soil erosion losses. Later, in 1930, investigations on erosion control were started on steeper land at Bethany. These later studies were carried out jointly by the Missouri Agricultural Experiment Station and the United States Department of Agriculture. Both of these investigations confirmed the observation that crops vary widely in their influence upon erosion, and measured their relative effectiveness in reducing soil losses. Generally speaking, the clean-tilled crops, such as corn and soybeans, were least effective in controlling soil erosion and the sod crops were most effective.

Comparative losses of soil from continuous corn, from a good crop rotation, and from continuous grass are shown in Figure 3. Soil loss from bluegrass was almost zero. Erosion was reduced more than 80 per cent at both locations by using a rotation instead of continuous corn.

There are two principal reasons for the very effective reduction of erosion by crops in the rotation. One is the soil cover. Under continuous corn the land is bare almost the year round. In the rotation it is covered almost the year round. The sod preceding the corn is not plowed until early April, and wheat follows the corn in October. Again, instead of wheat alone occupying the land for the wheat years, grass and clover are seeded in the wheat. After harvest the grass and clover growing in the wheat stubble reduce erosion materially. The

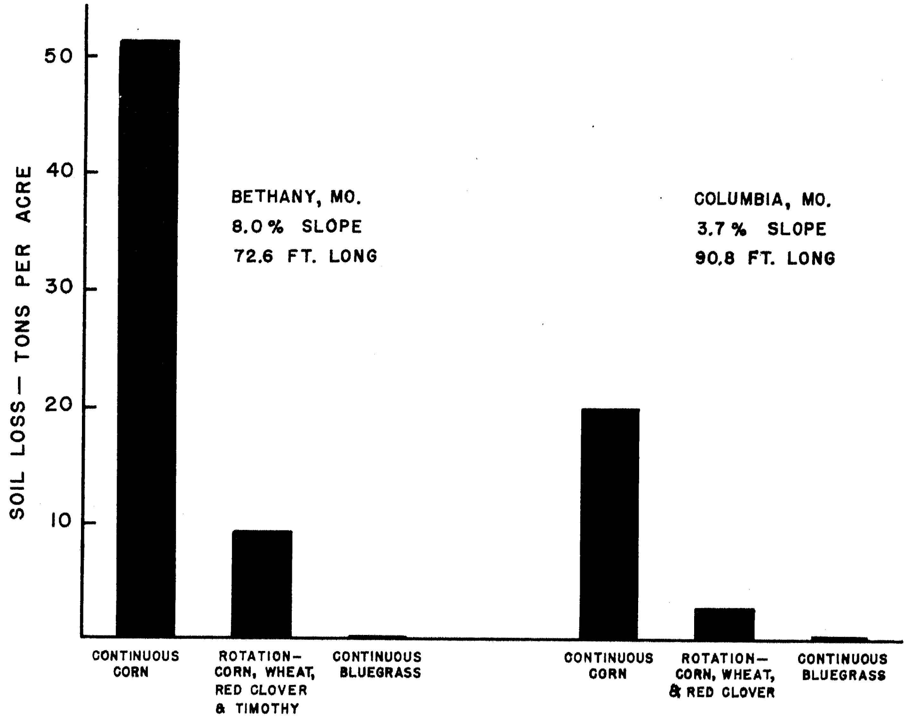


Figure 3.—Effect of cropping system and slope on erosion.

grass and clover crops then occupy the land through a full year following and until the time of spring plowing for corn.

The other principal reason for effective reduction of erosion by the rotation lies in the fact that soil loss is reduced while the cultivated crop is growing. In other words, land in corn which follows grass and clover loses considerably less soil than land in corn following corn. This reduction can be attributed to the beneficial effects of a grass-legume sod in conditioning the soil to resist erosion.

A more comprehensive investigation of the effects on soil erosion by the crop and the crop rotation was started at the Missouri Soil Conservation Experiment Farm near McCredie in 1940. This work is carried on cooperatively by the Soil Conservation Service Research, U. S. Department of Agriculture, and the Missouri Agricultural Experiment Station. The soil is rolling Putnam silt loam. It is medium to low in fertility, and water passes down through it very slowly. Here most of the common upland crops in Missouri are being studied in numerous combinations or crop sequences. The equipment used in these studies for measuring runoff and soil loss is shown in Figure 4. From these detailed studies it has been possible to determine which

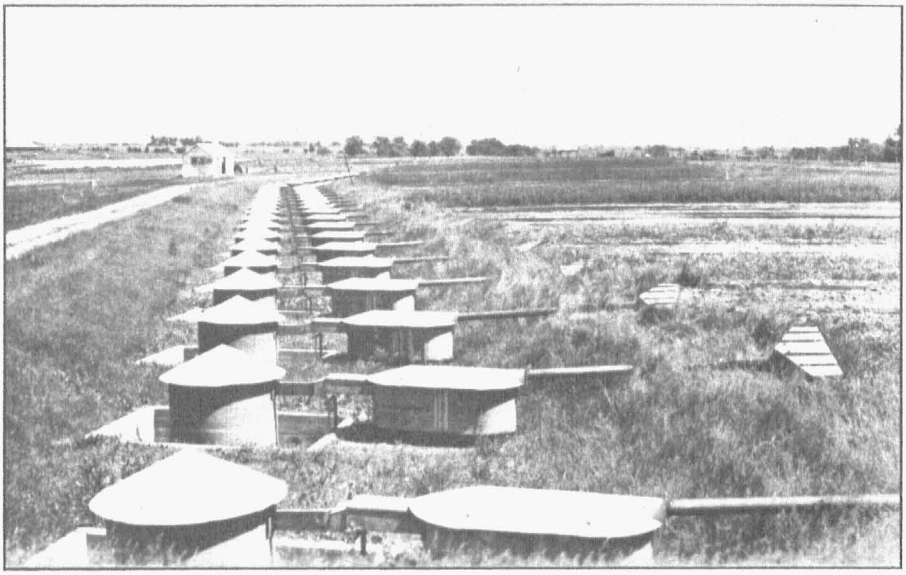

Figure 4.—Equipment used to measure runoff and soil loss from different crops and cropping systems on the Missouri Soil Conservation Experiment Farm at McCredie.

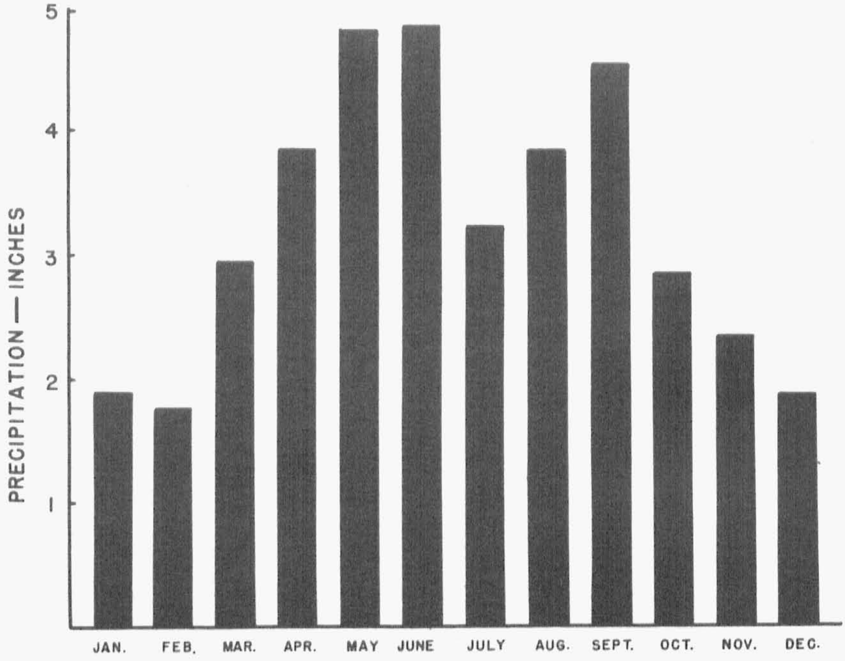


Figure 5.—Average monthly rainfall at Columbia, Missouri. Mean annual rainfall (1890-1947) 38.85 inches.

crops should precede and follow the intertilled crops for least erosion.

**Rainfall is a Factor.**—In planning any cropping system it is important to consider the amount of erosion that is likely to take place each month of the year. One should plan the cropping systems, in so far as possible, so that the land is covered with a thick growing crop during those months when erosion is likely to be greatest. Naturally, the amount of erosion depends primarily upon the amount of torrential rainfall. In this section of the country the number of torrential rains is greatest in those months with the greatest amount of total rainfall. The 58-year average rainfall by months for Columbia is shown in Figure 5. Each of the months from April through September, on the average, has more than three inches of rain. In these same months ninety percent of the torrential rains for the year occur. It is imperative, therefore, that the land be left bare as little as possible during these months. If the cropping system calls for a cultivated crop during the summer, the soil should be conditioned to resist erosion during this period.

## FERTILITY IS BASIC

High yields and erosion control go hand-in-hand. Higher fertility means more vigorous crop growth. More vigorous plants provide better cover and produce higher yields. A comparison of soil loss under wheat and oats, both with and without fertilizer, in Figure 6, illustrates this fact. Soil loss from land in wheat was cut almost in half, while the loss from oats was cut more than half as a result of the increased cover secured by the higher fertility from the use of 200 pounds of fertilizer per acre. At the same time, the wheat yield was increased 91 per cent and oat yield 77 per cent, as the average over a 7-year period, by the use of this treatment. The effect of a 10-20-20 fertilizer on the early growth of oats on Putnam soil is shown in Figure 7.

Studies at the McCredie experiment farm demonstrate the value of high fertility for sod crops. Abundant fertility not only increases the yield of hay or pasture, but also gives the improved residual effects of the sod which reduce the soil losses from the intertilled crop which follows. Some soils of the state will require little fertilizer to produce high acre yields, while others will benefit from large amounts of soil treatment. The rolling Putnam silt loam, on which the McCredie studies are made, is medium to low in natural fertility. It requires substantial additions of fertilizer and lime to produce vigorous crops. On plots which received 200 pounds of 0-20-10 fertilizer per acre, with wheat, the grass and legume mixture grew well for only two years. The 200-pound application was not enough to carry the mixture

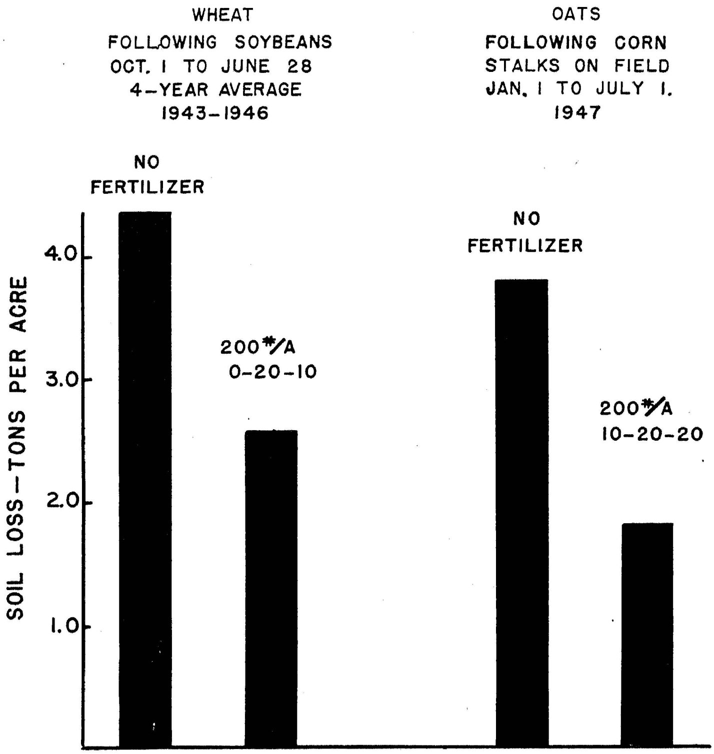


Figure 6.—Effect of fertilizer on erosion under small grain. Missouri Soil Conservation Experiment Farm, McCredie.

through four years. As a result, soil loss under corn following four years of this sod was greater than that under corn following one or two years of it. If larger soil treatments had been given, according to the fertility needed to produce good crops of corn and small grain, the residual effects of the fertilizer on the last two years of sod would doubtless have overcome this condition and carried its benefits into the corn year of the next round of the rotation.

A discussion of the economics of fertilizer use is beyond the scope of this publication. However, it has been proved that the lime and other fertilizers required to produce high acre yields also reduce erosion through stimulation of the growth of crops. Missouri soils are too variable to suggest blanket soil treatments. Many counties of the state now have soil testing laboratories. The county extension agent can give advice regarding tests of soil for its fertility needs. Reliance should not be placed on old rule-of-thumb methods of using fertilizer. Bring the results of experimentation to bear on the problems encountered in producing high yields and conserving the soils.

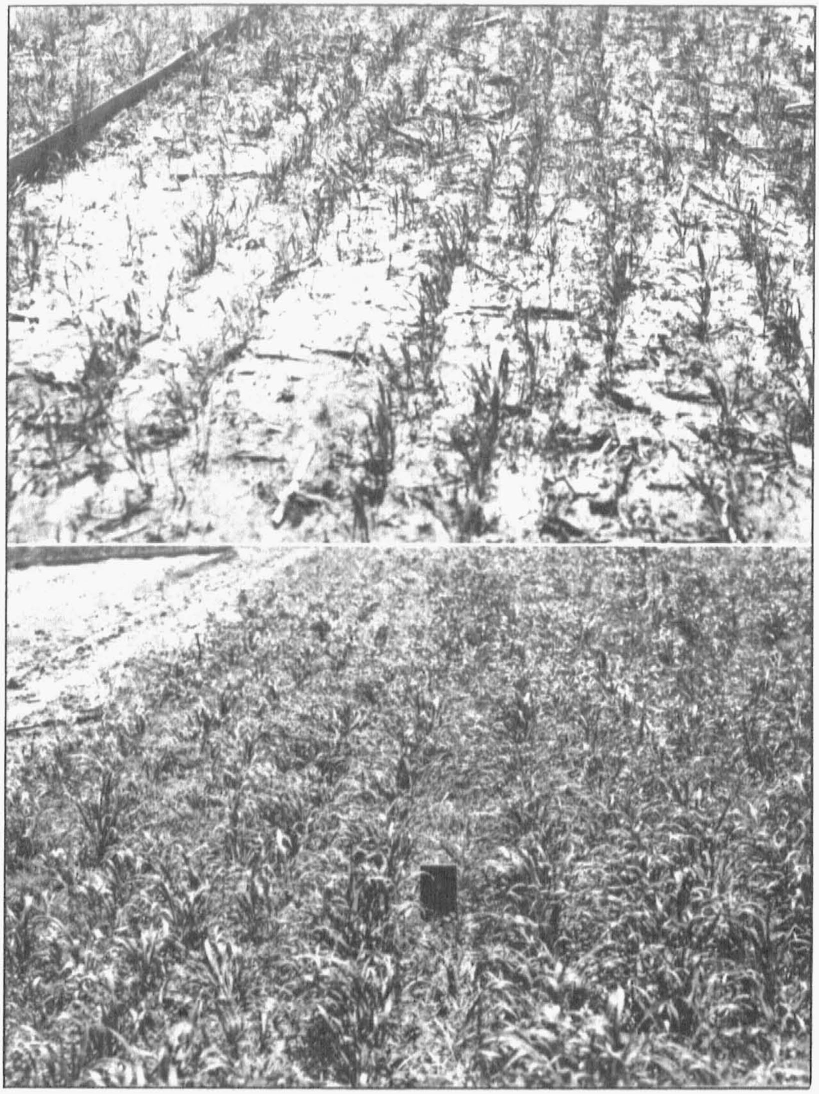

Figure 7.—The oats crop on the Putnam soil requires fertilizer for high yields and erosion control. Above: Oats in a 2-year rotation with corn, but without soil treatment. Below: Same basic rotation as above but with lime and with sweet clover as green manure crop before the corn, and with 200 pounds of 10-20-20 fertilizer per acre on the oats and corn. Missouri Soil Conservation Experiment Farm, McCredie.

## COVER PROVIDES PROTECTION

It is common knowledge that land growing perennial grasses with legumes loses small amounts of soil. Demands for other products, however, make it impossible to seed all land to pasture or meadow. Some must be in cultivated crops. We need corn, soybeans, and small grains to provide a balance of production on the farm. But these crops, too, may be grown without excessive erosion. To do so requires care in placing crops in a particular sequence in a rotation. Also, in many cases, contour farming and terraces are needed. Attention was called earlier to one way that rotations function to reduce erosion, namely, by keeping the soil covered a greater part of the time by close-growing sod crops. In a three-year rotation of corn, wheat, clover and timothy mixture the soil is covered by the sod crops 22 months out of 36. The soil is open under an intertilled crop only 5½ months of the total time.

In well designed rotations the seeding of a new crop quickly follows the harvest of the preceding one. Thus, the length of time the land remains bare between two crops is reduced to a minimum. In some rotations improvement may require a change of crops. For example, a change from oats to a fall seeded small grain reduces the time the land lies bare by about 5 months. Where the situation does not permit a change in the basic crops of the rotation, a cover crop to serve as green manure may be seeded to close the gap between the crops to be harvested. This is the case where soybeans or corn follow corn. Rye or barley may be drilled between the corn rows to provide cover over the fall, winter, and early spring. The cover crop may then be plowed under as green manure before the succeeding corn or soybeans. Another example is the case where small grain follows small grain. Lespedeza or sweet clover may be used to close this gap. Increased control of erosion should more than pay for any extra work involved.

Even though the fall and winter months are not high in rainfall, much can be done to reduce losses during this period by use of winter cover. Data from a study at the McCredie farm illustrate this point, as shown in Figure 8. Leaving land in corn stubble was the most erosive practice studied. Leaving corn stalks on the field reduced soil loss almost one-half. Drilling small grain in corn stubble reduced losses still further. And, erosion protection secured by combining the two, as shown in Figure 9—rye drilled between corn rows early in September and the corn stalks left on the field—will be almost as good as meadow stubble, during this period, according to observations and early results.

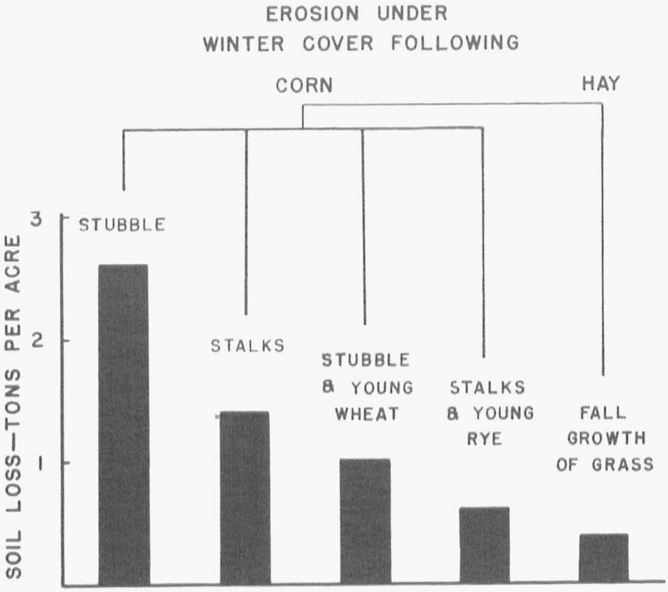


Figure 8.—Effect of cover on erosion after corn harvest on Sept. 29 to soybean seedbed preparation, May 9. Missouri Soil Conservation Experiment Farm, McCredie.

Figure 9.—Winter cover of rye and corn stalks between crops of corn and soybeans reduces erosion to ¼ of that from corn stubble. Missouri Soil Conservation Experiment Farm, McCredie.

Annual systems of small grain and lespedeza grown year after year provide almost continuous cover throughout the year. For this reason they are good erosion control cropping systems. They have given about the same degree of control as secured with a 3-year rotation of corn-small grain-grass and clover mixture. Seedbed preparation by use of a field cultivator or disk in the annual systems leaves a surface mulch of stubble. This mulch tends to accumulate when the systems are used year after year. If the soil is plowed in seedbed preparation, higher rates of erosion could be expected. Small grain-lespedeza does not form a sod in the same sense as a grass. Thus, when the field slope is long and uneven, appreciable quantities of runoff concentrate in depressions, causing numerous small washes or rills. Where the slope length is reduced by terraces, this does not occur.

It should be remembered in connection with soil cover that the total protection afforded is only as good as that provided in the most critical period of the rotation. Erosion control may be perfect while excellent sod covers the ground, but every effort must be made to see that the land is adequately protected when it goes to corn or soybeans. To secure this protection, conditioning of the soil is required. In many cases terraces and contour farming are also necessary.

## CONDITIONING THE SOIL FOR CONSERVATION

Grasses and deep rooted clover crops have been very effective in developing a stable soil structure and decreasing erosion under the cultivated crops which follow. This is illustrated in Figure 10. Experimental studies on the McCredie farm during the past 7 years have measured the soil conditioning qualities of 8 different crops. Soil losses under corn during the 5½-month period beginning with plowing in April, through seedbed preparation, planting, cultivating and maturing of the corn by the end of September, are shown in Figure 11.

When the corn crop was preceded by a grass and clover mixture in which the grass was growing vigorously at the time of plowing, the soil loss under the corn was reduced to one-fifth of that under corn following oats. Similarly, either sweet clover as meadow or sweet clover as green manure, preceding the corn, resulted in a reduction of the erosion under the corn by more than one-half. This same reduction was secured on the Shelby soil with a much steeper slope when corn followed a grass and clover mixture in contrast to that under corn year after year.

Erosion under corn the second year after sweet clover as green manure was two-thirds greater than under the corn which immediately followed the sweet clover. This second-year corn has always yielded less than the first-year corn. In 1947, 8 years after the experiments were begun, first-year corn produced 42 bushels per acre in comparison with only 22 bushels for second-year corn.

Results of soil conditioning for soybeans have been similar to those for corn. Soybeans following a grass and clover mixture have allowed about one-fourth as much erosion as soybeans following corn. Limited data indicate that beans in rows and cultivated the same as corn, will allow one-half more erosion than beans drilled solid. In general, this appears to be the principal advantage in favor of drilled

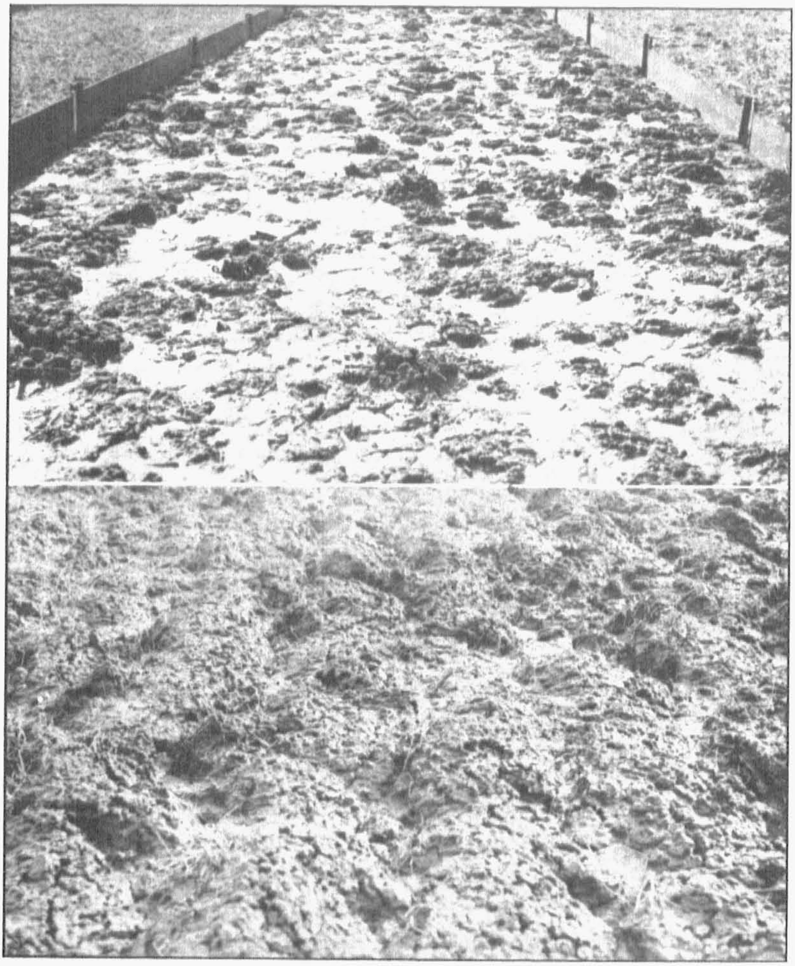

Figure 10.—A grass-legume sod produces a stable soil structure—a condition that resists erosion. Above: Fall plowed corn land on Shelby soil in the spring. Below: Same as above except grass-legume sod.—Soil Conservation Experiment Farm, Bethany.

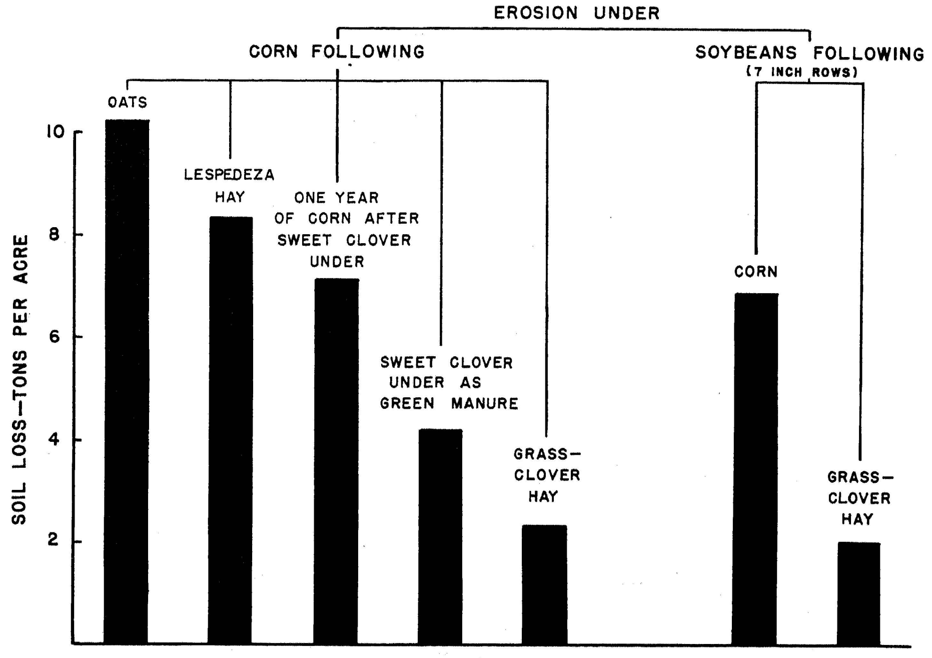


Figure 11.—Effect of preceding crop on erosion under corn and soybeans during the period April 27 to October 7. Missouri Soil Conservation Experiment Farm, McCredie.

beans. There is also the indication that beans grown in contour rows and cultivated would allow about the same erosion as corn grown similarly. When drilled solid, beans have allowed less erosion than corn. Regardless of the distance between bean rows, the important consideration is that they should follow soil conditioning crops, preferably grass and legume mixtures.

*For minimum erosion under rowed crops it is essential that a vigorous sod of grass and legumes immediately precede them.*

## COVER PLUS CONDITIONING

The 4-year rotation of corn-soybeans-small grain-hay has been a popular rotation in some sections. With the corn stalks removed, leaving the land bare until late the next spring and with lespedeza used as the hay crop, this rotation has permitted excessive soil loss. Data from sequence studies indicate that the erosion can be reduced one-half by adding cover and soil conditioning. This is accomplished without changing the basic crops of the rotation by drilling rye between the corn rows early in September, leaving the stalks on the field, and changing the lespedeza hay crop to a grass and legume mixture. Losses by crop periods within the rotation cycle for both systems are shown in Figure 12.

Changing the lespedeza hay crop to a grass and legume mixture adds soil conditioning and reduces the soil loss under corn during the spring and summer seasons from 8 to nearly 2 tons per acre. Leaving the corn stalks on the field and seeding rye (with fertilizer) between the corn rows early in the fall, reduces the erosion during the intervening period between corn and soybeans from 2 tons to one-half ton.

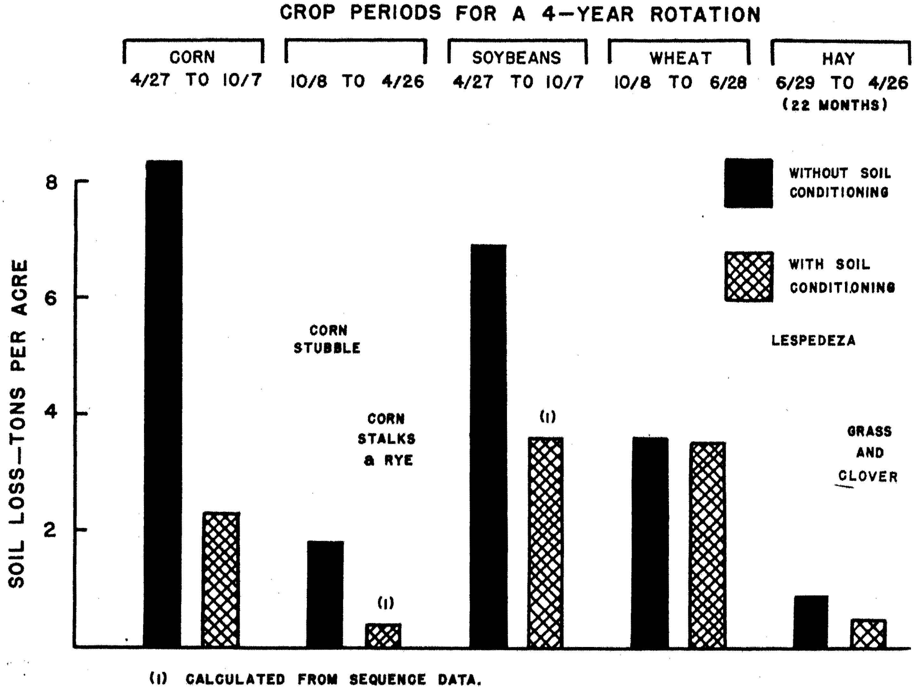


Figure 12.—Erosion losses by crop periods for a 4-year rotation without and with soil conditioning and maximum soil cover. Missouri Soil Conservation Experiment Farm, McCredie, Mo.

Plowing under the rye cover crop with the corn stalks adds a measure of reconditioning to the soil which reduces the loss under soybeans from 7 tons to 3½ tons. There is little difference in erosion under the wheat crops. The measured loss under a grass-clover mixture has been about one-half that under lespedeza, although both are very low.

Another example of what can be accomplished by combining crops into a rotation for maximum crop cover and soil conditioning is shown by the results from the 3-year rotation of soybeans(hay)-winter barley-grass and clover hay. Seeding of barley follows immediately after

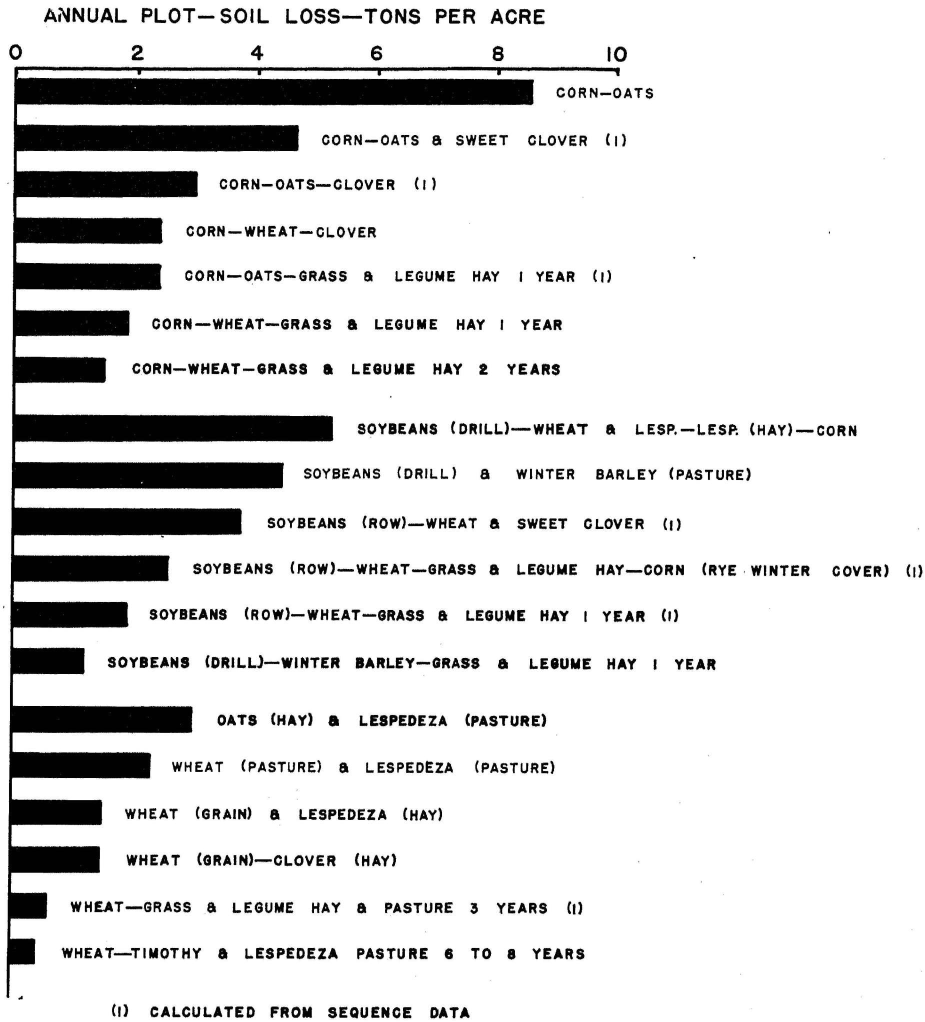


Figure 13.—Erosion under different rotations from small plots on rolling Putnam silt loam soil of 3% slope. Missouri Soil Conservation Experiment Farm, McCredie, Mo.

removal of the soybean crop. Grass and clover sod protects the soil after barley harvest for the next 22 months until it is plowed shortly before seeding the soybeans. The soil loss for this rotation has averaged only 1.2 tons per acre annually on small plots—equivalent to that for a 5-year rotation of corn-wheat-3 years of grass-clover mixture.

Soil losses to be expected from representative corn, soybean, small grain-lespedeza, and small grain-grass legume or lespedeza rotations are shown in Figure 13. The losses are those from small plots on a 3 per cent slope of rolling Putnam soil, with rows up and down slope. They are not the losses to be expected from field areas where the slopes are longer and often steeper.

## APPLICATION OF CROPPING SYSTEMS

A representative list of grain and row-crop systems, arranged in the order of increasing soil loss, is shown in Table 1. The first rotation in the table would allow a soil loss of about 0.4 ton per acre annually when grown up and down slope on a small Putnam silt loam plot, of 3 per cent slope, with a length equivalent to a terrace spacing. The soil losses for the succeeding rotations gradually increase in the order of the list. Rotation number 22 would allow nearly 12 times the soil loss of rotation number 1. The soil losses for these rotations are the results of actual measurements of the material washed from plots over a period of years.

TABLE 1.—REPRESENTATIVE CROPPING SYSTEMS FOR GROWING SMALL GRAIN AND ROW CROPS, ARRANGED IN ORDER OF INCREASING SOIL LOSS. (1)

| Number | Rotation |
|---|---|
| 1 | Fall grain—grass legume mixture 6 to 8 years |
| 2 | Fall grain—grass legume mixture 3 years |
| 3 | Fall grain—grass legume mixture 1 year |
| 4 | Row crop—fall grain—grass legume mixture 4 years |
| 5 | Row crop—spring grain—grass legume mixture 4 years |
| 6 | Fall grain—legume meadow 1 year |
| 7 | Row crop—fall grain—grass legume mixture 2 years |
| 8 | Row crop—fall grain—grass legume mixture 1 year |
| 9 | Row crop—spring grain—grass legume mixture 2 years |
| 10 | Row crop (winter cover)—row crop—fall grain—grass legume mixture 2 years |
| 11 | Fall grain, lespedeza |
| 12 | Row crop—row crop—fall grain—grass legume mixture 2 years |
| 13 | Row crop—spring grain—grass legume mixture 1 year |
| 14 | Row crop—fall grain—legume meadow 1 year |
| 15 | Row crop (winter cover)—row crop—fall grain—grass legume mixture 1 year |
| 16 | Row crop—spring grain, lespedeza—fall grain—grass legume mixture 1 year |
| 17 | Row crop—row crop—fall grain—grass legume mixture 1 year |
| 18 | Row crop—spring grain—legume meadow 1 year |
| 19 | Spring grain, lespedeza |
| 20 | Row crop—fall grain (sweet clover under) |
| 21 | Fall grain, soybeans |
| 22 | Row crop—spring grain (sweet clover under) |

(1) Soil treatments as indicated by soil tests are to be applied, and crop residues are to be conserved and incorporated in the soil. When crops are removed for silage, manure is to be spread back on the field.

The rotations near the top of the list include a minimum of cultivated crops. Progressing downward in the table, the cultivated crops appear with increasing frequency—first in rotations with a grass and legume mixture, and toward the bottom of the table with green manure crops. Rotations with row crops one-half of the time in systems with small grain and green manure crops represent the maximum we should go toward intensive farming. Moreover, use of the latter systems with safety against serious erosion is limited to the moderately sloping fields when combined with the more effective conservation practices. All of these systems may be considered as soil-conserving only when used with the recommended conservation practices, with consideration of the erosion hazards existing on the different land classes involved, and the fertility needs of the soil to produce the desired crops.

Erosion increases with the length and the steepness of the slope. Some soils erode more easily than others. From an erosion control standpoint, soil treatments are of greater importance on the soils of low fertility. Thus, cropping recommendations including soil treatments and the supporting conservation practices must be varied for the different conditions as they exist in the field. The cultivated soils of the state have been divided into five general soil areas and conservation practices recommended for the rotations of Table 1 and the different slopes within each soil group. These suggestions are given

TABLE 2.—THE CONSERVATION PRACTICES REQUIRED FOR USE OF THE ROTATIONS OF TABLE 1 ON THE MARSHALL AND SIMILAR DARK COLORED LOESSIAL SOILS OF NORTHWEST MISSOURI. (1)

| Land slope | Farming or Conservation Practice | | | | |
|---|---|---|---|---|---|
| | Field boundary (2) (3) | Maximum safe slope length | Contour farmed (2) | Terraced & contour farmed: Conventional contour plowing | Terraced & contour farmed: Up-slope contour plowing |
| Per cent | Rotations (4) | Feet | Rotations (4) | Rotations (4) | Rotations (4) |
| 3-4 | 1 to 9 | 300 | 1 to 17 | 1 to 22 | 1 to 22 |
| 5-6 | 1 to 4 | 250 | 1 to 9 | 1 to 20 | 1 to 20 and 22 |
| 7-8 | 1 to 4 | 200 | 1 to 7 | 1 to 19 | 1 to 20 and 22 |
| 9-10 | 1 & 2 | 200 | 1 to 4 | 1 to 10 | 1 to 10 12 to 18 20 & 22 |
| 11-12 | 1 | 200 | 1 & 2 | 1 to 7 | 1 to 10 12 to 18 and 20 |
| 13-14 | 1 | 200 | 1 & 2 | 1 to 4 | 1 to 10 12 to 15 and 17 |
| 15-16 | - | 200 | 1 | 1 to 3 | 1 to 10 12,15,17 |

(1) Application is limited to the cultivatable soils or those in Classes I to IV. Soil treatments to produce good stands of small grain and grass legume mixtures are required. Increased treatments will be necessary for Class III land over Class II and also for Class IV land over Class III.
(2) Reduce slope length when necessary by terracing. All waterways must remain in a grass sod.
(3) Farm with field boundary which is nearest to being on the contour.
(4) Rotations are those of the corresponding numbers in Table 1.

in Tables 2 to 6. The rotation numbers refer to those given in Table 1. These suggestions are based upon an average annual soil loss (a) of 4 tons per acre as the maximum tolerable for the Marshall, Shelby, and loessial river hill soils (Tables 2, 3 and 4); (b) of 3 tons for the claypans (Table 5); and (c) of 2 tons for the sloping soils of the Ozark region (Table 6). Fertility needs are to be determined from soil tests.

TABLE 3.—THE CONSERVATION PRACTICES REQUIRED FOR THE USE OF THE ROTATIONS IN TABLE 1 ON THE SHELBY AND ASSOCIATED GLACIAL SOILS OF NORTH MISSOURI. (1)

| Land Slope | Farming or Conservation Practice | | | | |
|---|---|---|---|---|---|
| | Field boundary (2) (3) | Contour farmed | | Terraced & contour farmed | |
| | | Maximum safe slope length | (2) | Conventional contour plowing | Up-slope contour plowing |
| Per cent | Rotations (4) | Feet | Rotations (4) | Rotations (4) | Rotations (4) |
| 3-4 | 1 to 7 | 300 | 1 to 14 | 1 to 22 | 1 to 22 |
| 5-6 | 1 to 4 | 250 | 1 to 7 | 1 to 19 | 1 to 20 and 22 |
| 7-8 | 1 & 2 | 200 | 1 to 4 | 1 to 14 | 1 to 18 20 & 22 |
| 9-10 | 1 | 200 | 1 & 2 | 1 to 7 | 1 to 10 12 to 18 20 & 22 |
| 11-12 | 1 | 200 | 1 & 2 | 1 to 4 | 1 to 10 12 to 15 and 17 |
| 13-14 | - | 200 | 1 | 1 to 3 | 1 to 10 12 & 15 |
| 15-16 | - | 200 | 1 | 1 & 2 | 1 to 4 6 & 7 |

(1) Application is limited to the cultivatable soils or those in Classes I to IV. Soil treatments to produce good stands of small grain and grass legume mixtures are required. Increased treatments will be necessary for Class III land over Class II and also for Class IV land over Class III.
(2) Reduce slope length when necessary by terracing. All waterways must remain in a grass sod.
(3) Farm with field boundary which is nearest to being on the contour.
(4) Rotations are those of the corresponding numbers in Table 1.

The rotations recommended for the steeper slopes may appear restrictive. Such restrictions are necessary according to experimental data if soil erosion is to be controlled to the extent where productivity of the soil may be economically maintained. The tables show that more intensive cropping may be followed on the steeper slopes when these are terraced and plowed up slope by use of a two-way or hillside plow than for any other combination of practices. The excess soil eroded into the terrace channel with the more intensive cropping is moved back up the slope by the up-slope plowing as required normally in the farming operations. This method of plowing, shown in Figure 14, with the improved farm equipment now available and with soil

TABLE 4.—THE CONSERVATION PRACTICES REQUIRED FOR THE USE OF THE ROTATIONS IN TABLE 1 ON THE LIGHTER COLORED LOESSIAL SOILS BORDERING THE MISSOURI AND MISSISSIPPI RIVERS. (1)

| Land Slope | Farming or Conservation Practice | | | | |
|---|---|---|---|---|---|
| | Field boundary (2) (3) | Contour farmed | | Terraced & contour farmed | |
| | | Maximum safe slope length | (2) | Conventional contour plowing | Up-slope contour plowing |
| Per cent | Rotations (4) | Feet | Rotations (4) | Rotations (4) | Rotations (4) |
| 3-4 | 1 to 7 | 300 | 1 to 10 | 1 to 22 | 1 to 22 |
| 5-6 | 1 to 3 | 250 | 1 to 7 | 1 to 19 | 1 to 20 and 22 |
| 7-8 | 1 & 2 | 200 | 1 to 4 | 1 to 10 | 1 to 10 12 to 18 20 & 22 |
| 9-10 | 1 | 200 | 1 & 2 | 1 to 7 | 1 to 10 12 to 18 and 20 |
| 11-12 | 1 | 200 | 1 & 2 | 1 to 4 | 1 to 10 12 to 15 and 17 |
| 13-14 | - | 200 | 1 | 1 & 2 | 1 to 8 10 & 15 |
| 15-16 | - | - | - | 1 & 2 | 1 to 4 and 6 |
| 17-18 | - | - | - | 1 & 2 | 1 to 3 and 6 |
| 19-20 | - | - | - | 1 | 1 to 3 and 6 |

(1) Application is limited to the cultivatable soils or those in Classes I to IV. Soil treatments to produce good stands of small grain and grass legume mixtures are required. Increased treatments will be necessary for Class III land over Class II and also for Class IV land over Class III.
(2) Reduce slope length when necessary by terracing. All waterways must remain in a grass sod.
(3) Farm with field boundary which is nearest to being on the contour.
(4) Rotations are those of the corresponding numbers in Table 1.

conditioning rotations, is practical and can be accomplished with no more difficulty than conventional contour plowing except on the extremely steep slopes. Even on these slopes it is a practical method when the results obtained are considered. With it and the recommended rotations, terrace maintenance will be limited to repair of rodent or similar damage. The use of rotations allowing higher soil loss than those suggested will necessitate terrace maintenance and occasional rebuilding, and will be accompanied by declining soil fertility.

A combination of diversion terraces and strip cropping offers possibilities for extending the use of cultivated crops to a limited extent on slopes ranging as high as 16 to 24 per cent. Additional development work and field testing will be required before definite

TABLE 5.—THE CONSERVATION PRACTICES REQUIRED FOR THE USE OF THE ROTATIONS IN TABLE 1 ON THE CLAYPAN SOILS, NORTHEAST AND SOUTHWEST PRAIRIES OF MISSOURI. (1)

| Land Slope | Farming or Conservation Practice | | | | |
|---|---|---|---|---|---|
| | Field boundary (2) (3) | Contour farmed | | Terraced & contour farmed | |
| | | Maximum safe slope length | (2) | Conventional contour plowing | Up-slope contour plowing |
| Per cent | Rotations (4) | Feet | Rotations (4) | Rotations (4) | Rotations (4) |
| 1 | 1 to 17 | 500 | 1 to 19 | 1 to 22 | 1 to 22 |
| 2 | 1 to 10 | 400 | 1 to 17 | 1 to 22 | 1 to 22 |
| 3 | 1 to 9 | 300 | 1 to 16 | 1 to 22 | 1 to 22 |
| 4 | 1 to 4 | 300 | 1 to 9 | 1 to 22 | 1 to 22 |
| 5 | 1 to 4 | 250 | 1 to 7 | 1 to 20 | 1 to 20 and 22 |
| 6 | 1 & 2 | 250 | 1 to 5 | 1 to 19 | 1 to 20 and 22 |

(1) Application is limited to the cultivatable soils or those in Classes I to IV. Soil treatments to produce good stands of small grain and grass legume mixtures are required. Increased treatments will be necessary for Class III land over Class II and also for Class IV land over Class III.
(2) Reduce slope length when necessary by terracing. All waterways must remain in a grass sod.
(3) Farm with field boundary which is nearest to being on the contour.
(4) Rotations are those of the corresponding numbers in Table 1.

Figure 14.—Farming the steeper slopes requires the use of terracing, up-slope plowing, contouring and rotations with grass-legume mixtures for control of erosion. Soil Conservation Experiment Farm, Bethany, Mo.

TABLE 6.—THE CONSERVATION PRACTICFS REQUIRED FOR THE USE OF THE ROTATIONS IN TABLE 1 ON THE SLOPING SOILS OF THE OZARK REGION. (1)

| Land Slope | Farming or Conservation Practice | | | | |
|---|---|---|---|---|---|
| | Field boundary (2) (3) | | Contour farmed (2) | Terraced & contour farmed | |
| | | Maximum safe slope length | | Conventional contour plowing | Up-slope contour plowing |
| Per cent | Rotations (4) | Feet | Rotations (4) | Rotations (4) | Rotations (4) |
| 3-4 | 1 to 3 | 300 | 1 to 5 | 1 to 22 | 1 to 22 |
| 5-6 | 1 & 2 | 250 | 1 to 3 | 1 to 19 | 1 to 20 and 22 |
| 7-8 | 1 | 200 | 1 & 2 | 1 to 10 | 1 to 10<br>12 to 18<br>20 & 22 |
| 9-10 | 1 | 200 | 1 & 2 | 1 to 7 | 1 to 10<br>12 to 18<br>20 & 22 |
| 11-12 | - | - | - | 1 to 4 | 1 to 10<br>12 to 18<br>and 20 |
| 13-14 | - | - | - | 1 & 2 | 1 to 10<br>12,15,17 |
| 15-16 | - | - | - | 1 & 2 | 1 to 4<br>6 to 8<br>10 & 15 |

(1) Application is limited to the cultivatable soils or those in Classes I to IV. Soil treatments to produce good stands of small grain and grass legume mixtures are required. Increased treatments will be necessary for Class III land over Class II and also for Class IV land over Class III.
(2) Reduce slope length when necessary by terracing. All waterways must remain in a grass sod.
(3) Farm with field boundary which is nearest to being on the contour.
(4) Rotations are those of the corresponding numbers in Table 1.

recommendations can be made for slopes of such magnitudes. Their application would probably be limited to the river hills and possibly the steeper slopes of the Ozark region.

These suggestions are based upon research work in soil conservation carried on in Missouri and other states, beginning with work of the Missouri Agricultural Experiment Station in 1917. Careful application of these suggestions will yield satisfying returns, not only in the conservation of a basic national resource, but in an increased farm income. It must be remembered, however, that each part of a conservation farm plan, whether it is of the water management or of the crop-soil management phase, must be intelligently applied and conscientiously maintained. No part can be slighted. In this manner the soil can be profitably farmed, yet preserved for the use of future generations.

## Summary

This publication discusses the sequence of crops in rotations for effective soil conservation and suggests the supporting conservation practices required for the different rotations on the major soil and topographic conditions existing in Missouri.

Control of erosion is necessary for sustained crop yields. Loss of an inch of surface soil has reduced average corn yields 4 bushels per acre. For economic maintenance of soil productivity field soil loss may not exceed 2 to 4 tons per acre annually.

High fertility and erosion control go hand in hand. When not existent, fertility must be supplied by use of fertilizers, manure, etc. Erosion from small grain has been reduced one-half by use of fertilizers. Vigorous grass and legume sods before corn, as a result of increased fertility, reduced erosion under the corn to less than one-half that following a grass-legume mixture that deteriorated through a decline in fertility.

Crop sequences for effective soil conservation provide (a) maximum of cover protection, and (b) soil conditioning to resist erosion when a new crop is seeded or when row crops are grown.

In well designed rotations the seeding of a new crop quickly follows the harvest of the preceding one. Thus, the length of time the land remains bare between two crops is reduced to a minimum.

Corn stalks as soil cover reduced late fall, winter, and early spring erosion to one-half of that with corn stubble. Stalks and rye as winter cover were even more effective. A legume seeding in small grain provides a very effective cover from grain harvest to seeding of the next crop.

Small grain-lespedeza, grown year after year, provides almost continuous cover and thus is an effective cropping system for erosion control. It has been equal to a 3-year rotation of corn-small grain-grass legume meadow.

Soil conditioning crops are the grasses and legumes.

Sweet clover under as green manure before corn materially reduced the erosion under the corn. A grass and legume mixture preceding the corn, however, has been the most effective crop for conditioning the soil and reducing erosion under the corn or soybeans.

Soybeans grown in contour rows and cultivated, allow about the same erosion as corn. Drilled solid they allow less than corn.

Soils, cropping systems, and fertility treatments are major factors in erosion control. Length and steepness of slope must also be con-

sidered in the selection of supporting practices, such as contour farming and terracing, needed for an adequate erosion control plan.

Rotations with the necessary supporting conservation practices that will provide desirable erosion control for different slope groups on five major soil areas of Missouri are tabulated in Tables 1 through 6.

**NOTE. This bulletin is a sequel to the earlier Bulletin 366, "Cropping Systems in Relation to Erosion Control", by M. F. Miller.**