SUGGESTIONS ON EROSION CONTROL

A vegetative cover is nature's way of protecting the soil.

Circular 406

UNIVERSITY OF KENTUCKY
College of Agriculture and Home Economics
Agricultural Extension Division

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EVERYONE should have a vital interest in soil conservation because all are affected by the condition of the soils of the nation. This interest should be such that all groups would be willing to make whatever contribution they can to soil conservation. Cheap food today at the cost of soil exhaustion will mean not only high-cost food tomorrow, but malnutrition and inefficiency also.

The rural church can exert a great influence by constantly emphasizing the obligation to conserve the soil. The duty to conserve the soil certainly falls within the Golden Rule and the behest to consider the rights of one's neighbor.

Every rural school teacher should be informed upon the basic principles of soil conservation and should make pupils at an early age conscious of their obligation to conserve the soil.

Our apparent prosperity in the past has been largely at the price of prodigal use of natural resources. Our prosperity for the future must depend on the most rigid conservation of our natural resources, the chief of which is the soil.

Lexington, Kentucky

July, 1945

Suggestions on Erosion Control

By George Roberts[1]

THE MAIN PURPOSE of this publication is to impress upon farmers the seriousness of soil erosion and to urge the use of better practices for its control. If farmers could become fully conscious of the enormous losses caused by erosion, surely they would use every reasonable practice to prevent it. Specific directions for carrying out the various control practices are not given here. For such details farmers should consult their county agents, teachers of vocational agriculture, and soil conservation district technicians. A list of publications dealing with soil-improvement practices is given on page 20 of this circular.

For a convincing statement of the enormous extent of soil erosion in this country, the reader is referred to U. S. Department of Agriculture Circular 33 (1928), entitled "Soil Erosion, A National Menace," by H. H. Bennett, now Chief of the Soil Conservation Service, and W. R. Chapline. Mr. Bennett, who had spent many years studying the soils of the United States, stated that he was "of the opinion that soil erosion is the biggest problem confronting the farmers of the Nation over a tremendous part of its agricultural lands." He estimated that at least 126,000,000,000 pounds of plant food material (that is, elements of the kind taken from the soil by plants) were being removed from the crop and pasture lands of the United States annually by erosion. This, he stated, was more than twenty-one times the amount of plant food removed in crops. He further estimated that if only nitrogen, phosphorous, and potassium (the elements bought in commercial fertilizers) were considered, the loss amounted to 2 billion dollars annually, at the lowest cost at that time (1928) at which these could be purchased in commercial fertilizers. He estimated the "tangible yearly loss" to be at least 200 million dollars a year. That is, it would cost the farmers at least 200 million dollars a year in buying fertilizers or cultivating more land, to obtain the production which would have been obtained without this extra cost if the land had not been depleted by erosion.

According to a report of the National Resources Board (1934) it was estimated that 35 million acres of farm land in the United States had been damaged by erosion beyond reclamation for agricultural purposes; that 125 million acres had had most of the original plow-layer of soil removed; and that on 100 million acres more a part of the plow-layer had been removed. The total of these acreages amounts to nearly 30 percent of the total crop and pasture land of the United States. While no accurate estimates for Kentucky are available, it is reason-

[1] Professor of Agronomy, Emeritus.

able to believe that, considering topography and rainfall, erosion in the state has been equal to the average for the United States, and perhaps has been greater.

If Kentucky had the average rate of erosion, her share of the annual 2-billion-dollar loss was more than 30 million dollars a year. Mr. Bennett quotes an eminent geologist as saying that he would be unwilling to name an average rate of soil formation greater than one foot in 10,000 years. Soil is being allowed to wash away, in many cases, at the rate of a foot in less than a lifetime.

Ownership of land does not confer the right to misuse it or let it be ruined by erosion. Owners of land should look upon themselves as trustees with a sacred obligation to pass it on to the next generation in the best condition possible. Soil is indispensable to life, and no one can have true reverence for human life who does not have reverence for the soil as a source of life.

For many years the writer of this circular has made careful observations on erosion and the farm practices associated with it, especially at the times when the soil is most susceptible to erosion.

TERRACES AND CONTOUR CULTIVATION

Terraces are very effective in the control of erosion on land to which they are adapted, provided contour cultivation and the proper cropping practices are used with them. Otherwise they will not be effective. (Detailed information on terraces is given in Kentucky Extension Circular 304, "Soil Erosion and its Control." Details are given on the treatment of gullies also.) Diversion ditches may be effectively used on land too steep for terraces.

Observations have shown that a very large part of the crops grown in Kentucky are planted without any attention to the contour. A "contour line" is a line around a slope at the same elevation at all points. If a uniform furrow were opened strictly on the contour, water would stand at the same depth in it throughout its length. It is not uncommon to see winter grain seeded off the contour on very expensive land in the Bluegrass area of Kentucky, and to see corn and tobacco planted off the contour in the same area.

If seeding and cultivating are done on the contour, the furrows hold much of the rainfall and allow it to enter the soil, thus greatly benefiting the crop in critical dry periods. A report based on 1,200 acres of corn in Grant county (Kentucky) cultivated on the contour in 1943 states that yields averaged 8 bushels higher with contour cultivation than where cultivation was off the contour. A report based on 800 acres of tobacco cultivated on the contour in the same county the same year stated that the increase was about 125 pounds per acre for contour cultivation. The latter part of the 1943 season was dry.

In comparisons of contour cultivation with off-the-contour cultivation in Illinois from 1939 to 1943 the following results are reported:[1]

Small grain on lespedeza sod, planted on contour

The increase in corn yields on 102 farms for contour cultivation was 7.5 bushels; for soybeans on 12 farms, 2.7 bushels; for oats on 28 farms, 7.4 bushels.

Some very interesting results showing the effect of contour cultivation on crop yields were recently reported from the New York Experiment Station.[2] In 1943 the yield of sweet corn was increased 35 percent and that of cabbage 13 percent, with quality and uniformity of maturity markedly improved. Evidently contour cultivation is profitable for the effect of moisture conservation on the crop, to say nothing of the soil saved from washing away.

Experiments in Alabama[3] showed that where cotton rows were slope-planted the loss of soil was about twice as great as where the rows were on the contour. While contour cultivation is immediately profitable in increased yields from moisture conservation, the prevention of loss of soil by erosion is, in the long view, the most important effect.

One observation was made in a hilly section of the Bluegrass region of Kentucky following a very heavy rain soon after the planting of corn and tobacco. Where the rows were off the contour there was very great erosion, but in the few places where the rows were on the contour erosion was greatly reduced or practically prevented.

One practice that has been observed to result in very great erosion

[1] Illinois Farm Economics No. 107, College of Agriculture, University of Illinois.
[2] Farm Research, Geneva, N. Y., Vol. X, No. 1, January 1, 1944.
[3] Alabama Exp. Sta. Bul. 245.

is rolling, dragging, or otherwise smoothing sloping land for planting and then not getting the planting done before a heavy rain comes. Land so treated has been seen with soil washed away in places almost to the plow sole. Sloping land should not be smoothed in this way faster than it can be planted. The planting should be on the contour,

Corn planted on the contour.

and the land should then be cultivated as soon as possible, to produce ridges and furrows to check and hold the water so that it will enter the soil. Sloping land planted on the contour should be recultivated when the ridges produced by former cultivations have been leveled or compacted so much that they do not effectively check run-off. While it has been proved that on level land cultivation is generally beneficial only for killing weeds, and not for direct conservation of moisture, this is not true for sloping land where the water runs off rapidly if not held back by contour cultivation.

Many farmers do not realize the seriousness of erosion until gullies begin to appear. When this stage is reached the rich topsoil is usually nearly all gone. The attitude of some farmers is well illustrated by the experience of an extension worker. He saw a field that had been prepared for planting without regard to the slope. A heavy rain that had fallen before planting had made many small gullies in the field, some going almost to the plow sole. The extension worker told another farmer about the field, and he replied that it did not amount to much because the farmer could immediately disk and smooth the field so that no one could tell that the washing had occurred. This was in a region of expensive land.

Abrupt changes in the slope of land often make sharp curves in the contour line, especially at "draws" or water outlets. Instead of trying to cultivate such places, they should be kept in a good grass-legume sod, which can be used for hay when the field is in cultivation. All water outlets should be kept in sod extending far enough up the sides of the outlet to prevent the peak run-offs from reaching cultivated land.

Corn planted with the slope, in straight rows.

Sometimes a steep hillside is seen plowed for tobacco when at the top of the hill there is fairly level land in grass. While it may be true that the hillside produces a better quality of tobacco, it is doubtful if the gain will compensate for the loss of soil from erosion.

Where there is enough sloping land to use strip cropping, strips may be laid out as nearly on the contour as possible. Instead of having cultivated strips and dense seeded strips alternating, it would be much better, if enough land is available, to have rotational strip cropping with two or three strips in sod to one in a cultivated crop. As soon as a cultivated crop is removed the strip should be seeded again to grass and legumes. If there is not enough land for strip cropping and the whole sloping field must be plowed, it would help to prevent erosion if narrow sod strips 10 to 12 feet wide were left on the contour at intervals.

EROSION CONTROL BY VEGETATIVE COVER

There can be no effective control of erosion without a large use of vigorous vegetative covers—not even on land of moderate slope, hence the stress in succeeding pages on increasing the fertility of the soil as an aid to erosion control. There are large acreages in Kentucky so depleted of fertility that they will not produce enough growth of cover crops to protect the soil against erosion. On Kentucky land of even moderate slope used every year for cultivated crops, it is doubtful if erosion can be effectively controlled by contour cultivation and winter cover crops because of the heavy rains that so frequently occur.

The role of grass (including legumes) in preventing erosion may be summarized as follows:

1. A grass covering lessens the force of the impact of the raindrops upon the surface of the soil, and thus prevents the compacting of the surface of the soil. The surface of the soil is thus left more open for the entrance of the water.

2. The penetration of the grass roots loosens up the soil, and thereby increases the pore space and water-holding capacity of the soil.

3. The grass cover slows the velocity of the run-off and gives the water more time to enter the soil.

4. By reducing the velocity of the run-off, the erosive power of the water is greatly reduced.

5. The grass covering directly protects the soil against the erosive power of the moving water.

6. Grassland plowed for cultivated crops erodes less than if grass had not been grown, because the grass roots cause the soil particles to form larger granules, while the roots themselves have a binding effect on the soil for some time after the sod has been broken.

7. The decay of the grass roots and the residue of the tops forms humus which increases the water-holding capacity of the soil and also increases its resistance to erosion.

Kentucky should be more largely a livestock state to utilize more of the land in grass for pasture and hay. Moreover, the grass-livestock type of agriculture fits in best with the production of tobacco of high yield and quality.

If the soil is properly treated with lime and the necessary fertilizers to produce a vigorous grass-legume growth, the grasses and legumes will be of a high nutritive quality, and livestock can be carried more on pasture and hay and with less grain than if the pasture and hay were produced on soil deficient in the mineral nutrients. The reduction in grain requirement enables the farmer to confine grain crops to the less sloping land and thus more effectively to control erosion. The high quality of pasture and hay produced on the high-phosphorus soils of the Central Bluegrass area and the long grazing periods possible there account in a large measure for the small corn acreage. For example, in Bourbon county, according to the census of 1940, an average of about $7\frac{3}{4}$ acres out of 100 acres of crop and plowable pasture land were in corn, and about $5\frac{1}{2}$ acres in tobacco. This county produces a large amount of livestock, and though some corn must be bought for feeding, it is better to buy the needed corn than to grow it on erodible land, and it is cheaper than to plow good pasture for corn. Cover crops extend the grazing period; and in this and similar areas a cultivated field is seldom seen without a winter cover, much of which is used for grazing and not for harvest. Such practices occur very naturally where good pasture and hay can be produced. However, in the Bluegrass region much planting is done without regard to the contour. The basic reason for the high productivity of the soils of the Bluegrass region is their high content of phosphorus.

Good grass-legume pastures and hay can be produced on almost any soil in Kentucky, though badly depleted, if it is properly limed and fertilized and thereafter properly managed. Good examples of this are found in Taylor county, among others. They are cited because of the location of a soil experiment field in the county. The crop and plowable pasture land was about 90,000 acres in 1929 and 98,000 acres in 1939. The acreage of corn remained about stationary for the two periods, but the plowable pasture and hay acreages increased from approximately 45,000 to approximately 57,000 acres, an increase of about 12,000 acres. Observation indicates that the pastures are generally productive and are kept clean by cutting the weeds. This county used approximately 134,000 tons of liming material from 1925 to 1942 and also made a large use of phosphates. Many other counties have made similar records.

Hay crop at the Campbellsville Experiment field. On the left, no lime nor fertilizers were used, and the yield was 660 pounds per acre. On the right, where lime and superphosphate had been applied, the yield was 4,220 pounds per acre, from 2 cuttings in one season.

On the Campbellsville (Taylor county) Experiment Field,[1] established in 1919, with a moderate use of lime and phosphate in a rotation of corn, wheat, and mixed grass and legume hay, the average yields through 1943 were as follows (nearest whole numbers used):

	No lime or phosphate	*Limestone and superphosphate*
Average all crops		
Corn, bushels	33	58
Wheat, bushels	5	16
Hay, pounds	1,642	4,080
Average, first 6 crops		
Corn, bushels	20	46
Wheat, bushels	4	11
Hay, pounds	945	2,820
Average, last 6 crops		
Corn, bushels	38	59
Wheat, bushels	5	21
Hay, pounds	1,973	4,932

These yields are given to show how soils of this nature can be improved at a moderate cost. With increased yields the required grain crops and other cultivated crops can be confined to the more level land of the farm, and release the steeper land for grass. It will be noted from the yields of the first six crops on the untreated land that the soil was in a badly depleted condition. No manure was used for the first six years, but thereafter it was used on the corn crop on both the fertilized and unfertilized plots in amounts equal to the weight of the crops removed in the preceding rotation. The results of the last six crops show that without lime or fertilizer considerable improvement can be made by saving and returning the manure made by feeding the crops. Excellent bluegrass sods have been established on the field for tobacco, which has produced good yields of good quality. More will be said about short rotations for limited level land.

An experiment in pasture production on badly worn sandstone land on the Western Kentucky Substation farm at Princeton shows that good pasture can be made on practically any soil of Kentucky, no matter how badly depleted, for this land was about as unfavorable as will be found in the state. Land adjacent and similar to the pasture land produced 12 bushels per acre of corn in 1928, a fairly good season for corn as shown by land on the same farm under fair management yielding more than 50 bushels per acre. Three 10-acre fields of similar productivity, eroded and grown up in briars and bushes, were cleared, terraced, and prepared for seeding in the fall of 1927. Field 1 was left untreated; Field 2 was treated with 1,200 pounds of ground

[1] For these results and the results on other experiment fields, with different forms of phosphate, see Ky. Agr. Exp. Sta. Bul. 397.

Pasture on sandstone soil at Western Kentucky Agricultural Experiment Substation before and after improvement. Upper: Typical scene when work was started in 1925. Note the eroded slopes at the right, bushes (mostly persimmon and sassafras sprouts) and briars in the low ground where a little topsoil remained, and the small cornstalks in the foreground. Middle: The same field after the brush was cut and grubbed, and piled on rocky bare spots and in gullies. Lower: A basic treatment of limestone and phosphate started this field on the road to recovery, and now it supports a good sod of bluegrass. In June, 1941, when this picture was taken, the bluegrass was knee high.

rock phosphate per acre; and Field 3 was treated with 1½ tons of limestone and 600 pounds of superphosphate per acre. Field 1 was the least eroded and Field 3 the worst. The fields were seeded the last of August to rye, and the following spring to a mixture of orchard grass, redtop, Canada bluegrass, Kentucky bluegrass, white clover, sweet clover, common lespedeza, and Korean lespedeza, at the rate of 17 pounds per acre, orchard grass predominating in the mixture. All 3 fields were pastured with yearling steers since 1929, inclusive. Beginning with 1934, phosphates were applied as top dressings, making a total of 2,900 pounds of rock phosphate per acre on Field 2 and the equivalent of 1,460 pounds of 20-percent superphosphate per acre on Field 3, in 16 years (15 years of grazing). Field 3 was relimed at the rate of 1 ton per acre in 1935. The attempt has been made to keep the total cost of phosphate treatment of Fields 2 and 3 equal. The results of the tests through 1943 are given below:

Field No.	*Treatment*	*Average number of steers carried per field*	*Average yearly gain per field (lb)*	*Average cost per pound of gain (cents)*
1	None	2.6	457	10.05
2	Rock phosphate	6.5	1,610	3.26
3	Limestone, superphosphate	6.7	1,634	3.08

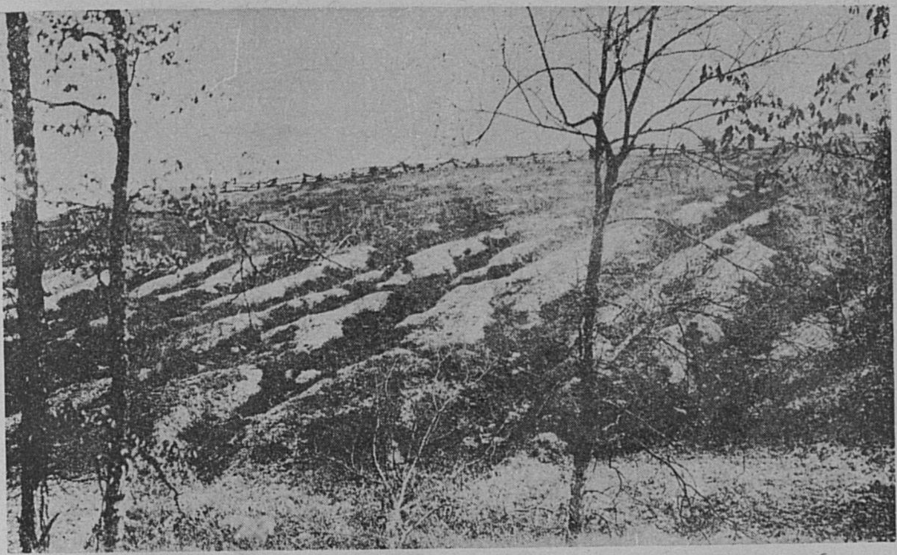
The cost of gain includes all expenses, such as taxes and interest on the investment. The chief cash outlay for the farmer would usually be for lime, fertilizers, and seeds.

In some years the grazing capacity was very much reduced by drouth. One was 1930, when the largest gain was only 770 pounds for the 10-acre field, treated with rock phosphate. In some other years the gains were 2,000 pounds or more.

The writer believes that the treated pastures would have been more productive if they had been limed and fertilized more heavily in the first six years and if sweet clover and other adapted legumes had been grown the first year and turned under before seeding the permanent pasture mixture.

Excellent pastures may now be seen in all sections of Kentucky where the soil has been properly treated. The purpose of the discussion of pastures is to emphasize their importance in preventing erosion and in reducing the cost of livestock production by reducing grain requirements.

One reason for failure of grass seedings in Kentucky is that there may not be enough available nitrogen in the soil to give the grass a vigorous start so it can survive in competition with the nurse crop and the legumes seeded with it which can obtain nitrogen from the air. Another reason for failure of grass is late fall or spring seeding, which usually results in not enough growth to enable the grass to survive the



Sweet clover starting on badly gullied land.

The same hillside later in the season.

competition with nurse crop and legumes. Still another reason is too light seeding of grass.

To succeed with grass the nitrogen content of the soil should first be built up through the proper use of legumes. An excellent start on depleted soil is to lime the soil, use a liberal application of phosphate where it is deficient, and seed heavily to sweet clover in the spring. The next year this should be turned under and followed in early September with grass seeded with a nurse crop. The next spring, seed with this the desired legumes. Another good practice is to seed alfalfa and the desired grass together following the turning under of the sweet clover.

Seeding bluegrass with alfalfa gives better protection against erosion than alfalfa alone, and is a good way of establishing a pasture after a few years of hay crops. This field is now ready for pasture.

The alfalfa may be harvested for hay for two or three years and then turned into pasture. All alfalfa grown for hay on sloping land should have grass seeded with it to prevent erosion. Alfalfa alone does not completely cover the soil, and on sloping land the soil erodes from between the alfalfa crowns. Alfalfa fields on slopes have been observed in which the soil was washed away enough to expose the roots of the alfalfa. The grass associated with alfalfa is usually higher in protein than when grown alone and makes good hay.

If one is not able to lime the soil so as to grow sweet clover and alfalfa, cowpeas may be grown and turned under for fall seeding of grass.[1]

Land that has been eroded so badly that it cannot be reclaimed for pasture or other crops should be planted to trees. Locusts will grow on badly eroded land of limestone origin. After locusts get a start grass will grow with them. The locust is a nitrogen-fixing legume.

There are various forms of phosphate which are highly effective, such as ordinary superphosphate, double superphosphate, raw ground rock phosphate, colloidal phosphate, basic slag, and the metaphosphates. They should be compared on the basis of applications of equal cost. Their effect in a continued soil-building program should be considered, and not merely the effect of an application for a single

[1] County agents are prepared to advise farmers on the details of these procedures. Copies of the publications listed at the end of this circular will be sent on request.

crop. Care must be used in their use with lime, for heavy liming affects particularly the availability of the relatively insoluble phosphates, such as rock phosphate. Data on long-time comparisons of phosphates will be found in Ky. Agr. Exp. Sta. Bul. 397.

SHORT ROTATIONS

If cultivated crops must be produced on steep slopes, effort should be made to have them in good sod when plowed, and then put them back to grass immediately. If such land must be cultivated, it would be good practice to use strip cropping in a rotation with a cultivated strip, followed by three to four years of sod. If there is not enough land for this and a whole slope must be plowed, it would be good practice to leave sod strips on the contour at intervals. However, if there is any level or moderately sloping land on the farm, it is best to try to produce cultivated crops on this land in short rotations or in extreme cases in continuous cultivation. Usually better yields are obtained in rotation. Good yields and quality of tobacco have been produced in continuous culture. The tobacco should be liberally fertilized and should be followed by a cover crop containing a legume. A winter grain with vetch or crimson clover seeded as early as possible usually makes a good cover. Manure, if available, may be used on the tobacco. Where there is very little fairly level land, it perhaps would be better to grow tobacco and buy corn. Some farmers do this rather than plow up good grass on fairly level land.

Following are some results obtained in rotations of two, three, and four years that show the possibilities of improving depleted soils (yields are given in the nearest whole numbers).

A two-year rotation of corn and wheat on the Hopkinsville experiment field[1] illustrates the possibilities of a short rotation. Rather thin land was limed and treated with superphosphate. Sweet clover was sown on the wheat in the spring and turned under the next year for corn. The yield of corn for the first three years (1922-24) was 26 bushels per acre, and for the last three years (1927-29) 55 bushels. Manure was used on the corn in 1926-27 at the rate of 6 tons per acre. The average yield of corn for the eight years was 43 bushels. Regular use of manure would no doubt have greatly increased the yields, but it was not regularly obtainable.

In a three-year rotation of corn, wheat and red clover on adjacent land not limed or phosphated, the yield of corn for the first three years was 19 bushels per acre, and for the last three, 31 bushels. In the three-year rotation on land treated with limestone and superphosphate, the yield was 25 bushels for the first three years and 49

[1] See Ky. Exp. Sta. Bul. 299, a report on the Hopkinsville soil experiment field, which was operated from 1922 to 1929.

bushels for the last three. Manure was used at 5 and 6 tons per acre on the corn in 1927-28, on both the fertilized and unfertilized plots.

While the effects of the two rotations on the yield of corn are not strictly comparable, because the productivity of the soil differed somewhat in the different cases cited, the very large increase in the yield of corn is highly significant and indicates the possibilities of a short rotation. Lespedeza may be used instead of sweet clover, but it should be followed by a cover crop which may be seeded by disking the sod. Lespedeza may also be mixed with sweet clover. Sweet clover should be plowed under by the last of April when it is to be followed by corn. Land in a short rotation like this should be liberally manured if possible until it is brought to a stage where legumes supply enough nitrogen for the corn. If barley is used, it may be advisable to topdress with nitrogen, for it requires a liberal supply of nitrogen.

It is not best to try to produce corn in continuous culture, even though the land may be liberally manured. An experiment on the Experiment Station farm at Lexington indicates that it is not possible to maintain a high yield of corn in continuous culture, though the land is fertile to begin with and is liberally manured thereafter. The experiment was begun in 1920, on land that yielded 70 bushels per acre the first year, without manure or fertilizer. The average yield of the unmanured check plots for eleven crops was 33 bushels per acre, while on the plot manured at the rate of 15 tons per acre in alternate years the yield was 46 bushels per acre. Ten tons of manure was as effective as 15 tons. A rye cover crop was used each winter. In a three-year rotation of corn, wheat, and clover begun at the same time on adjoining land not quite so fertile, the average yield for the same period was 51 bushels per acre without the use of manure and 60 bushels per acre with the use of 4 tons of manure per acre for each corn crop.

In 1933 a two-year rotation of corn and wheat was begun in which sweet clover was sown on the wheat in the spring, to be turned under the next spring for corn. Lespedeza was included beginning in 1938. The plots used in continuous culture were divided crosswise to make two plots for the two-year rotation. Thus each of these new plots contained equal parts of all the plots in the continuous culture experiment. The average yield of all the plots in the continuous culture tests was 39 bushels for eleven crops of corn. Potash deficiency began to show on the corn, and beginning in 1939, 100 pounds of muriate of potash per acre was applied for each corn crop. This would naturally occur, since no manure was used in the two-year rotation. If the legumes thrive in the rotation, they should largely meet the needs of the corn and wheat for nitrogen, and using manure heavily enough to meet the potash needs would be a waste of nitrogen. The logical procedure would be to use manure moderately and use fertilizer potash to meet the potash deficiency. The plots were limed. This soil contains sufficient phosphate.

The average yields of corn and wheat were:

Corn 1934-43 (10 crops)	55 bushels per acre
Wheat 1935-42 (8 crops, failure 1943)	23 bushels per acre

There was one very dry year (1936) when the corn yield was 25 bushels. Leaving this year out, the average yield was 58 bushels. The yield of corn in 1938 was 82 bushels per acre, and 80 bushels in 1942.

In some areas of the state there is level land along streams and in other places that is unproductive because of poor drainage. Where such land can be drained it can be made to produce high yields of corn and thus release cultivated sloping land for pasture and hay. Where there is enough level or gently sloping land on the farm, longer rotations should be used. The results from a three-year rotation at Campbellsville were given on page 10.

On badly worn land on the sandstone area of the Western Kentucky Experiment Substation at Princeton, a similar three-year rotation was begun in 1929. The land used for the experiment made only 12 bushels of corn per acre the year before, which was a favorable season. The results in this experiment through 1942 were:

	No limestone or fertilizer	*Limestone and superphosphate*
Corn, bushels per acre	25	44
Wheat, bushels per acre	5	17
Mixed legumes and grass, pounds per acre	1,230	3,654

These averages include low yields at the beginning of the experiment, and some dry years. The maximum yields for a single year were: corn, 67 bushels; wheat, 40 bushels; and hay, 6,180 pounds.

Four-year rotations of corn, wheat, and two years of grass and legumes have been used on some of the outlying experiment fields.[1] The following results from the Fariston (Laurel county) field for 1916-42 are given to show what can be done with very badly depleted soils. The soil of this field was the worst depleted of all the experiment fields.

Various modifications of the rotation were used. For some years it was corn, soybeans, wheat, and clover. Wheat was dropped for a while and rye was substituted as a nurse crop for clover and grass, and was clipped in the spring. Sorghum for sirup was substituted for corn for three years. This statement is made to explain the irregularity in the number of crops. Manure was not used until 1925 because it could not be obtained. It is not feasible to keep livestock in connection with small experiment fields. The results at Fariston were:

[1] See Ky. Agr. Exp. Sta. Bul. 397 for details of treatment and results.

	No limestone or phosphate	Limestone and superphosphate
Corn, 24 crops, bushels per acre	10	46
Soybean hay, 16 crops, pounds per acre	1,272	4,383
Wheat, 18 crops, bushels per acre	3	14
Mixed grass and legume hay, pounds per acre		
1st year, 22 crops	272	3,320
2nd year, 8 crops	337	3,465

Rock phosphate was highly effective after the effects of overliming disappeared.

For soil that is adapted to alfalfa, a four-year rotation gives good results in producing a large amount of feed where there is a limited amount of level land. In a rotation of these crops the following results were obtained on the Experiment Station farm at Lexington.[1] Eight tons of manure per acre was applied for corn. The alfalfa yields are on the basis of three cuttings per year, although there were times when four cuttings could have been made.

Corn, 7 years, bushels per acre	67
Wheat, 7 years, bushels per acre	25
First-year alfalfa, 7 years, tons per acre	3.7
Second-year alfalfa, 6 years, tons per acre	4.2

These yields are averages of all plots. The plots were all limed. Some had no fertilizer; some were treated with phosphate, some with potash (200 pounds per acre when wheat was sown), and some with both. The fertilizers had no significant effect on corn and wheat, but potash increased first-year alfalfa about 300 pounds per acre per cutting, and second-year alfalfa about 150 pounds per cutting. On the basis of three cuttings a year, this would be an increase of 1,350 pounds of hay per acre in two years. This soil does not need phosphate. Alfalfa is such a heavy feeder on potash that it is not feasible to keep up the potash supply for alfalfa by applying manure beyond that necessary for the other crops in the rotation, for to apply enough manure to meet the potash needs of alfalfa would supply so much nitrogen that it would reduce nitrogen fixation by alfalfa. About 8 tons of manure per acre on corn would be a logical amount in such a rotation, the additional needs of the alfalfa for potash to be supplied by fertilizer potash.

Alfalfa is the most reliable hay crop on land adapted to it, because there is very seldom a season so dry that one or more cuttings are not obtained. Serious drouth hardly ever begins before the first cutting, and usually there is a late cutting following drouths.

Where there is poorly drained level or fairly level land, it should be drained and properly treated and used for cultivated crops so as to release the steeper land for pasture and hay production. There is

[1] See Ky. Agr. Exp. Sta. Bul 397 for details of treatment and results.

considerable land in river and creek bottoms in eastern Kentucky, the Western Coal Field, and the Purchase area that needs draining. Demonstrations have shown that such land can be made to produce high yields of cultivated crops, particularly corn, that will soon pay the cost of tile drainage. On the drained land crop rotations should be used, of such length as the area will permit.

CONSERVATION OF FARM BYPRODUCTS

As previously stated, there can be no effective erosion control without a vigorous vegetative cover, and this kind of cover cannot be produced on depleted soil. The wastage of farm manure in Kentucky is enormous. It is estimated that about 16 million tons of manure are produced per year in Kentucky, worth 40 million dollars with manure valued at $2.50 per ton, a conservative evaluation in terms of its effect on crops. Probably 30 to 40 percent of the value of this manure is lost under prevailing practices. The manure from a 1,000-pound animal is worth about $25 a year. The proper conservation and use of farm manure and crop residues is one of the most effective ways of preventing erosion. This is true because it makes the grassland more effective and because, by increasing the productivity of the cultivated land, a smaller acreage is needed to produce the necessary grain.

Most of the potash in feed consumed by animals is returned in the excrement, and if it is not conserved serious potash deficiencies will occur in the soil, as has been clearly shown by experiments, and as is evident from observations in all parts of the state. An average of about three-fourths of the nitrogen in feed consumed by animals is found in the excrement. Much of both the potash and nitrogen is in the liquid excrement. This should be conserved by using bedding.

All corn should be cut and the stalks run through the stalls or feeding sheds. Many farmers who do not have enough straw and stalks for bedding their animals could profitably cut weeds and wild grasses before the seeds mature, and use them for bedding. About three-fourths of the potash and one-fourth of the nitrogen of grain crops are in the stalks and straw, hence the great importance of conserving these byproducts.

Large amounts of plant food are wasted in Kentucky through failure to use tobacco stalks properly. A ton of tobacco stalks contains $10 to $12 worth of nitrogen and potash, a large part of which is soluble in water. When, as is often done, the stalks are exposed to rain a large part of these elements is lost. The stalks should be kept under cover till spring and then spread on grain or grass. They can be mixed with straw bedding in stalls and feeding sheds. Serious potash deficiency will soon develop in soils if all byproducts are not carefully saved and returned to the soil. The larger the crops that can be grown, the easier it is to keep land productive, because of the larger amount of crop residues and manure that can be returned. This, of course, implies good rotations with sufficient legumes in them, and the careful saving and use of the residues and manure.

PUBLICATIONS ON SOIL IMPROVEMENT AND CONSERVATION

Copies of the following publications by the Kentucky Agricultural Experiment Station and Agricultural Extension Division may be obtained free by citizens of Kentucky from their county agricultural agents, or by addressing the Director, Agricultural Experiment Station, Lexington 29, Kentucky. Other publications, by the U. S. Department of Agriculture, also are available.

BULLETINS

374. Legumes in Cropping Systems
379. Soil Management and Fertilization for Tobacco
397. Soil Management Experiments
420. Field Tests of the Relative Effectiveness of Different Phosphate Fertilizers

EXPERIMENT STATION CIRCULARS

52. Grass Farming for Improving Depleted Soils

EXTENSION CIRCULARS

54. Soils
272. Soil Management for Kentucky
304. Soil Erosion and Its Control
312. Growing Alfalfa in Kentucky
318. Crimson Clover and Other Winter Legumes
350. Save the Soil and Improve It
366. Sweet Clover for Kentucky
402. Seeding Meadow and Pasture Crops

LEAFLETS

18. Soil-improving Materials
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81. How to Succeed with Winter Pastures
82. Sow Small Grain on Lespedeza Fields for Pasture

A- 1. Cover Crops
A- 4. Contour Cultivation
A- 7. Value, Conservation, and Use of Manure
A-10. Cutting, Curing, and Storing Hay
A-16. Winter Pastures
A-19. Sow Alfalfa and Grass Together
A-20. Save Vetch Seed on Kentucky Farms

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