CROP ROTATION FOR ILLINOIS SOILS

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In order to give intelligent and profitable consideration to the subject of crop rotation, it is necessary to keep in mind the limitations as well as the advantages of this practice. In both grain farming and live-stock farming there are three absolute essentials that should receive attention, and these are of just as great importance in the growing of plants as in the growing of animals.

First, the seed of plants and the breed of animals.
Second, the food for plants and the food for animals.
Third, the home or lodging place, with proper protection and care, for both plants and animals.

The seed for crops is just as important as the breed of animals. The food for plants is just as necessary as the food for animals. The home, physical surroundings, protection, and care are just as important for plants as for animals.

In the briefest words we may well repeat:
Good breeding, good feeding, and good care, for animals and for plants.

Attention to each of these essentials is necessary in order to provide a permanent, prosperous agriculture in Illinois; but has each of these essential factors received attention from the average farmer and landowner?

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In animal production they have, as a rule, all received much consideration. The average live-stock farmer considers the selection and breeding of his animals, never forgets the importance of feeding his stock, and tries to give them the care they should receive.

In crop production the average farmer does give much attention to the selection of seed and very much attention to the care of the crop, including the preparation of the seed-bed, the planting and cultivation; but does he also provide plant food for the crops he is trying to raise? He does not. The American farmer in general, and the Illinois farmer in particular, has almost invariably followed the plan of working the land for all that's in it. He has practiced, and still practices, every expedient known to man to get fertility out of the soil, without making any adequate return.

Worse than that: he deceives himself, depletes his land, endangers his own prosperity, and robs his children of a rightful inheritance; and all this even when it would be much more profitable for him, and for all who are dependent on him, to adopt a permanent system of agriculture while he is still able to do so.

But will the owner of Illinois land ever pause in his onward rush toward soil depletion and land ruin before his lands, like those of the Eastern States, pass the point of possible self-redemption? I am truly an optimist, and I believe he will. Indeed, some Illinois farmers are already adopting permanent systems of farming, under which the soil grows positively richer, and permanently more productive.

If we plow the ground, prepare the seed-bed, plant the seed, cultivate the corn, harvest the crop, and pay the taxes and interest or rent on the land, why not give some intelligent consideration to the simple, common-sense problem of furnishing the plant food which the crop needs and must have for its own growth, especially when the cost of all the farm operations in growing the corn crop is just the same whether we grow 40 bushels or 80 bushels to the acre?

What are the essentials required in a system of farming that will increase and permanently maintain the fertility and productivity of the common land of Illinois? Phosphorus, organic matter, and limestone. Let these words be repeated and repeated until they find lodgment in the mind of the Illinois landowner. How much phosphorus? More than is required for the crops produced. What form of phosphorus? Any form, but if natu-
ral rock phosphate is used it should be so finely ground that at least 90 percent of it will pass thru a sieve with 10,000 meshes to the square inch. About one-half ton of good rock phosphate every four years will be ample to maintain the phosphorus content of the soil, even tho large crops are removed; but the first application may well be a ton or more per acre.

How much organic matter? Enough to maintain the nitrogen content of the soil. What form of organic matter? Farm manure, or clover, or other legume crops. For a 50-bushel crop of corn we must plow under the equivalent of 8 tons of average farm manure, or 2 tons of clover hay; and whoever fails to do as much as that will finally have soil that will not produce 50 bushels of corn per acre. That statement is not a guess, not an estimate, not a theory; it is a plain, hard agricultural fact, and it must be reckoned with and applied, or impoverished land will be the penalty.

The nitrogen of the soil is contained only in the organic matter, which in our common soil consists of the partially decayed roots and residues of prairie grasses or other vegetation; and, if we are still producing fair crops of corn, oats, wheat, or timothy, without plowing under equivalent amounts of manure or legumes, we are still wearing out the organic matter of the soil.

The following facts should be noted and used in connection with the study of crop rotation. To produce:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1 1/2 pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy hay requires 24 pounds of nitrogen.

For cereal crops about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks, and if these are burned their nitrogen is lost.

1 ton of average manure contains 10 pounds of nitrogen.
1 ton of clover hay contains 40 pounds of nitrogen.
1 ton of cowpea hay contains 43 pounds of nitrogen.

The roots and stubble of clover contain no more nitrogen than the clover plant takes from the ordinary soil, so that, if we grow clover and return to the soil only the roots and stubble, we do not increase the nitrogen content of the common Illinois prairie land. Not more than one-third of the nitrogen of the clover plant is found in the roots and stubble, and not more than one-tenth of the nitrogen of cowpea plants is found in the roots and stubble, at the usual time of harvesting these crops.
In live-stock farming the total animal excrements contain, as an average, three-fourths of the phosphorus, three-fourths of the nitrogen, and one-third of the organic matter from the food consumed. The liquid excrement contains more nitrogen than the solid. Of all farm produce, manure is probably the most susceptible to loss and waste. From the moment it is voided loss begins from leaching and from fermentation, and, as a rule, if left exposed for three months, half its value will be lost.

How much limestone? Enough to more than correct the acidity of the soil (if it is acid), and repeated applications of about two tons per acre every four years, in order to keep the soil sweet. What kind of limestone? Any kind that is high in carbonates,—the dolomitic limestone, found in northern Illinois being as good if not better than the pure calcium limestone found so abundantly along the Mississippi bluffs and in the Ozark Hills.

Phosphorus, organic matter, and limestone. What will it cost? About $1.50 per acre a year will provide both the phosphate and limestone delivered at almost any railroad station in Illinois. Thus, these two materials which must be bought will cost about 3 bushels of corn or 1½ bushels of wheat per acre per year, or, if a four-year rotation of crops were practiced, including wheat, corn, oats, and clover, it would require for one acre of land about 6 bushels of wheat or 12 bushels of corn to pay for the phosphate and limestone needed during four years.

After the system is well under way, the phosphate and limestone produce an increase of a ton per acre in the clover crop, an increase of 10 bushels per acre in the wheat crop, and an increase of 20 bushels per acre in the corn crop, above the yields produced without limestone and phosphate. The proofs of these statements are manifold, and amply sufficient to convince any man who will honestly examine the facts which are now easily available to every Illinois landowner. Not only the absolute chemical analysis giving the invoice of total plant food in the soil, but also the accurate results of hundreds of actual trials on many experiment fields, give this positive information.

Thus, in 1895 a piece of uniform land of the common cornbelt prairie was broken out of old pastures on the University farm at Urbana. Three divisions of this field were each divided into three plots, and corn was grown on all of the nine plots for three successive years. The average yield of corn on one set of three plots for three years was 63½ bushels per acre; on a second set of plots it was 63 bushels; and on the third set the three-year average yield was 66 bushels per acre. Later a three-year rota-
tion was adopted including one year each of corn, oats, and clover, and by having three divisions of the field it was possible to have each crop grown every year and still maintain the rotation.

On one set of plots, where organic matter has been added in the form of catch crops and crop residues produced on the land, the average yield of corn for the last three years, 1907, 1908, and 1909, was 58 bushels; on another set of plots, where organic matter and limestone have been added, the average yield of corn for the last three years has been 64 bushels; and on the third set of plots, where organic matter, limestone, and phosphorus have been added, the average yield of corn for the last three years has been 87 bushels per acre. We have also had about one ton more clover on the phosphorus plots, and accordingly we have plowed under more organic matter. If phosphorus increases the yield of clover by one ton per acre, then one ton more clover should be plowed under on that land, either directly or in manure.

Here we have an average increase in the three corn crops of 29 bushels per acre, due directly and indirectly to the addition of limestone and phosphorus. During the previous three years the average increase was 20 bushels of corn, or, as an average of the last six years, the difference has been 24 bushels per acre per annum; and these results were obtained on land which had been shown, by cropping with corn for three years in succession before beginning the treatment, to differ by only $2\frac{1}{2}$ bushels per acre.

Where farm manure has been applied in the same field in proportion to the crop yields produced, the last-three-year average shows an increase of 13 bushels from manure alone, 19 bushels from manure and limestone, and 31 bushels increase from manure, limestone, and phosphorus, thus making 18 bushels increase for the limestone and phosphorus above the yields produced where manure alone was used.

Hundreds of practical, progressive farmers in Illinois have been using phosphorus from one to five years. In permanent systems, where provision is made for supplying organic matter, fine-ground natural rock phosphate is commonly used; but in some cases temporary use is made of steamed bone meal, which is more active, but more expensive or less durable. So far as I have learned, no man has given the use of phosphorus a fair trial and been disappointed in the results secured. As a rule, the phosphorus benefits the clover crop more than any other crop.
Mr. Frank I. Mann, one of the directors of the Illinois State Farmers' Institute, farms 500 acres of common corn-belt land in Iroquois county. He has already covered all of his fields with half a ton of rock phosphate per acre, excepting untreated check strips in each field; and most of the farm has now received the second application of phosphate. He reports 65 bushels of corn per acre in 1909 on untreated clover sod, 82 bushels in the same field where phosphate has been applied, and 84 bushels where both phosphate and limestone were used. Where corn followed corn on well-manured land, the yield was 70 bushels, but where phosphate had also been applied, 78 bushels were produced. Phosphate produced about 1 ton increase in the clover crop. His results during several previous years will be found in the Illinois Farmers' Institute Report for 1909, which I assume can now be obtained from the secretary.

In the heart of the wheat belt in southern Illinois, as an average of the last six years, limestone has increased the yield of wheat from 15 to 19 bushels, and both limestone and steamed bone meal have increased the yield from 15 to 27 bushels, making a gain of 12 bushels of wheat per acre; this result being the average of two trials each year for six years on the Odin experiment field in Marion county, where a four-year rotation is practiced, including one year each of corn, cowpeas, wheat, and clover, which is one of the good rotations for that part of the state.

Many thousand tons of ground limestone are being used each year by the farmers of southern Illinois, and it is reported that most of the men who have used it one year use still more the next year. In most soils in southern Illinois, limestone is of first importance, but as soon as organic matter can be plowed under, phosphorus should also be added in order to provide a permanent system of soil improvement; while on the common corn-belt soils phosphorus should first be applied, especially for the benefit of the clover crop, and on most of the older, thinner soils, limestone should also be added, at least in the near future.

But it should never be forgotten that the organic matter of the soil must also be maintained, by plowing under much clover and all produce except the grain, as in grain farming, or by using all produce for feed and bedding in live-stock farming and returning all manure to the land with the least possible loss.

Whether grain farming or live-stock farming will be the more profitable, no man can foretell. I certainly do not advise the
live-stock farmer to become a grain farmer, nor would I dissuade the grain farmer from becoming a live-stock farmer, if he has the knowledge, skill, and equipment required in these days for successful live-stock farming; but I would urge the grain farmer who remains a grain farmer not only to maintain but to increase the fertility and productive power of his land, and I would designate as ignorant or prejudiced any man who insists that live-stock farming is the only profitable method of maintaining or increasing the fertility of the land.

Systems of permanent agriculture must be based upon facts and not upon opinion or preference. If there are four times as many grain farmers as live-stock farmers, it might be argued that the problem of maintaining soil fertility on the grain farms should receive four times as much attention as live-stock farming from the Farmers' Institute, from the agricultural press, and from the Agricultural College and Agricultural Experiment Station; but in the past not better than the reverse ratio has obtained, with the result that the grain farmer's problem has received no adequate share of attention from these various agencies devoted to the interest of improvement in agriculture.

The Illinois Agricultural Experiment Station is under obligation to the state to develop practical and profitable systems of farming that will make possible the restoration of our partially depleted lands and the permanent maintenance of all our soils. Grain farming and live-stock farming are recognized as the two most extensive, distinct systems of farming which are and must be practiced, and on almost every experiment field in the state both of these systems are fairly represented, and in some cases mixed farming is also practiced.

The value of farm manure is always emphasized, but we also emphasize the fact that one ton of clover plowed under adds to the soil as much organic matter and as much nitrogen as four tons of average farm manure; and there are many farmers who can plow under a $2\frac{1}{2}$-ton crop of clover or cowpeas on forty

*I constantly make an exception to this rule in the case of wealthy business men of the cities who "farm" not from necessity or needed profit, but for pleasure and recreation. Such men ought not to enter on any large scale into the narrow field of the most intensive agriculture, such as fruit growing, market gardening, or the production of high class dairy and poultry products, which they often produce with actual loss, because they can afford it. They rob the bona fide farmers in this class of their rightful and necessary markets, and as object lessons they contribute little or nothing to the solution of real agricultural problems. Such men should be grain farmers; they should demonstrate that lands can be profitably enriched and maintained without the purchase of feed or manure produced at the expense of other farms; and they should sell corn and wheat or other grains on the great open markets.
acres better than they can apply 400 tons of manure to the same acreage.

No one knows better than the live-stock farmer that the supply of farm manure is limited. Indeed, I need not remind the average Illinois live-stock farmer that he has land on his farm that has not received a load of manure in forty years, and that as a general rule the live-stock farms in this state are gradually decreasing in fertility, not only in phosphorus, which is carried away in the bones and flesh and milk of animals, but also in organic matter, which is so largely destroyed and lost in live-stock farming that it usually takes all the crops from a 320-acre farm to make enough manure to cover 20 acres with a moderate application. Indeed, the live-stock farmers were the first to take advantage of the soil fertility investigations which demonstrated the practical value of using phosphate in connection with organic matter for soil improvement; and even at the present time the live-stock farmers are far ahead of the grain farmers in the application of this knowledge. Moreover, many live-stock farmers are supplementing their farm manure, not only with phosphate, but also with green manures, and the fact should also be noted that all investigations relating to grain farming have direct application in live-stock farming, for grain must be produced before it can be fed to live-stock.

If the art of agriculture has reduced the fertility of the soil, the science of agriculture must restore it; and not only restore it, but increase it even beyond the productive power of the original virgin soil; but do not let us make the mistake of assuming that we can do this by the same means that have been used in the small countries of Western Europe.

The 10-year average yield of wheat in the United States is 14 bushels per acre, while the 10-year average yield of wheat in Denmark is more than 40 bushels per acre, and there are plenty of good people who tell us that we should do as Denmark has done; but such people know not what they say.

Note well the following facts:

Denmark produces 4 million bushels of wheat, and in addition Denmark imports 5 million bushels of wheat, 15 million bushels of corn, and 800 million pounds of oil cake.

The United States produces 700 million bushels of wheat; but can we import 800 million bushels of wheat, and then import 2½ billion bushels of corn,—or twice as much as all the world outside produces? And, in addition, can we import 140 billion pounds
of oil cake, which is perhaps ten times the total production of oil cake in the world? And yet this would be necessary if we were to maintain the Danish proportions of wheat produced and foodstuffs imported.

Because Denmark exports 180 million pounds of butter, shall the United States therefore try to export 30 billion pounds of butter? If so, we should need to ask every inhabitant of the globe to take 20 pounds of our butter.

What American agriculture needs is not further advice and encouragement to continue depending upon the impossible, but rather a clear recognition and an honest, intelligent presentation of the facts.

Is the cost of living high in America? No, not yet; but it will be if in the future as in the past we continue to allow the fertility of our soils to decrease and the population of this country to increase with practically no check even upon the degenerate classes, who already constitute the chief burden upon the revenues of the state. The cost of living is high in India, where the average wage of a working man is 50 cents a month, and where from two to six month’s wages are required to pay for a bushel of wheat.

Even the cost of meat is not high in America. If corn is worth 60 cents a bushel; if a bushel of corn produces only 5 pounds increase in the live weight of a steer; if only one-half of the finished steer is edible food; and if the expense of maintaining a cow for a year must be charged to the cost of the steer; then what is the cost of a pound of corn-fed beef? Even a ton of clover hay may sometimes be worth more to plow under as a fertilizer for corn or wheat than the net value of the beef and manure produced by feeding it. But I need hardly remind the people of Illinois that the world does not live on animal products. Bread is the staff of life, not meat.

Grain will be sold and must be sold from the farms of Illinois, and the problem of Illinois agriculture is to bring about the adoption of systems of farming that will not only permanently maintain but will increase the fertility and productive power of both grain farms and live-stock farms. In both systems, in order to maintain adequate supplies of nitrogen, large use must be made of legume crops, and this alone will compel the rotation of crops.

Crop rotation is also of value because it helps to avoid insect injury and fungous diseases; because it helps to distribute the farm labor over the season; and because it provides some fresh
organic matter which decays quickly in the soil, and by its stimulating action thus liberates from the soil itself more plant food than would otherwise become available.

What is the best crop rotation? No man can tell that in advance. Farms differ in size and in soil; farmers differ in knowledge and skill; seasons differ; prices change; and labor problems vary.

A good four-year rotation for grain farming is wheat, corn, oats, and clover, with an extra catch crop of clover seeded on the wheat land and plowed under the next spring for corn. Only the seed crop of clover should be harvested the fourth year; and all produce should be returned to the land except the grain and clover seed. (Where hay is made for the work animals, manure should be returned.) This system, with the addition of phosphate (and of limestone where needed), will maintain the fertility of the soil.

In live-stock farming, two crops of corn followed by oats with clover seeding, and a full clover crop the fourth year, is a good rotation, and if all the produce is used for feed and bedding and the manure returned with but little loss, the supply of organic matter and nitrogen will be maintained nearly as well as in grain farming; and quite as well if timothy is seeded with the clover and one or two additional years allowed for pasture. Only half as much phosphate will be required as in the grain system, but limestone should also be used where needed to make and keep the soil sweet.

For any one to believe that crop rotation alone will maintain the fertility of the soil reveals gross ignorance of agricultural history and of absolute science; and for one to teach such a doctrine is a crime against posterity. Mathematics alone will show that the rotation of crops will no more maintain the fertility of the soil than the rotation of the check book among the members of the family will maintain the bank account. But, someone will ask, Don't we grow larger crops when we rotate? Certainly, and don't we also get more money out of the bank by rotating the check book? It is a fair comparison.

Agricultural history and long-continued agricultural experiments have always shown that crop rotation alone leads steadily and rapidly towards soil depletion and ultimate land ruin.

Crop rotation is no new thing. It was the common practice in Maryland and Virginia for many years on lands which were finally agriculturally abandoned.
The rotation of crops was better understood in Roman agriculture 2000 years ago than it is in Illinois agriculture today. Varro, who was born 116 years before Christ, wrote as follows:

"The land must rest every second year, or be sown with lighter kinds of seeds, which prove less exhausting to the soil."

"A field is not sown entirely for the crop which is to be obtained the same year, but partly for the effect to be produced in the following; because there are many plants which when cut down and left on the land, improve the soil."

In the first century after Christ, Columella wrote:

"Some of the leguminous plants manure the soil."

The value of seed selection was also understood in those days. Thus, before the time of Christ, Virgil wrote:

"Still will the seeds, tho chosen with toilsome pains, Degenerate, if man's industrious hand Cull not each year the largest and the best."

Thoro tillage was also the rule in those days. Thus Cato wrote in the century before Christ:

"Wherein does a good system of agriculture consist? In the first place, in thoro plowing; in the second place, in thoro plowing; and, in the third place, in manuring."

"Plowing the land simply means rendering the earth more porous and friable, which must tend to increase its productiveness."

But history tells us that all these rules had only a temporary effect; and the crop yields of the Roman Empire gradually decreased until one bushel of seed brought only four bushels in the harvest; and finally, following the exhaustion of the lands and the fall of the successive empires of Babylon, of Carthaginia, and of Greece, the impoverished Roman Empire also fell, and the high civilization of the Mediterranean countries passed into the Dark Ages, which covered Western Europe for a thousand years until the discovery of the New World brought food and prosperity and light to those small countries. But the Dark Ages still exist for most of our own Aryan race in Russia and in India; and they will just as surely blot out American civilization in the future if we continue our past and present methods of soil depletion.

The following article has been circulating thru the press of Illinois during the past few weeks:

"Near Milford, Iroquois county, Illinois, there is an 80-acre farm which has been in corn and oats for just fifty years. No clover has ever been grown upon it and, so far as is now known, not even a load of manure has ever been spread upon it. It has been rented almost continuously up to 1909. The corn yields ran down to twenty bushels per acre, and no
one wanted to rent it at any price. Rothgeb brothers, living near by, saw great possibilities in this land. They knew how it had been worked, and they believed that the ground had more goodness left in it than previous crops had given evidence. The land is favorably located and thoroughly drained. Rothgebs bought it and this year is their first crop upon it. They got a yield of over forty bushels per acre. No fertilizer was applied, but they did unlock some of the unspent fertility which had been locked up by poor management. They plowed every foot of that ground thoroly. They cultivated it six times within one season; they brought it back into tolerably good condition.

Sometimes an application of brains is quite as effective as an application of fertilizer."

Brains! Does it require brains to work out of that soil the "unspent fertility" which it still contains? No, not brains; but merely brawn—merely hard work—merely thorough plowing, as Cato taught 2000 years ago; and when thorough plowing begins to fail, then we rotate the crops and plow under a little clover or a little manure, and then remove in subsequent crops not only the small amounts of plant food thus applied, but by the stimulating action of the clover and manure, we can get out of the soil some more "unspent fertility," and then proceed to spend it by moving to town or to Canada, where 90 million dollars of American money went last year that ought to have been put back into our own soils in the form of phosphates, limestone, and manure or clover.

In an address before the Railway Business Association, November 10, 1909, President William C. Brown, of the New York Central Lines, made the following statement:

"If the converging lines of production and consumption in the United States continue to approach each other as they have during the past ten years, before the middle of the next decade the last vessel loaded with the agricultural product of this country will have left our shores, the great exporting grain elevators in our seaboard cities will stand empty, and this great nation, like those of the Old World, will be looking for a place to buy the necessaries of life."

In the World's Work for November, 1909, ex-President James J. Hill, of the Great Northern Railway Company, made the following statements:

"We have to provide for a contingency not distant from us by nearly a generation, but already present. The food condition presses upon us now. The shortage has begun. . . . . . . . Obviously it is time to quit speculating about what may occur even twenty or thirty years hence, and begin to take thought for the morrow. As far as our food supply is concerned, right now the lean years have begun."

In the Bloomington Pantagraph for January 21, 1910, the
editor of *The Farm* is quoted as answering the question, why farm products are high, in the following words:

“For the simple reason that consumption has overtaken production.”

These facts are serious, but by no means so serious as they would seem from these statements. There is still one outlet which is ample for another generation at least, and this is the outlet which the simple laws of economics have forced upon all older peoples: namely, the gradual elimination of animal products from the daily diet of the masses. When the population shall exceed the food supply under the present standards of living, if we fail to increase our food productions or to check the increase in population, we shall then be compelled to consume more and more of the grain we now feed to animals, and less and less of meat and milk, for the simple reason that when grain is fed to cattle or swine the value of the animal products for human food is only one-tenth to one-fifth of the nutrient value of the grain consumed; and, if we must finally consider the ultimate resource, it should be known that 24 million tons of human manure are annually applied to the soil of Japan, and its value is counted greater than that from domestic animals. Even now it is probably safe to say that what Illinois needs is not more but better live-stock.

Let us consider briefly a few far-reaching facts which show plainly and unmistakably the goal toward which we Americans are hastening:

According to the statistics of the United States Government, a comparison of the last five years reported in this century with the last five years of the old century shows that our annual production of wheat has increased from 500 million to 700 million bushels; that our annual production of corn has increased from 2¼ billion to 2¾ billion bushels; that our wheat exports have decreased from 37 percent to 17 percent of our total production; and that our corn exports have decreased from 9 percent to 3 percent of our total production. Thus, we have added enormously to our supplies of food for domestic consumption, both by increased production and by decreased exportation; but notwithstanding these increased supplies, the average price of wheat by these five-year periods has increased 27 percent; the average price of corn has increased 77 percent, and the farmer does not fix the price of his produce.

The latest Year-book of the Department of Agriculture (1908) furnishes the average yields per acre of wheat and corn for four
successive ten-year periods from 1866 to 1905. By combining these into two twenty-year periods, the records of forty years show that the average yield of wheat for the United States increased 1 bushel per acre, while the average yield of corn decreased 1 1/2 bushels per acre, according to the first and second 20-year averages.

If we consider the statistics for the North Central States, from Ohio to Kansas, and from Cairo to Canada, the same 40-year record shows the average yield of wheat to have increased 3/4 bushel per acre, while the average yield of corn decreased by 2 bushels per acre.

Thus, notwithstanding the great areas of rich virgin soils brought under cultivation in the West and Northwest during the last forty years, notwithstanding the abandonment of the great areas of worn-out lands in the East and Southeast during the same years, notwithstanding the great extension of dredge ditching and tile drainage, and notwithstanding the improvement in seed and in implements of cultivation, the average yield per acre of the two great grain crops of the United States has not even been maintained, the decrease in corn being greater than the increase in wheat, not only for the entire United States, but also for the great new states of the corn belt and wheat belt.

Meanwhile the total population of the United States increased from 38 millions in 1870, to 76 millions in 1900, or 100 percent during the last thirty years of the old century, and the only means by which we have been able to feed the continued increase in our population has been by increasing our acreage of cultivated crops and by decreasing our exportation of foodstuffs.

I need not remind you that there is a limit to our relief in both of these directions. At the most we may ultimately, by large expense of money, labor, and years, add to the area of cultivable lands in the United States, by drainage and by irrigation, the equivalent of three corn-belt states, and by ceasing altogether to export corn and wheat, we can further increase our home consumption of these products by another 10 percent.

Without doubt our present population exceeds 90 million people, and without much doubt the population of the United States will approach 180 million people thirty years from now, if the increase continues unchecked.

Thus, the relief which can possibly be afforded by additional acres put under cultivation and by further decrease in our exportations is almost insignificant, compared with the enormous de-
mands upon this country for food. Of vastly greater importance than these is the possibility of restoring to fertility and productive power the great areas of depleted and abandoned lands in our older eastern states and of doubling the average yield per acre on the lands in the great humid section of central United States. How? By the application of science to agriculture; that is to say, by the application of existing knowledge—of known facts—to the development of agriculture.

How can we enrich and preserve our lands? By making adequate use of phosphorus, organic matter, and limestone. And let us never forget that phosphorus is the master key to systems of permanent agriculture upon these lands. Limestone we have within the borders of our own great state in inexhaustible amount, and if we can obtain the phosphorus we can then continue to produce the organic matter upon the farm, and at the same time to secure nitrogen from the inexhaustible supply in the air. But clover will not grow without phosphorus. Indeed, a 2-ton crop of clover contains more phosphorus than 50 bushels of corn.

At present prices the application of $8 worth of fine-ground rock phosphate to an acre of Illinois land makes possible the production of 1500 bushels more corn from that acre than can ever be grown without the addition of phosphorus. At present prices for phosphate delivered in Illinois, the total phosphorus content of the plowed soil of an acre of our most common $200 prairie land can be doubled for less than $40.

Did I say that our exportations were decreasing? In food-stuffs, yes; but not in phosphate. During the years of the present century our exportation of rock phosphate has increased from 680,000 tons in 1900 to 1,330,000 tons in 1908, an increase of practically 100 percent, according to the published records of the United States Geological Survey.

Seven years ago this month I made the following statement to the Illinois States Farmer Institute:

"Phosphorus is the one element of fertility above all others which has a high absolute and permanent value to Illinois farmers. Nitrogen is free as air, and potassium is abundant in nearly all of the soils of the state, and both nitrogen and potassium remain in the straw and stalks, and in the farm manure to a considerable extent. Phosphorus, on the contrary, is present in nearly all soils in limited amounts, and it is being continually removed from the land by both grain farming and live-stock farming, altho two or three times faster by grain farming than by live-stock farming. The sin of the live-stock farmer is the same as that of the grain farmer; the only difference is in degree."
These statements were true seven years ago; they are true to-day; and they will be true every day until about five tons of phosphate per acre have been applied to most Illinois soil. Meanwhile the United States continues to export more than a million tons a year of our richest phosphate rock for which less than five million dollars are received at the mines, an amount of phosphate which, if applied to our Illinois lands, would be worth to us and our children, not five million, but at least a thousand million dollars, for the clover, corn, and wheat whose production would be made possible thereby.

How much phosphate should you apply? If you own a piece of the common Illinois land, the safest investment you can make is to buy fine-ground rock phosphate and apply it to that land. Five tons to the acre is not too much. That amount of phosphate will cost about $40, and it will double the total phosphorus content of your plowed soil. If you have a 240-acre farm upon which you and your children must depend for future prosperity, it would be altogether sensible, wise, and businesslike to sell 40 acres at $200 an acre, and invest the money in 1000 tons of phosphate with which you could double the phosphorus content of the remaining 200 acres.

Is it wise to apply $40 an acre to $200 land if you can thereby so enrich the land that you can take from that acre $4000 worth of corn before it will again become as poor in phosphorus as it is at the present time? That you can do, not by growing corn all the time, but by continuing to make large use of legumes and of limestone, when needed, both of which can be used anytime now or hereafter by yourself or your children.

If you cannot apply five tons per acre, apply three tons, one ton, or even half a ton, and repeat the application every rotation, and in larger amount if possible, until the total amount applied aggregates five tons per acre; and even then you may well continue to apply as much as you sell from the farm in grain and bone or other products.

This statement applies to all of the ordinary level or gently undulating upland soils of this great state, excepting those commonly called black gumbo, which are still rich in phosphorus; but even they should be kept as rich as they now are.

It should not be forgotten, however, that some of the soils which are deficient in phosphorus are already markedly deficient in limestone, especially in southern Illinois, and frequently they are also very deficient in decaying organic matter. On the
sloping hill lands which are subject to appreciable surface-washing, I do not advise the application of phosphorus, but only a large use of limestone and legume crops in connection with long rotations, preferably including much pasturing. Alfalfa is one of the valuable crops to be grown on these hill lands, and with proper treatment alfalfa has power to change the value of such lands in southern Illinois from $20 to $100 an acre.

Don't use burned lime, which is very expensive, and which tends to burn out the organic matter of the soil and to destroy or waste the nitrogen which it contains; but wherever needed apply the natural limestone, such as can now be obtained from the Southern Illinois Penitentiary and from many other places in the state.

And when you apply phosphorus, don't use small amounts of manufactured acidulated high-priced commercial fertilizers, which serve as soil stimulants, and which have been used so extensively in the Eastern States in systems which lead only toward ultimate land ruin; but use large amounts of steamed bone meal, in emergencies, or, better, still larger amounts of fine-ground natural rock phosphate, neither of which will ever injure any soil. Let the supply of phosphorus in the soil increase and not decrease; let the soils of Illinois not grow poorer, but positively richer and richer,—for your own sake, for your children's sake, and for the sake of all those who must hereafter depend upon the productive power of these lands for bread. Let us have one state in the Union whose soil shall not be ruined and whose children shall not be left with only a memory or tradition of the bountiful harvests of former years.

Get from the Experiment Station Bulletin 123 on “The Fertility in Illinois Soils,” Circular 110 on “Ground Limestone for Acid Soils,” Circular 116 on “Phosphorus and Humus in Relation to Illinois Soils,” and Circulars 127, 129, and 165 on the use of different phosphates and commercial fertilizers; and then study the problem of maintaining the soils of Illinois. “Study to show thyself approved unto God, a workman that needeth not to be ashamed.”
NOTES

NATURAL ROCK PHOSPHATE

Fine-ground raw rock phosphate, containing from 10 to 14 percent of phosphorus, can be obtained from Mt. Pleasant Fertilizer Co., Mt. Pleasant, Tenn.; from Robin Jones, Nashville, Tenn.; from the Natural Rock Phosphate Co., Nashville, Tenn.; the Farmers Ground Rock Phosphate Co., Mt. Pleasant, Tenn.; Ruhm Phosphate Mining Co., Mt. Pleasant, Tenn.; Powdered Rock Phosphate Co., Columbia, Tenn.; Farmers Union Phosphate Co., Birmingham, Ala.; Southern Lime & Phosphate Co., Birmingham, Ala.; Blue Grass Phosphate Co., Mt. Pleasant, Tenn.; Federal Chemical Co., Columbia, Tenn.; Lexington Phosphate Co., Midway, Ky.; Central Phosphate Co., Mt. Pleasant, Tenn.; delivered in bulk on board cars at the mines in Tennessee for $2.50 to $5 per ton, the price varying with the quality. The freight rate from Tennessee per ton of 2000 pounds in carload lots varies from $2.50 to points in southern Illinois, to $3.58 to northern Illinois points. Of course, these addresses are given solely as a matter of information, and the Experiment Station makes no recommendations or guarantees as to reliability.

It should be borne in mind that rock phosphate varies much in quality. Consequently, it should always be purchased upon a guaranteed analysis, and it is advisable for the purchaser to take an average sample of the carload when received and have it analyzed both for phosphorus and fineness, even tho it cost him $2 or $3 for the analysis. To collect an average sample take a small teaspoonful from about fifty different places in the car, not only from the surface but also from different depths. These fifty spoonfuls well mixed together will make a trustworthy sample and about one pound of this should be sent to some commercial chemist for analysis.

If 12½-percent rock, containing 250 pounds of phosphorus per ton, costs $7.50 (including freight), then 10-percent rock, containing 200 pounds of the element per ton, is worth 86, a difference in value of $1.50 per ton, which amounts to $45 on a 30-ton car of rock phosphate.

The important phosphorus compound in rock phosphate is calcium phosphate, \( \text{Ca}_3(\text{PO}_4)_2 \). The percentage of this compound in the rock phosphate marks the purity of the rock. Thus, if the rock phosphate contains 60 percent of calcium phosphate, it is 60 percent pure, with 40 percent of impurities.

Sometimes the guarantee is given as "phosphoric acid," meaning phosphoric oxide, \( \text{P}_2\text{O}_5 \). This also is a definite compound and always contains 43.3 percent of the element phosphorus. Thus it will be seen that the same sample of rock phosphate may be guaranteed to contain 62 percent of calcium phosphate, \( \text{Ca}_3(\text{PO}_4)_2 \), or 28.4 percent of "phosphoric acid" \( \text{P}_2\text{O}_5 \), or 12.4 percent of phosphorus.

Raw rock phosphate should be very finely ground, so that at least 90 percent of the material can be washed thru a sieve with 100 meshes to the linear inch, or with 10,000 meshes to the square inch. Of course, anyone can test for fineness by sifting 10 ounces and then drying and weighing what will not wash thru the sieve.

As a rule, it is more satisfactory to purchase in bulk rather than in bags (see page 15 of Circular 110).

BONE MEAL

A good grade of steamed bone meal (about 12½ percent phosphorus) can be obtained delivered in Illinois for about $25 a ton, from the local agents of Morris & Co., Swift & Co., Armour & Co., the American Glue Co., or from the American Fertilizer Co., Chicago, Ill., or from the Empire Carbon Works, National Stock Yards, East St. Louis, Ill.
POTASSIUM SALTS

Potassium chloride (so-called "muriate of potash"), containing about 42 percent of potassium, can be obtained for about $45 a ton from Armour & Co., Swift & Co., or Darling & Co., Union Stock Yards, Chicago, Ill., from the German Kali Works or the Nitrate Agencies Co., Chicago, Ill., from A. Smith & Bro., Tampico, Ill., or from American Agricultural Chemical Co., New York, N. Y.; and kainit, containing about 10 percent of potassium, together with some magnesium sulfate, magnesium chloride, and sodium chloride, can also be obtained from Armour & Co., Swift & Co., Hirsch, Stein & Co., the Chicago Fertilizer Works, or the German Kali Works, Chicago, Ill., for about $13 a ton.

GROUND LIMESTONE


Stone furnished by Stolle Quarry, East St., a product that will all pass through a mesh of 8 or finer dust produced in the process of crushing or grinding, is very satisfactory.

Some of these companies furnish fine-ground limestone and some furnish limestone screenings, which include both very fine dust and some coarser particles even as large as corn kernels. In cars and on board cars at the plant varies from 50 cents to $1 a ton according to fineness. The freight charges are one-half cent per ton per mile, with a minimum charge of 25 cents per ton by each railroad handling the car, and with a minimum carload of 30 tons. At most points in Illinois the cost delivered in bulk in box cars should be between $1 and $2 a ton. Sometimes one can get one and one-half tons of material containing one ton of fine dust and half a ton of coarser particles, varying in size from less than pinheads to corn kernels, at no greater expense than would be required for one ton of fine-ground stone containing no coarser particles.

Portable machines for crushing and grinding limestone, using threshing engines for power, can be obtained from Williams Patent Crusher & Pulverizer Co., St. Louis, Mo., from the Universal Crusher Co., Cedar Rapids, Iowa, and the Pennsylvania Crusher Co., Pittsburgh, Pa.