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PUBLICATIONS FOR REFERENCE

Any of the following publications on soils and crops will be sent free to citizens of Kentucky upon request addressed to the Director of the Experiment Station, Lexington, Ky.

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339 Black-Stem of Alfalfa, Red Clover and Sweet Clover.
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Circular No. 350

SAVE THE SOIL AND IMPROVE IT

By GEORGE ROBERTS

Soil conservation in its fullest sense means preventing as much as possible all kinds of losses from the soil. The principal sources of loss are erosion, the leaching of plant nutrients in the underdrainage waters, and the removal of plant nutrients by crops. For the state as a whole, the greatest loss is from erosion. However, if there were no erosion, the losses from uncontrolled leaching and by crop removal without the return of manure and crop residues would soon reduce a fertile soil to a low state of productivity.

Some soils, in their virgin state, are so deficient in mineral plant nutrients that it is impossible to maintain satisfactory productivity unless the deficiencies are remedied. The mineral deficiencies of Kentucky soils are generally calcium (lime), phosphorus and, in some cases, potassium (potash).

The first step in improving soil is to supply the mineral plant nutrients in which the soil is deficient and then to grow legumes and properly utilize the nitrogen they gather from the air in growing grasses, grain crops, tobacco, and other non-legume crops. There can be no effective control of erosion without a dense ground cover, even tho terraces and other engineering practices are used. Neither can leaching of plant nutrients be reduced without a ground cover ready to grow when weather conditions are favorable. A protective covering is dependent upon a sufficient supply of plant nutrients.

THE PREVENTION OF EROSION

Erosion causes the greatest loss from soils on sloping land, and it may be very great even on moderate slopes. Fortunately this source of loss has been greatly stressed in recent years, and farmers are becoming conscious of its seriousness. Erosion has caused enormous damage to soils in most parts of Kentucky. Just how much damage it has done it is not possible to estimate accurately, but it is the greatest cause of low soil productivity in the State. A great deal of uniform surface washing often occurs before the farmer is very much aware of it. Too often he is not seriously impressed until gullies begin to form. This stage usually occurs after a large part of the top soil has been removed.

As stated. the most effective means of preventing erosion is keeping a dense vegetative cover on the soil as much of the time as pos-

sible. A very large part of the soils of Kentucky has been so reduced in fertility that a cover cannot be produced that will prevent erosion, and for this reason much of the cultivated area of the State is not even seeded to winter cover crops.

The best land cover is a vigorous grass-legume sod. For this reason, Kentucky farmers should maintain livestock as much as possible on pasture and hay. To get good results, the pasture and hay must be of high quality. This requires that the soil be well supplied with mineral plant nutrients and with nitrogen, which is most

A good pasture made on unproductive land at Western Kentucky Experiment Substation.

economically obtained thru legumes. The minerals most often deficient in Kentucky soils are lime and phosphate. Pasture and hay grown on soil deficient in these minerals often lack sufficient calcium and phosphorus for the proper nutrition of animals. Animals usually are not well nourished when fed crops grown on impoverished soil, altho they may have all the feed they can consume. Animals often will refuse to graze pasture on soil deficient in mineral nutrients when pasture on treated soil is available.

With good pasture, the grazing period will be longer, and with plenty of nutritious hay less grain will be required during the winter feeding period, thus greatly reducing the acreage that will have to be plowed for grain. If the cultivated land is made productive, less acreage will be required, and it will produce a good

winter cover crop which can be used for fall, winter and early spring pasture, which will further reduce grain requirements. Acre yields of corn can be increased by the use of hybrid corn, making possible a futher reduction of the corn acreage.

An outstanding example of the grass-livestock type of farming is in the Central Bluegrass region, in some parts of which as much as 80 percent of the land is in grass for pasture and hay. This system is also best for the production of both Burley and dark tobacco. This area has, in the judgment of the writer, suffered less from erosion than any other agricultural land in the United States, of similar topography and rainfall. That productive pasture of protective sods can be produced economically on badly impoverished soils in the State has been well demonstrated.

Mechanical means of controlling erosion are highly valuable under many conditions, but none of them will prevent erosion unless the soil is made fertile and good cropping practices are used. Terracing and gully control practices are very important and are treated in Kentucky Extension Circular No. 304.

Contour cultivation is effective in reducing erosion. It is described in Kentucky Agronomy Extension Leaflet No. 4. Contour cultivation means planting and cultivating across the slope. The furrows and ridges made by contour cultivation check the flow of water, causing more of it to enter the soil. When seeding and cultivation are done with the slope, the furrows cause a rapid runoff of the water, carrying with it much soil. It is very impressive to observe fields after spring planting and see the difference in erosion on land planted and cultivated in the two ways. The amount of erosion is often very great on land seeded to winter grain drilled with the slope, as compared with drilling on the contour.

The writer has observed serious erosion on land that was prepared for planting by rolling or dragging it smooth and on which a heavy rain fell before planting. Land smoothed in this way should be planted on the contour at once before a rain comes, and immediately cultivated to roughen the surface. Land planted to row crops on the contour should be cultivated after rains, to loosen and roughen the compacted surface to reduce runoff. Erosion may be lessened by leaving sod strips on the contour at intervals on sloping land.

Where sloping land must be cultivated frequently, strip cropping is helpful in controlling erosion. Strip cropping consists in laying out narrow strips or fields across the slope and alternating the

intertilled crops with thick-seeded crops or, better, having as many of the strips as possible in grass or other dense-seeded crop, always having the intertilled crops between thick-seeded crops except, of course, when the intertilled crop is on the top or the bottom strip. In other words, adjoining strips should never be used for intertilling crops at the same time. (For types and details of strip cropping see Farmers Bulletin 1776, U. S. Department of Agriculture.) The writer believes, however, that if there is level or gently sloping land on the farm, it is better to keep the steeper land in a grass-legume mixture for pasture and hay and produce corn on the level to gently sloping land in a short rotation or even in continuous culture. A two-year rotation of corn and winter grain can be used, with a legume seeded grain to be turned under the next spring for corn. If the land can be limed, a mixture of sweet clover and lespedeza is excellent. If only lespedeza is used, a winter cover should be seeded in the fall. If the legumes thrive, they will furnish a large part of the nitrogen required by the corn and small grain, and using enough manure to furnish potash for these crops may involve a considerable waste of nitrogen in the manure. It would be better to use fertilizer potash for the corn and winter grain along with the phosphate required, and to use the manure elsewhere, if needed, or perhaps use a limited amount of manure for the corn. The Experiment Station has had some excellent results with similar two-year rotations.

SUPPLYING DEFICIENT MINERAL NUTRIENTS

If any one plant nutrient is deficient in a soil, it will limit crop growth, altho all others are present in sufficient quantities for maximum growth. This fact is well illustrated in an experiment on one of the Kentucky soil experiment fields where an untreated plot yielded 575 pounds of tobacco per acre. Another plot treated with limestone, potash and nitrogen yielded 580 pounds, while another plot with the same treatment plus phosphate yielded 1410 pounds. Phosphorus was the first limiting element, and its deficiency prevented the other application from having any effect.

Phosphorus is deficient in practically all soils outside the Bluegrass area and in many places within the Bluegrass area. Most of the soils of the State need liming. The exceptions are soils that contain limestone fragments in or near the surface soil, and soils in regions of marl deposits, particularly on slopes below marl outcrops.

Sandy soils are usually deficient in potash, but there is not much sandy soil in Kentucky. The soils of Kentucky generally have a

high content of potash, but potash deficiency will develop in any soil if crops are harvested regularly and crop residues and manure are not saved and returned to the soil. This will be discussed under the heading "Conservation and Use of Crop Residues and Manure." No other serious mineral deficiencies are likely to occur in Kentucky soils if crop residues and manure are properly saved and used.

A plentiful supply of the mineral nutrients is absolutely essential to soil improvement and conservation. As already indicated, a lack of any of them limits the growth of legumes necessary as a source of nitrogen for the non-legume crops. An abundant supply of nitrogen is required for high yields of general farm crops and for the production of good grass for pastures and hay and for soil protection. The mineral nutrients are, of course, just as necessary for the non-legume crops as for the legume crops. The soils of the Central Bluegrass region are fertile because they contain a large supply of mineral nutrients. The chief difference between the mineral content of these soils and the soils of other parts of the State is the content of calcium and phosphorus, the elements supplied in liming materials and in phosphate fertilizers. There is abundant evidence in experimental work and practical farm experience that if sufficient lime and phosphate are used on soils deficient in these elements, and legumes are grown and properly used, such soils can profitably be made highly productive. (See Kentucky Bulletin 397, "Soil Management Experiments.")

Excellent bluegrass sods have been economically produced on the soil experiment fields at Campbellsville, Greenville, Princeton, and Mayfield, on which tobacco of high yield and good quality has been produced. (See Kentucky Bulletin 379, "Soil Management and Fertilization for Tobacco.")

Results from the outlying soil experiment fields in Kentucky show clearly that unproductive soils can be made productive at comparatively small cost by the use of lime and phosphate and the proper use of legumes and manure. Following is a summary of the results from the use of lime and phosphate on ten Kentucky soil experiment fields, extending over periods of ten to twenty-six years.

With one exception, these experiments were established on badly depleted soils. The average yields include the low yields in the experiments. The average yield of corn for the last eight years on the older fields was approximately 53 bushels per acre. The other crops were correspondingly higher in the later years.

Crops	No. crops averaged	No. corn crops for which manure was used	Yield per Acre: Yield without limestone or phosphate	Yield per Acre: Yield with limestone and superphosphate
Corn, bus.	163	106	29.2	46.7
Soybean hay, lbs.	89		2218	3611
Wheat, bus.	120		7.3	16.5
Mixed clover hay, lbs.	137		1301	3721

The average rate at which limestone was used was about 1 ton in four years. The average annual rate for superphosphate was equivalent to approximately 130 pounds per acre of 20 percent superphosphate. Rock phosphate used on limed soil at double the rate of superphosphate gave practically the same results, except where the soil was overlimed in the earlier years of the experiments. (See Kentucky Experiment Station Bulletin 397.) The phosphate was applied in sufficient quantity on corn or wheat for the rotation. Three and four-year rotations were used.

Bluegrass-legume Mixture, Greenville Experiment Field

Manure, when used, was applied for corn at a rate equal to the weight of the crops removed in the rotation the preceding year (wheat grain excepted). Manure was used both where limestone and phosphate were used and where they were not used, but of course at a heavier rate where limestone and phosphate were used, because of the heavier yields of crops.

When phosphate is used liberally (with lime where necessary), it not only profitably increases yield while being used, but a reserve of phosphorus may be built up in the soil which will be effective for a long time without further application. For example, on the Campbellsville Experiment Field, 900 pounds of 16 percent super-

phosphate per acre, applied once each three years on limed ground for a three-year rotation of corn, wheat and mixed clover hay, was compared with 600 pounds used in the same way. The extra 300 pounds barely paid for itself over the twelve-year period (1919-1930) in which it was used. The use of the 900-pound rate was discontinued after 1930. From 1931 to 1938, the average yields of crops where the phosphate was discontinued and on check plots where no lime or phosphate had been used were:

	Corn, bus.	Wheat, bus.	Mixed hay, lbs.
No phosphate (check plots)	38.2	6.3	2558
Phosphate used previously	60.1	15.9	4632

Raw ground rock phosphate used at double the rate of superphosphate gave similar residual effects. Used at these comparative rates the rock phosphate supplied four times as much phosphorus as the superphosphate. The experiment will be continued without addition of phosphates to see what the results will be over a much longer period of time. (See Kentucky Bulletin 397, pages 361 to 367, for a fuller statement of these results. For further experiments on the residual effect of phosphates, see pages 354, 374 and 380 of the same bulletin.)

On the average, raw ground rock phosphate contains approximately twice as much phosphorus as an equal weight of 16-percent superphosphate, or 1.6 times as much as an equal weight of 20-percent superphosphate. On some soils, two parts of phosphorus in rock phosphate is about as effective as one part in superphosphate. On other soils the ratio required may be as great as 4 to 1. The relative effectiveness varies with the soil type and previous treatment, particularly liming. It is obvious that the price relationship between rock phosphate and superphosphate is an important factor in determining which to use. A much larger reserve of phosphorus is built up in the soil from the use of rock phosphate than from superphosphate when used on the same cost basis.

Basic slag is another effective source of phosphorus (see Kentucky Bulletin 397, pages 363-365 for tests). Bone meal is also an effective source of phosphorus.

The effectiveness of phosphorus in "colloidal phosphate" is similar to that of phosphorus in finely ground rock phosphate, altho we do not have enough experimental tests to warrant a definite statement of relative value.

When both limestone and rock phosphate are used, the limestone should not be used too heavily, for heavy liming reduces the

effectiveness of rock phosphate on some types of soil. Usually one to two tons of limestone is sufficient for a period of ten to twelve years, when used with rock phosphate, except for alfalfa. If a farmer is unable to use both lime and phosphate where both are needed, it is best, in most parts of the State, to use phosphate. However, in the Purchase region it is usually best to use lime if only one material can be used. This may be true of some of the more strongly acid soils of the limestone area in southwestern Kentucky. Many of the high-phosphorus soils of central Kentucky need liming but do not need phosphate.

THE GROWING AND USE OF LEGUMES

(See Kentucky Bulletin 374, "Legumes in Cropping Systems")

There can be no significant improvement of Kentucky soils without the growing and proper use of legumes. If not properly used, the ultimate result from growing them may be a further depletion of the soil. It is believed that on the average soil, legumes take about one third of their nitrogen from the soil and two thirds from the air. Thus if the part removed for hay weighs more than twice as much as the roots and stubble, the soil may be left poorer in nitrogen by growing the legume. Also, the percentage of nitrogen in the roots is, on the average, less than in the tops, and decidedly so in cowpeas and soybeans. When soybeans and cowpeas are removed from the land without the return of the straw or the manure made by feeding the crops, the soil is left poorer in nitrogen, except possibly when the soil is extremely deficient in nitrogen. (See Kentucky Bulletin 374, pages 134 and 139). The richer the soil in nitrogen, the less is the proportion of nitrogen that legumes take from the air. Thus even red clover harvested may leave some soils poorer in nitrogen.

All the legumes make a heavy draft on the mineral nutrients of the soil. Alfalfa is especially exhaustive of mineral nutrients. A ton of alfalfa contains about 40 pounds of potash. It is not uncommon to keep alfalfa on a piece of land five years or more. If 3 tons of hay a year for five years are harvested, it takes from the soil about 600 pounds of potash. This draft will soon render any soil deficient in potash unless manure or potash fertilizer is used liberally.

If legume crops are to increase the nitrogen in the soil and not rapidly deplete the mineral elements, the crops must be returned in some way. It is expensive to grow them to be turned under. It is usually better to graze them or to feed them and carefully save the manure and return it. However, it often pays to turn under the first le-

gume crop grown on poor land as a means for quickly improving it. Sweet clover used in this way is very effective. Where a winter cover crop is used on cultivated land, it is good practice to grow a winter legume, if possible, or a mixture of the legume with a winter grain or rye grass. Crimson clover and hairy vetch are good for this purpose.

Legumes, with the exception of alfalfa, should have a grass grown with them, when possible, to prevent leaching. Where this is not practical, a winter cover crop should be used, as will be discussed under "Losses from Leaching." Grass should be grown with alfalfa on sloping land, to prevent erosion. Seeding bluegrass with alfalfa is an excellent way to get a good bluegrass sod.

A ton of average legume hay contains about 40 pounds of nitrogen, which represents roughly what the crop, including roots and stubble, gets from the air, except the soybean and cowpea hays generally contain more nitrogen than the whole crop gets from the air, because the roots and stubble of these crops are such a small part of the whole crop. Animals excrete, on the average, about three fourths of the nitrogen in the feed they consume, but a large part of it is in the urine. Therefore, the careful saving and use of manure, including the urine, is very important in maintaining the nitrogen supply.

THE CONSERVATION OF FARM BY-PRODUCTS

The wastage of farm manure in Kentucky is very great. It is estimated that manure produced annually in Kentucky amounts to about 16,000,000 tons a year, worth $40,000,000, with manure valued at $2.50 per ton—a conservative valuation in terms of its effect on crops. Probably 30 to 40 percent of the value of this manure is lost under prevailing practices. The average yearly excretion of manure by horses and cattle is about 10 tons per 1000 pounds of live weight. Using fertilizer terms, a ton of average fresh manure contains about 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash. Nearly half of the nitrogen and two-thirds of the potash are contained in the liquid excrement, as an average of horse and cow manure; hence the very great importance of conserving the liquid with bedding and so handling the manure as to prevent losses from heating and from leaching, which are great from manure as commonly handled. (See Kentucky Agronomy Extension Leaflet No. 7 on conservation and use of manure.)

A practice that is prevalent in parts of Kentucky and which should be discontinued is husking corn from the standing stalk

and leaving the stalks on the field. The corn should be cut and the stover used for whatever feeding value it may have, with the refuse going thru the stalls for bedding. Such fields often do not have cover crops on them because they are difficult to seed. If there is a shortage of bedding, it would pay to cut weeds and wild grasses before seeds mature and use them for bedding.

That the failure to conserve and use manure may result in serious potash deficiency is forcibly illustrated by the two following experiments:

Average yield per acre

	Corn, bus., 24 crops				Wheat, bus., 22 crops			
	First 9	Next 9	Next 5	1939	First 7	Next 7	Next 7	1939
MLP	40.7	52.7	50.9	69.7	18.6	25.8	21.9	25.3
—LP	36.3	39.2	32.7	37.6	17.1	21.1	18.8	16.7

	First-year hay, lbs., 20 crops				Second-year hay, lbs., 8 crops	
	First 7	Next 7	Next 5	1939	First 7	1939
MLP	3673	4967	6000	3820	4707	1400
—LP	3417	3696	4409	2870	3997	780

M = manure, L = limestone, P = superphosphate.

A test was begun on the Mayfield Experiment Field in 1913, in which two sets of plots (four in each set) were liberally limed and treated with phosphate thruout the period since. No manure or crop residues were returned to either set of plots for the first three years. Beginning with 1916, manure was used at a practical farm rate on one set of plots. The crop yield, by periods, are shown below. The yields of corn on the two sets of plots for the first round of the four-year rotation were 39 and 38 bushels, respectively.

Potash deficiency symptoms in corn were observed in the later years on the unmanured plots. In 1937, corn on a part of the unmanured plot was treated liberally with fertilizer potash in the hill. The yield of corn for the potash-treated part of the plot was 52.1 bushels per acre, and on the remainder of the plot it was 29.3 bushels. The yield of corn on the regularly manured plot was 52.6 bushels per acre.

An experiment on the Experiment Station farm at Lexington shows how fertile land may be rapidly depleted in potash if manure and crop residues are not saved and returned to the soil. The experiment was begun in 1920 on soil that was in a good state of productivity. It would produce about 75 bushels of corn per acre in a good season without the use of manure or fertilizer. The rotation used was corn, wheat and clover.

Seven sets of plots were not manured. Four sets of plots were treated once each rotation period with 4 tons of manure per acre, four sets with six tons, and four sets with 8 tons. This was continued from 1920 to 1938, inclusive. In 1939 the use of manure was discontinued. One half of each plot that was planted to corn in 1939 was treated with 200 pounds of muriate of potash, applied broadcast. The yields of corn were as follows:

Former manure treatment	Yield of corn, 1939, bushels per acre		
	No potash	Potash	Increase for potash
None	38.3	48.1	9.8
4 Tons	47.8	53.0	5.2
6 Tons	51.4	54.2	2.8
8 Tons	56.8	57.6	0.8

About 11 tons could have been produced from the crops grown on an acre in three years where the 8-ton application of manure was used.

The low yields of crops grown upon unproductive soils do not make a heavy draft on potash. When these soils are treated with lime and phosphate and legumes are grown, good yields of legumes and other crops usually follow with a heavy draft on potash. A potash deficiency may not show up at once, but unless potash is returned in manure or is supplied in fertilizers, a shortage will sooner or later develop. Symptoms of potash shortage are showing up in many places where yields have been improved with lime, phosphate and legumes but manure or fertilizer potash has not been used. Alfalfa makes a very heavy draft on potash, taking up 40 pounds or more per ton of hay. A 50-bushel corn crop requires between 40 and 50 pounds of potash. Fortunately for the farmer, about three fourths of the potash of grain crops is in the stalk and straw and can be saved and returned to the soil. About nine tenths of the potash in the feed eaten by animals is returned in the manure; but, as previously stated, about two thirds of it is in the liquid manure. A large part of that contained in the solid manure is soluble in water. Hence great care is necessary to conserve the potash taken from the soil by crops. A large wastage of potash and nitrogen occurs when tobacco stalks are exposed to rain before spreading. A ton of tobacco stalks is worth ten to twelve dollars for the nitrogen and potash they contain, valued at commercial fertilizer prices. Conservation of crop residues and manure is indeed a big phase of soil conservation.

PREVENTING LOSSES FROM LEACHING

Leaching is a source of much loss from land unprotected thru the fall, winter and early spring by a green crop. Annual lespedezas stop growing early in the fall, and there is considerable decay of material before much growth occurs the next spring. When any vegetable material decays, a large part of the nitrogen that it contains is converted into soluble form and is subject to leaching unless there is some green crop on the land to use it. Annual lespedezas should have grass growing with them or the lespedeza sod should be seeded to a winter cover crop each fall. There may be considerable leaching of nitrogen under red clover any time after a considerable part of the plants die, as often occurs following hay harvest. In some experiments at Lexington where red clover and bluegrass were seeded together on soil in tanks the annual loss of nitrogen was at the average rate of 6.2 pounds per acre over a period of five years, while with red clover seeded alone the rate was 55 pounds. There would evidently be much leaching of nitrogen following the second year's growth of sweet clover that had no grass or winter cover crop following it, for sweet clover dies in its second year.

In some tanks at the Experiment Station, lespedeza was cut into the soil on October 1. In one set of the tanks no cover crop was sown, and in the other set rye was sown October 1. Between October 1 and June 30 the soil without a cover crop lost nitrogen at the rate of 127 pounds per acre, while the soil with a cover crop lost only 2 pounds per acre. Where lespedeza was allowed to stand without a cover crop and was not cut into the soil the loss was 56 pounds. It takes 800 pounds of nitrate of soda to furnish 127 pounds of nitrogen. Similar losses have been found to occur in the field, tho not so large. It should be remembered that much of Kentucky's soil rests upon limestone, and that drainage thru it is very rapid.

Lespedeza is the most important legume at present grown in Kentucky, and can be used to greatly improve soils, but if, as already stated, it does not have either grass with it or some other cover crop thru the winter, there may be much loss of nitrogen from leaching. Also, the removal of lespedeza without returning manure from it is a heavy draft on the mineral nutrients of the soil, as has already been indicated. Lespedeza is so generally grown that attention to its use is especially important.

Leaching of nitrogen is great on cultivated soil left without a cover crop unless the soil is too poor in nitrogen to develop much soluble nitrogen. On the Experiment Station farm, tobacco was grown following a very rich sod. A cover crop experiment following the tobacco showed that a cover of barley seeded early took up over 150 pounds of nitrogen per acre by December 1. (See Kentucky Experiment Station Bulletin 374 and Extension Circular 272 for leaching experiments.) In another experiment, barley seeded September 11 following tobacco took up 46 pounds of nitrogen by December, whereas wheat seeded October 10 took up only 10 pounds. Early seeding of winter cover crops is very important.

Some of the mineral nutrients leach readily, particularly calcium (lime) and potassium. This can be prevented to some extent by keeping the land covered as much as possible with growing crops. However, there is a large loss of calcium in the drainage water under any crop. For this reason, no more lime should be applied than is necessary to meet crop needs. In other words, instead of heavy applications at long intervals, it is better to make lighter applications more frequently. (See Kentucky Experiment Station Bulletin 397, pages 338-40.)

To repeat, the best protection against leaching is a heavy grass-legume sod—another reason for using the grass type of agriculture as much as possible, to say nothing of the lessened amount of work in maintaining livestock more on grass.

Eternal vigilance is the price of a productive soil. How many farmers reseed thin places in their pastures and meadows or give the thin places special treatment to ensure a stand of grass and legumes? How many watch for the first signs of gullies and try to stop them? How many continue to seed and cultivate with the slope notwithstanding the numerous warnings against it? How many continue to expose tobacco stalks to the rain before spreading them? Vigilance requires knowledge and wisdom in its application. It is the earnest plea of the writer that farmers study diligently their soil problems by every means available. Especially should farmers read carefully the bulletins and circulars on the subject issued by the College of Agriculture and Experiment Station. They are based on many years of experimental work, observation and experience.

There will never be effective soil conservation until all who use the land realize and fulfill their obligation to pass the land on to the next generation unimpaired.

Keep Kentucky covered with grass and legumes!