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THE RELATION OF LIVE STOCK to the MAINTENANCE OF FERTILITY

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The Relation of Live Stock to the Maintenance of Fertility.*

By GEORGE ROBERTS

TWO SYSTEMS OF FARMING

In discussing this subject, I shall proceed upon the well established basis that fertility may be maintained by a system of cropping and soil treatment without the feeding of live stock and the use of manure, or with feeding and the use of manure.

The fundamental practises underlying both systems are the same; namely, a sufficient stock of mineral plant food in the soil and the maintenance of nitrogen and organic matter sufficient to produce maximum profitable crops.

If a soil is deficient in any of the minerals necessary to plant growth, such as lime and phosphates, there is only one way to supply them in either system, and that is to purchase them. But these and other mineral plant food materials may be obtained from mineral deposits without a draft upon any other farms.

The relative efficiency of the two systems in maintaining productiveness, then, rests largely upon the question of the return to the soil of organic matter and nitrogen in the two systems, altho not entirely, for there is some difference in the mineral matter removed by crops from the soil that can be returned by the two systems.

THE TWO SYSTEMS DEFINED

I shall designate the two systems "the grain system" and "the live-stock system." In a typical grain system, grain and seed are sold. All stalks and straw are returned to the soil, and

*An address delivered at the Farm and Home Convention, University of Kentucky, February 1, 1922.

if clovers are used in the cropping system the first crop of clover is left on the ground, and the second crop is cut for seed and the straw and chaff returned. In the live-stock system, usually only wheat grain is sold and everything else is fed or used for bedding. The manure produced is returned to the soil. There may be various combinations of the two systems from that in which a small proportion of the crops is fed, to that in which nearly all is fed, but we shall consider each as defined above. When these are understood, an understanding of any combinations of the two systems is easy.

I shall limit the use of manure in the live-stock system to what can be produced by feeding the crops grown on the individual farm. In other words, the feeding of purchased feeds will not be considered, for fertility gained on one farm from the use of purchased feeds is lost from another farm. The practis is applicable without injury to the farm selling feed provided only grain is sold and sufficient residues and legumes are used. This necessitates that the farmer who buys grain for feeding shall produce his own hay and roughage. As a matter of fact, only about 20 per cent of the corn grown in this country is shipped out of the county in which it is grown, and much of that is used in the industries and for human food.

To maintain productiveness by the use of purchased feeds is no test of a farmer's ability as a farmer to maintain productiveness on a scientific basis. It is a measure of his ability to buy feed and live stock and sell the animals at a profit.

COMPARISON OF THE TWO SYSTEMS

1. *On Basis of Crop Yields.*

In Illinois there is a large number of soil experiment fields which have been under way from four to nineteen years, on which the grain system and the live-stock system have been compared. The rotation used in each case is corn, oats, clover and wheat. In the grain system, the cornstalks and the oats and wheat straw are returned to the soil. The first crop of clover is cut and left on the ground. The second crop is cut for seed and

the straw and chaff from threshing the seed are returned to the soil. The grain and seed are sold.

In the live stock system, all the crops are harvested and are fed or used for bedding, except the wheat grain. One ton of manure is returned to the soil for each ton of produce removed. This is about the amount of manure that can be saved in the best farm practis, altho under certain ideal conditions more may be saved.

As an average of the yields from 18 fields where a strict comparison of the two systems is possible, we get the following results:

	Corn, bus.	Oats, bus.	Wheat, bus.
Increase for manure in live stock system	8.3	4.3	2.6
Increase for residues in grain system	5.2	2.9	2.2
Increase for manure, limestone and phosphate in live-stock system	14.6	9.5	8.9
Increase for residues, limestone and phosphate in grain system	14.3	10.2	8.8

It will be noticed that where lime and phosphate are not used the crop increases are greater in the live-stock system, that is, where manure is used; but where limestone and phosphate have been used, the increases are *practically the same.* There is a reason for this. The soils of Illinois, like the soils of Kentucky, outside of the Bluegrass region, are deficient in phosphorus. Manure returns more of the phosphorus removed by crops than do residues. This extra return of phosphorus, tho small, affects crop yields, but since the manure is applied to corn, by the time the wheat, the fourth crop in rotation, appears, the phosphorus has been largely used up. The difference in return of phosphorus in favor of the live-stock system amounts to the equivalent of about 75 to 100 pounds of acid phosphate per acre in four years, worth about .75 to $1.00, an amount so small that it is negligible in choosing the system one prefers to follow.

2. *On Basis of Plant Food Returned.*

In the grain system three-fourths of the potassium removed by the crops may be returned in the crop residues, while in the live-stock system three-fourths or more may be recovered in the manure if properly saved. Since soils in this State contain large amounts of potassium and since such large amounts may be returned in either system, this is not a question of serious concern. This is substantiated by numerous experiments in many sections of the State, which have always shown little or no increase for the use of potassium fertilizers.

As already suggested, the chief problem centers on the return of nitrogen to the soil. Let us consider nitrogen in the crop yields in the foregoing rotation, which are approximately as follows:

Nitrogen	Grain	Roughage
Corn, 50 bu. per acre	50 lbs.	24. lbs.
Oats, 50 bu. per acre	33 lbs.	16 lbs.
Wheat. 25 bu. per acre	36 lbs.	13 lbs.
Clover, 2 tons per acre		80 lbs.
Total	119 lbs. plus 133 lbs = 252 lbs.	

In the grain system, 133 pounds of nitrogen would be returned. In the live-stock system, if the straw is used for bedding and the corn, corn stover, oats and clover are fed and three-fourths of the nitrogen is recovered in the manure, then about 170 pounds of nitrogen would be returned in the manure, provided the manure was saved without loss, but this is not possible under practical conditions. Counting one ton of manure saved to one ton of feed (instead of 1.3 tons to 1 ton of feed, the highest possibility), then, instead of 170 pounds of nitrogen returned, we would have 130 pounds returned, which happens to be about the amount estimated to be returned in the grain system. This is in keeping with the equal yields in the two systems in the Illinois experiments where lime and phosphate are used and nitrogen becomes the critical plant food factor. The assumption of a recovery of three-fourths of the nitrogen of

feed in the excrement of animals is approximately correct when applied to an average of all classes and ages of farm animals.

In either system some nitrogen will be provided in the growth of clover the year grain is harvested and some will be provided in the second growth of clover the next year.

THE VALUE OF ORGANIC MATTER IN THE SOIL

Animals excrete, on the average, about one-third of the organic matter of the feed consumed. Therefore in the grain system of farming, more organic matter can be returned than in the live-stock system. But I have come to agree with Dr. Thorne that manure and other organic matter is valuable primarily for the plant food it contains when used in a good rotation. It seems to me that the results which I have just presented in the comparisons from the Illinois experiment fields substantiate this belief, because more organic matter was returned in the grain system. The value of organic matter in the soil aside from the plant food it contains, lies chiefly in its effect in maintaining good structure or physical condition of the soil. If a good rotation of crops is used which includes a clover or grass crop, good physical condition will be produced by the roots and stubble of the crops.

THE CHOICE OF A SYSTEM

In view of the foregoing statements I would say that whether one is to practis grain or live-stock farming will be determined by the following considerations:

1. The personal preference of the farmer for producing crops only, or for growing animals in connection with his crop farming. (Some people do not like to care for animals.)
2. The ability of the farmer to breed or buy live stock of good quality and to properly feed, care for and dispose of it. He must be a good buyer and seller.
3. The relative prices of grain and live stock.
4. Whether his land is adapted to grain farming.

The first three points need no discussion by the agronomist, but the last point, the adaptability of the land, does need discussion.

There is much land in Kentucky that is too steep or rolling to be cultivated frequently. To do so means either a great deal of erosion or a great deal of expense to prevent erosion. Erosion is without doubt the greatest single cause of loss from our soils. It seems to me that the rational method of preventing erosion of such lands is to keep them in grass. This means the keeping of live stock to utilize the grass, and necessarily under such a system the crops grown on the farms will, most of them, be fed.

The farm management people would bring up the keeping of live stock as a means of better distribution of labor. It seems to me that this question is largely involved in the question of relative prices of grain and live stock, and I shall make no attempt to discuss this feature, altho where labor is employed for the entire year, this is an important consideration.

A point that may be mentioned in favor of the grain system is the smaller amount of labor involved in returning residues than in hauling manure, if all crops are fed under cover. If, however, stock is fed largely in the fields, or if crops are fed down, as in hogging down corn, then the statement does not apply. Another point in favor of the grain system is that after the land is built up to a good state of fertility, hay may be sold part of the time. On the Lexington farm we have a rotation of corn, soybeans, wheat and clover. In one place in this rotation, 10 to 12 tons of manure has been applied for corn for the last ten years. In another place, the cornstalks, wheat straw and soybean straw are returned, but the clover is removed for hay. In this system, the residues were not returned for the first five years. The average yield of corn for ten years, following manure is 56 bushels per acre, while following residues used as stated above, the average for the same period is 57 bushels. Of course, this does not prove that the selling of hay can be kept up indefinitely, but there is no falling off of yields as yet. But there is no doubt in my mind that as a practical system for the larger part of Kentucky, live stock is the most profitable system, but

before entering upon a more detailed discussion of the live-stock system, I wish to point out a case or two where the other system of farming may be practical.

On the level lands of the State, a rotation of corn, soybeans, wheat and clover may be used, and it seems to me a profitable rotation. On the Lexington farm such a rotation has yielded for the last ten years an average of 57 bushels of corn, 19 bushels of soybeans, 26 bushels of wheat and 4,375 pounds of clover hay. Properly used this rotation will keep up fertility and allow the selling of hay, for the rich soybean straw is returned, and considerable first-year growth of clover and second crop are left on the ground, as well as the cornstalks and wheat straw. At 50c per bushel for corn, $2.00 per bushel for soybeans, $1.25 per bushel for wheat, and $12.00 per ton for hay, the gross return per acre per year would be $31.00, which is probably more than most farmers get out of their land on the average.

In a tobacco-wheat-clover rotation at Greenville, we have had the following results:*

	Tobacco, lbs. (7 crops)	Wheat, bus. (5 crops)	Clover, lbs. (7 crops)
No treatment	424	6.7	727
Treated with limestone and phosphate	1003	24.0	3560

In this case only one of seven crops of clover was left on the land. The wheat straw, first year's growth of clover, tobacco stalks and second crop of clover were the source of organic matter and nitrogen.

For the tobacco farmer with small acreage of land, such a system with, say, every other clover crop turned under, should maintain yields. I may say that in the Greenville experiment

* This address having been made in 1922, the experimental yields have not been brought up to the date of this publication. To do so would not materially change them.

nitrate of soda used at the rate of 100 pounds per acre has not increased the yield of tobacco since it began to follow clover, and has increased the yield of wheat only 2.3 bushels per acre, not enough in the case of wheat to pay its cost. We do not know how much the yield would have been increased had all the clover been turned under, or had manure been used. We do know, however, that for a period of five years on the Lexington farm, 200 pounds of nitrate of soda per acre per year has been just as effective in increasing the yield of tobacco in rotation as 20 tons of manure per acre. The rotation was wheat, clover, orchard grass and tobacco, with all crops removed.

A fundamental consideration in either system, after supplying the necessary mineral matter, is a good rotation of crops containing clover of some kind, and better if lengthened to have grass for one or more years following the clover. Such a rotation should provide crops that would occupy the land thruout the year. Soil should not be left without a green crop of some kind thru the winter to serve the two-fold purpose of preventing washing, the greatest loss to Kentucky soils, and leaching, probably the next greatest loss. It has been proved that winter crops, such as wheat and rye, greatly reduce the leaching of nitrogen and that grass practically prevents it. If time permitted a study of the data, it would be very interesting.

THE LIVE-STOCK SYSTEM

It is sometimes said that the live-stock system is better than the grain system because more fertile live-stock farms are seen than grain farms. This is generally the case, for the reason that the grain farmer usually will not return his residues, and if he happens to be successful in growing clover he generally sells it.

There are a few live-stock farmers who maintain the fertility of their farms but often they are purchasers of feed, the manure from which helps to maintain fertility. Then again, the intelligence and care that are necessary to make live stock a successful venture mean the interest and intelligence necessary to keep soils fertile.

I wish to call your attention to the fact that most of our farmers in Kentucky are more or less live-stock farmers because nearly all crops are fed on the farm, but they have, in the main, failed to keep up the productiveness of the land. It is because they have not based their practises upon the principles already named as essential to productiveness.

When virgin lands were brought under cultivation, they were generally more or less productive. Altho the total amount of certain elements was small in some soils, they produced well because the plant food was available. Because the soils produced well, the farmer gave little thought to the return of plant food to replace what he was removing in his crops. He neglected winter cover crops to prevent erosion and the leaching of plant food. Clover began to fail, if he grew it at all before, and when he awakened to the necessity of improving his soil, he could not grow clover enough to furnish nitrogen, nor could he produce enough feed to make enough manure to go very far in the process of restoration.

The farmer then turned to complete fertilizers of low analysis, expecting them to solve his troubles without the necessary use of other good farm practises, and it took him a long time to learn that this would not save him. Having reached the bottom of soil depletion, the way upward is a long, hard one, and the rebuilding process must be based on sound principles.

I shall now discuss more in detail the relation of live stock to this rebuilding process.

THE UTILIZATION OF HILL LANDS AND UNPRODUCTIVE LANDS

I have stated that there is much rolling land in the State that should be kept in grass most of the time. There is much of this kind of land that has been cultivated to the point of abandonment and it has been thrown out as waste land and is practically worthless as now utilized. It can be made into first-class pastures by proper treatment. The first treatment it needs is limestone and phosphate. There are certain regions in the State where the limestone can be left off, such as the limestone hills of northern Kentucky. An example of this is in parts of Pen-

dleton county where sweet clover has been the means of restoring the land. Following sweet clover it has been easy to get grass, and when the land is well built up this way, alfalfa follows easily. There is no land in the State so poor that it will not grow sweet clover if given a treatment of limestone and phosphate. I cite some examples to show the great possibilities of some of the very poor soils of the State.

On a piece of badly worn land on the Berea Experiment Field the following results were obtained:

	No treatment	Treated with limestone and phosphate
Sweet clover, 1917	Failure	275 lbs. seed per acre; large yield of straw.
Clover straw plowed under, corn, 1918	20 bus.	40 bus.
Rye and sweet clover (pasture) 1919	Poor rye and clover failure	Good rye and clover.
Sweet clover hay, 1920	Failure	3,000 lbs.
Soybean hay,* 1920	1,570 lbs.	3,000 lbs.
Corn, 1921	10 bus.	43 bus.

The only return of organic matter made during this period was one crop of clover straw in 1917. The following case will show the effect of returning manure in connection with the use of lime acid phosphate.

In another experiment on this same field in 1921, 6 tons of manure on a clover sod with limestone and acid phosphate made 74 bushels of corn per acre, against 10 bushels per acre on the untreated land.

At Fariston, in Laurel county, on land that, untreated, has made an average of 12 bushels of corn per acre since 1916, and where clover is a total failure, we have made a first-class pasture of sweet clover and orchard grass during this period with one treatment of limestone and acid phosphate. On lands in Graves county, McCracken county and Muhlenberg county that were in

* The sweet clover was harvested in time to plant a crop of soybeans.

a low state of fertility very large yields of sweet clover have been made with the simple treatment of limestone and phosphate.

With experimental work done on eight different soil areas outside of the Bluegrass region, there is no escape from the conclusion that limestone and phosphate are necessary for the building up of the soil to a high state of production, and that it can not be done with manure only in the amounts that can be produced has been proved. In some regions where limestone cannot be used except at great expense, much headway may be made by the use of phosphate, but time will not permit me to go into detail in this. Information is available for those who desire it. On some types of soil, rock phosphate is almost fulfilling the function for both limestone and phosphate. When limestone and phosphate have been used, only the foundation has been laid for building the soil.

THE USE OF MANURE AND THE MAINTENANCE OF NITROGEN

How, then, shall the manure produced by feeding live stock be used for increasing productiveness?

One thing is sure and that is that the rotation must have enough legumes in it so that the recovery of nitrogen from them will offset the nitrogen that can not be recovered from the non-legume crops, whether in the grain system or in the live-stock system.

If, for example, a rotation without a legume in it were grown, as corn, wheat and timothy, and all the crops were fed with perfect saving of manure, it would not maintain the nitrogen supply. These crops get all of their nitrogen from the soil and at best only three-fourths of nitrogen in the feed can be recovered in the manure. If a rotation of corn, wheat and clover were grown, and all crops were harvested and no manure returned, the soil could not be built up to a high state of fertility, altho the clover would prevent its going backward so rapidly or to as low level as without it. Corn and wheat get all of their nitrogen from the soil. Clover does not get all of its nitrogen from the air. Neither is the nitrogen it gets from the air stored entirely in the roots or in the soil, but it is distributed fairly

uniformly thruout the entire plant, root and top. The assumption, fairly well supported by the experiment, is that the legume will take from the soil what nitrogen it is able to furnish and will draw upon the air for the remainder of its requirements. Of course this statement presupposes inoculation with the nitrogen-gathering organisms. According to Hopkins, legumes obtain, on the average, about one-third of their nitrogen from the soil and two-thirds from the air. In the case of red clover, about one-third of the weight of the entire plant is root and stubble and about two-thirds is the part removed for hay. It follows, then, that if the clover is removed and no manure made from it is returned, the soil is, on the average, no richer in nitrogen from the growing of clover. If the soil is quite poor in nitrogen, it will doubtless be left somewhat richer in nitrogen when the crop is handled in this way, whereas if the soil is quite rich in nitrogen, it probably will not be enriched and may be left poorer.

In the case of cowpeas and soybeans, only about one-tenth of the entire plants is root and stubble, while these plants obtain approximately one-third of their nitrogen from the soil. If this be true, it follows that the removal of these crops leaves the soil poorer in nitrogen. This is in keeping with farm experience where the manure made from these crops is not returned.

Let us consider here the sufficiency of a three-year rotation of corn, wheat and clover, for the maintenance of nitrogen.

	Nitrogen in:	
	Grain	Roughage
Corn, 50 bus.	50 lbs.	
Stover, 1½ tons		24 lbs.
Wheat, 25 bu.	36 lbs.	
Straw, 1¼ tons		13 lbs.
Clover, 2 tons		(80 lbs.)
	86 lbs. plus 37 lbs. = 123 lbs. taken from the soil.	

Return of nitrogen to the soil in manure:

¾ of nitrogen in corn and stover	55 lbs.
In wheat straw for bedding	13 lbs.
¾ of nitrogen in 2 tons of clover	60 lbs.
Total return	128 lbs.

To this should be added the nitrogen in first-year growth of clover and the aftermath after cutting hay, but this would probably about offset the necessary failure in practis to save all of the nitrogen voided by animals.

It is very evident that if the rotation is lengthened without putting another legume into it, it will be more difficult to maintain nitrogen. Another thing is also evident, and that is that the longer the rotation with only one legume in it, the greater the relative advantage of the live-stock system over the grain system in maintaining the nitrogen supply, for the reason that manure made by feeding the non-leguminous crops contains more nitrogen than the straw and stalks of these crops that would be returned in the grain system.

HOW MUCH MANURE CAN BE MADE?

1. From a given amount of feed.

Let us now answer the question, "How much manure can be made by feeding a given amount of feed?" which is the only test of how much manure may be used.

A number of tests made at the Ohio Experiment Station show that when animals are kept under shelter for the entire feeding period, from 1.3 to 1.5 tons of manure can be made for each ton of feed and bedding used. On this basis, the crops in the three-year rotation used above would produce about 9 tons of manure for each acre once in three years. However, it is hardly probable that such a saving would be made, but one ton of manure for each ton of feed and bedding would give 6.5 tons of manure, and this amount should be saved by reasonably good practis.

2. Amount of manure per aminal.

It may be of interest to note the amount of excrement voided per year by the various animals per 1,000 pounds live weight.*

	Amount tons	Per cent moisture	Solid
Horses	9.1	78	2.0 tons.
Cows	12.7	86	1.8 tons.
Steers	7.3	75	1.8 tons.
Hogs	15.5	87	2.0 tons.
Sheep	6.2	68	2.0 tons.

It is significant that when the solid matter is determined, that is, the actual dry matter, these animals produce almost the some amount of manure per 1,000 pounds live weight.

THE COMPOSITION OF MANURE

1. The composition of manure varies directly with that of the feed consumed. For example, animals fed on corn and timothy hay will produce manure much poorer in nitrogen than if they were fed on clover and wheat bran. A fully grown animal that is not giving milk nor producing young will return in the manure nearly all the plant food in the feed consumed, for they retain only what is necessary to replace broken down tissues, the products of which are voided chiefly in the urine.

2. The composition of manure varies with the kind of animal. Other things being equal manure from animals producing the wettest manure contains the lowest percentage of the plant food elements, altho animals producing the wettest manure produce the largest amount per unit of live weight.

3. The composition of manure varies with the age and condition of the animal. The manure of growing animals or animals producing milk does not contain as much nitrogen and phosphorus as the manure of grown animals, or animals not produc-

*These data are taken from "Soils," by Lyon, Fippin and Burkman.

ing milk, for the reason that these elements are important constituents of new bone and tissue and of milk.

It is sometimes stated that dairy farming is conducive to the conservation of fertility.

Using as a basis of calculation a good dairy cow producing 8,000 pounds of milk a year, we find that the following amounts of plant food are contained in the milk for one year:

		Value at Normal Prices
Nitrogen	45 lbs.	$9.00
Phosphorus	6.5 lbs.	.75
Potassium	11.3 lbs.	.75
		$10.50

The phosphorus and potassium outgo is not significant but the amount of nitrogen is. It is equal to the nitrogen in a crop of 45 bushels of corn, or 30 bushels of wheat, or 1,100 pounds of tobacco, leaf, or more than one ton of clover hay. The milk from 20 such cows would take from the farm the nitrogen contained in 22 tons of clover hay.

4. The composition of manure varies with the kind of bedding used. For example, manure mixed with sawdust bedding would not have the same value per ton as manure mixed with wheat straw bedding. A ton of average farm manure contains about 2 pounds of phosphorus, 10 pounds of nitrogen and 8 pounds of potassium.

RELATIVE VALUE OF SOLID AND OF LIQUID MANURE

The urine is as valuable as the solid manure. While the urine contains only traces of phosphorus, it contains on the average about 45 per cent of the nitrogen and 60 to 65 per cent of the potassium voided by the animal. It is therefore highly important that manure shall be so handled as to save the urine.

CONSERVATION OF MANURE

The first consideration in handling manure is to save the urine, which is usually best done by using enough bedding to absorb it. The use of cisterns involves an expenditure of money

and labor that I do not believe is profitable under present conditions.

The second consideration is to prevent heating and leaching. If the manure is removed daily or every two or three days and is spread on the land there is no loss from heating and little from leaching, except on bare ground. If manure cannot be spread frequently, special attention must be given to its storage.

If the manure can be allowed to accumuate in the stall, heating can be prevented by keeping it thoroly tramped, using just enough bedding to keep the animals dry. This method is specially applicable in the large feeding barns used by cattle feeders in western Kentucky.

Where stalls must be cleaned daily, as in dairy barns, or every few days, as in horse barns, there are two ways of handling the manure without much loss. One is the feeding shed where most or all of the stock on the farm is fed the roughage. The manure from the dairy cattle and horses is thrown into this shed and tramped in with the manure and litter of the feeding shed. The other way is to put the manure into a manure shed with a concrete floor and curbing and keep it well tramped and wet enough to exclude air and thus prevent heating.

If manure must be piled in the open then it should be built up in ricks well tramped and flat enough to admit enough water to keep the rick well wet, but not wet enough for water to run thru it into the ground. Exclusion of air by packing and wetting is the secret of prevention of loss by heating.

LOSSES IN MANURE

That manure will lose from one-half to two-thirds of its value in from four months to one year when piled in the open in the ordinary way is fully proved by many experiments, but I shall not attempt to quote them.

A very conservative estimate shows that the live stock on farms in Kentucky produce 10,000,000 tons of manure annually. It is also safe to assume that not more than half of this manure gets back on the soil where crops and pastures are being grown. This represents a loss to the State of at least $15,000,000.

THE VALUE OF MANURE

If manure is valued upon the basis of its plant food content at prices of commercial fertilizers in normal times, a ton of average manure is worth about $2.75.

We have been using manure on some of the soil of the experiment fields for the past six years. The rotation is corn, soybeans, wheat and clover. The application has been approximately six tons per acre once in the rotation, the manure being applied on the corn ground. As an average of five experiment fields on five different soil types, the crop increases produced by this amount of manure have been worth $2.45 per ton of manure, using the following prices for crops:

Corn, 50c per bushel.
Soybean and clover hay, $10.00 per ton.
Wheat, $1.00 per bushel.

When acid phosphate has been used with the manure, the manure has been worth $3.00 per ton, after deducting the cost of the phosphate. When limestone and phosphate have been used with it, it has been worth $4.25 per ton, after deducting the cost of lime and phosphate.

At the Ohio Experiment Station, where manure experiments have been in progress for twenty years, manure used on limed ground has been worth $3.34 per ton. When reinforced with acid phosphate it has been worth $5.72 after deducting the cost of the phosphate.

CONCLUSION

It seems to me that with the amount of rolling land there is in this State there can be no question that it can be most profitably utilized by keeping it in grass (including clover) to be pastured with live stock, while the more level lands are used to produce feed for carrying stock thru the winter and fattening it. Also, it seems to me that dairying and sheep raising may find a very large place in this State.

Of one thing I am sure. Our soils can not be built up with live stock upon our present methods of cropping and soil management. Outside of the Bluegrass region the soils should be treated with phosphate, and these, and some soils in the Bluegrass region, should be limed. After this is done there should be at least one acre in four of the cultivated acreage in legumes instead of one in *fifteen,* as is now the case. (Only 1 acre in 60 in clover.) Until the legume acreage is increased there is no hope of much improvement.

Lastly, the manure produced must be fully conserved.

By a universal adoption of the practises I have outlined, the net earnings of the farmers of the State could be increased many millions of dollars.