PART I—RESULTS OF SCIENTIFIC SOIL TREATMENT *
    BY FRANK I. MANN

PART II—METHODS AND RESULTS OF TEN YEARS’ SOIL INVESTIGATIONS IN ILLINOIS *
    BY CYRIL G. HOPKINS

1910 OATS: YIELD 88½ BUSHELS PER ACRE FOLLOWING TWO YEARS CORN AFTER SEVEN YEARS ALFALFA. ONE TON PHOSPHATE PER ACRE

*Addresses before the Illinois State Farmers' Institute, Ottawa, February 21, 1911.
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PART I—RESULTS OF SCIENTIFIC SOIL TREATMENT

BY FRANK I. MANN

One of the most important factors that has accompanied civilization has been the productiveness of the land, and to a great extent it has been a measure of the civilization. But if productiveness has been important in the past it will be of much more importance in the future. Civilization has developed the most when there were rich virgin lands to subject and their products to be disseminated.

The past is separated from the future by the fact of utmost importance that the fertile lands of all the earth are practically settled. In the past there have been new lands to relieve human congestion; in the future, an increasing population must be met by increasing productiveness, or the theory of Malthus can be applied to civilized races as it is now applicable to the great Eastern races, where there is a frequent readjustment of population to the food supply, such as is at the present time in progress in extensive provinces in China, where the reduction in numbers is certain to be measured by the million before another crop is grown.*

It has been said that the human race went down into the Dark Ages with laughter—the emotional pleasures so dominant there was no thought of the future; that there followed the period of universal insane lethargy and contrition until the new world contributed its influence in awakening civilization. Can such things be again? High civilization cannot be maintained unless there is an abundance of food products.

The only way to supply an abundance of food to the increasing population of the future is by increasing the productiveness of the land; and the only way to increase the productiveness of the land is in the application of scientific principles to the art of agriculture. Let us defer so long as possible the time when the standard of living will need to be lowered for the population to be maintained by the food production. Under present practices it will come only too soon.

The problem of the past was production; our problem is pro-

*Nankin, China, February 3.—That the deaths due to famine and the pestilence following in its wake will total 1,000,000 before spring was the estimate submitted to the relief committee here today.

Relief workers are aghast with the realization of the task before them. Even were they in receipt of unlimited contributions for relief, the missionaries, doctors, and other volunteer workers would be almost hopeless in the face of 2,500,000 suffering people in the Anhui and Kiang Su Provinces.—Press Dispatch.
ductiveness with permanency. We might ask what methods have been used in the past to obtain productiveness: Rotation of crops has probably been the most commonly observed, and has been held by some who ought to know better, as the essential method for high productiveness for an indefinite time. But rotation was practiced on all land that is now worn out.

A rotation with a clover or legume crop has long been practiced. Varro wrote, before the Christian era, that lupines are plowed into a poor soil in lieu of manure. The old lands would not have worn out if clover would have saved them.

It has been claimed that good tillage alone would keep up productiveness. But it has worn the land out only the faster.

The live-stock system has been depended upon for maintaining productiveness. But live stock was kept on land now abandoned till it became too poor to support stock. This system, when including the purchase or transfer of feed, may support productiveness on small areas, but has not prevented the depletion of large ones. This system is in use now in some small European countries, and much of their increased fertility has come from the use of foodstuffs from this country. But it is not permanent, because their supply of those foodstuffs is not permanent.

The use of complete mixed fertilizers, in which there are applied small amounts of plant food, somewhat in proportion to plant needs as regards the increase desired, but without reference to soil or total crop requirements, and containing stimulating compounds that force additional plant food from the soil, has proved a failure so far as permanency is concerned. This system can carry soil depletion farther than any other system.

The mineral theory advocated by Liebeg was a step in the right direction, but did not by itself maintain productiveness.

Each one of these methods is a valuable factor in productiveness, but not one of them alone will maintain fertility, and it is only necessary to call to witness the worn out land where they have been practiced a sufficient time. Each one, under particular conditions, may have been the means of a much increased production for a time, but in the end has proved to be the means of more rapid soil exhaustion.

Our problem has been productiveness with permanency. Have we met the problem?

The Illinois Agricultural Experiment Station has been investigating soils with reference to their fertility less than a decade,
and in that time has developed a system that means productivity and permanency.

It is permanent, because it is based on absolute facts of mathematics and chemistry. We prove things by mathematics because it is a science, and made up of well established absolute facts. There is no guess work in the statement that two and two are four, except to an immature mind. Chemistry is made up of absolute facts just as well established as are the facts of mathematics. The elements that compose food products and the sources from which derived are just as well known as the multiplication table, and there is no more doubt about one than the other. It is a well established fact that there is no transmutation of elements; that a plant that uses nitrogen must have nitrogen, and can not transform it from other elements; that a plant that needs phosphorus must have phosphorus, and if it does not, there is no plant. It is an absolute fact of science that crops are not made out of nothing, but out of certain elements that are ascertained by the science of chemistry, and the amount computed by the science of mathematics. It is an absolute fact that plants must be fed: the manner of their feeding is determined by the science of chemistry, and the amount of their feeding by the science of mathematics.

There is the old question of the availability of plant food, which has been surrounded by superstition ever since there was the semblance of agricultural chemistry. That there must be applied plant food in an available form is proved fallacious by science and practice. That the elements of plant food can be made available to the plant from inert materials by the action of acids formed in the decomposition of vegetable matter is an absolute fact of the science of chemistry, and its measure computed by the science of mathematics; and further, these acids are formed incidentally to the economic restoration of nitrogen to the soil, whereby such use of these acids is one of economic importance. Another fact of great economic importance in this connection is that the cheapest materials may be used that carry the element needed, regardless of its chemical combination.

Other facts well established by science and confirmed by practice are: That legume bacteria give us nitrogen from an inexhaustible supply; that these bacteria do not thrive in acid soils, but that such soils are sweetened by limestone, which is also in inexhaustible supply. It is a matter of common knowledge that
legumes can be grown on any soil that is sweet and contains sufficient mineral elements of plant food. Another fact of science is that one product of crop residues and other vegetable matter is humus, and that humus in the soil is the best means of securing any control over what are called the uncontrolled factors in crop production, heat and moisture.

Stated in a general way, the following facts are established by science: that of the ten elements essential for plant growth, nearly all are naturally supplied in great abundance; that the others can be determined by chemical analysis and supplied in the cheapest form; that nitrogen can be supplied by legume bacteria; and conditions for growth have been demonstrated; that the liberation of plant food and conditions for a maximum control of heat and moisture are incidental to other permanent and necessary factors. The scientific facts underlying the common knowledge of the past have been ascertained, measured and utilized.

There are yet many problems connected with permanent agriculture not solved; and there will be unsolved problems so long as there are mysteries connected with biological and chemical reaction: but these unsolved problems are details and will not materially affect the general scientific factors or principles of permanent fertility.

Every one of the great essential factors can be indefinitely maintained, and it is axiomatic that if every factor of permanent fertility can be maintained, then permanent agriculture can be maintained. Are these all the factors that enter into permanent agriculture? Who can name any other?

The development of this system which provides for a permanent agriculture is one of the most important events in human affairs: and too much honor can not be given to the able leaders and loyal assistants who have worked out this permanent system against the ignorance, superstition and prejudice that is almost universal. It will remain for coming generations to fully realize the great benefit to mankind.

This is the contribution of science to permanent agriculture, but what of the art? Science without art is useless. If we, as artisans of agriculture, do not apply the science of agriculture it will be the same as though the science was not developed.

Is this Illinois permanent system a productive system? To know what influence this system has on the productive capacity of the land, one has but to study the results from the numerous experiment fields in different parts of the State, upon the various
types of soil under the different climatic conditions afforded by a wide range in latitude. Some wonderful results in increased yields have been secured, and the general results, throughout the State have far exceeded the expectations of the friends of soil investigation when they were commenced. It should be remembered, however, that these fields have not been conducted long enough to have given maximum results in productiveness, but they are showing year by year an increasing fertility.

It has been a great pleasure to me to be able to apply some of these scientific principles of permanent agriculture to the practical operations of farming for several years. The farm involved consists of about 500 acres of brown silt loam of the Early Wisconsin glaciation, and is the so-called level black prairie land of the corn belt. It has been reasonably well drained, but the drainage outlet systems have not always been adequate for good drainage. The subdivisions are mostly eighty-acre fields. A four-year rotation of corn, corn, oats, and clover has been conducted on most of the fields for about thirty years. Some small fields have rotated blue grass pasture with grain crops.

Under the permanent scheme phosphorus is the only element of plant food that, as yet, must be purchased to be added. To supply phosphorus it was bought in raw rock phosphate, which was applied at the rate of 1000 pounds per acre, once in four years, the application being made to the clover field in the fall before it was plowed for corn the following year. At this rate the cost was approximately four dollars for each treatment, or an annual cost of one dollar per acre. Check strips three rods wide were left in each field without treatment with phosphate, but in every other respect they have been managed identically the same. These check strips were left in order to get a measure on the value of the treatment.

The data given as yields on a two-year rotation of corn and oats are taken from nearby fields, and are only approximate, though they compare favorably with general averages. The following figures are the average yields per acre for five

<table>
<thead>
<tr>
<th>Two-year rotation, corn and oats.</th>
<th>Four-year rotation, corn, corn, oats and clover.</th>
<th>Same rotation, and 1000 lb. rock phosphate once in 4 years.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn 34 bus.</td>
<td>54 bus.</td>
<td>70 bus.</td>
</tr>
<tr>
<td>Oats 32 bus.</td>
<td>47 bus.</td>
<td>70 bus.</td>
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<tr>
<td></td>
<td>Clover 1½ tons</td>
<td>2½ tons</td>
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years, from comparative data taken from large fields. It should be remembered that the rotation including clover has been run so long that the clover alone (on the check strips) is losing to some extent its efficiency for increasing yields.

One important fact not shown in these figures is that the

**Plate 2.** 1910 Oats: Yield 31 Bushels, 2-Year Rotation: Corn and Oats; No Treatment ("Across the Road").

**Plate 3.** 1910 Oats: Yield 55 Bushels (After 24 Years) 4-Year Rotation: Corn, Corn, Oats, Clover; No Treatment: Check Strip.
effect of this treatment is cumulative, as the difference in yields has a strong tendency to increase year after year.

PLATE 4. 1910 OATS: YIELD 78 BUSHELS (AFTER 24 YEARS) 4-YEAR ROTATION: CORN, CORN, OATS, CLOVER; TWO 1000-POUND APPLICATIONS OF PHOSPHATE.

PLATE 5. 1910 OATS: YIELD 89 BUSHELS (AFTER 24 YEARS) 4-YEAR ROTATION: CORN, CORN, OATS, CLOVER; FOUR TONS ROCK PHOSPHATE PER ACRE.
Another important fact not shown fully is the benefit of the treatment in getting a stand of clover on certain parts of the fields. Some portions of the check strips show but little if any clover the second year after seeding, while on comparable ground across the treated line there is a good stand.

The annual yields from which these averages are computed have been heretofore given to the Institute, and may be found in its printed proceedings, with the exception of the past year's results.

Wishing to know if a maximum application of phosphate would be profitable; that is, an application large enough to bring the total phosphorus content up to the standard of 2000 pounds per acre, average portions of the main fields were selected, to which an application of four tons of phosphate per acre was made. Also, some smaller fields have been given this full treatment, except for the check strip. The differences in yields for the past year indicate a good percent of profit on the investment for this heavy treatment, as shown by the following:

<table>
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<tr>
<th>Two-year rotation, corn* and oats</th>
<th>Four-year rotation, 24 years with clover</th>
<th>Same rotation and 1000 lb. phosphate</th>
<th>Same rotation and 4 tons phosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn 25 bus.</td>
<td>67 bus.</td>
<td>84 bus.</td>
<td>92 bus.</td>
</tr>
<tr>
<td>Oats 31 bus.</td>
<td>55 bus.</td>
<td>78 bus.</td>
<td>89 bus.</td>
</tr>
</tbody>
</table>

Another advantage of the treatment is its effect on the maturity and quality of the crops. In view of the widespread and annually increasing complaint from the commercial interests of the poor quality of grain, this problem of maturity is an important one. There is a difference between mature grain and grain that merely stops growth at the proper season and then dries out. Maturity is a completion of the process of growth, and not merely a cessation of growth, and the completed growth or full development can not take place without there is sufficient plant food. When crops do not fully mature the grain will be light and chaffy, or it may contain much moisture that would have been utilized if properly fed so as to mature. Some comparisons have been made between treated and untreated parts of fields as to maturity of the crops. In the case of corn, maturity has varied from 35% to 84%, respectively, for the untreated and treated.

*Corn figures are from pasture sod instead of clover.
doubt, some of this difficulty can be remedied by growing earlier maturing varieties, but with these the fact of immaturity still remains to some extent, for even the early varieties of pop corn with its small ears is likely to contain many immature ears. Plants will not properly mature when insufficiently fed any more than will animals when not properly nourished.

For the first time in the world's history, there is a basis for permanent agriculture, and it has been developed in Illinois, by the Illinois Experiment Station, fostered by the Illinois Farmers' Institute. Annual reports in its development have been made to this body, and every step in its progress is contained in our printed proceedings. Does this not place greater responsibility on the members of the State and county farmers' institutes to put into practice these fundamental principles? To such farmers are given greater responsibilities, better opportunities, and larger profits who put their business on this solid foundation. The parable of the talents is as significant now as when uttered. To us are given talents never before given. Will we carefully preserve them in the cloth that binds our proceedings, forgetting future humanity and our duty to prosperity; or will we realize what their proper use means to the higher civilization for the generations of the future?

Then we owe a duty to the State. This is a State development. Our duty to Illinois is to preserve her soil—her breast from which must be nourished her increasing sons and daughters. If we fail in this her fair name may become in time a byword for ignorance and poverty.

It is a duty to ourselves that we get as much out of this soil as possible, that we may be better able to secure the physical comforts and enjoyments which belong to a higher development. But it is a greater duty to posterity that we leave these lands richer than we found them.

Let us, then, adopt permanent agriculture, and learn the Science of Home from our sister organization, that those who come after us may build higher than we have built.
PART II.—METHODS AND RESULTS OF TEN YEARS’ SOIL INVESTIGATIONS IN ILLINOIS

BY CYRIL G. HOPKINS

Nearly ten years have passed since the General Assembly made the first appropriation to the Agricultural Experiment Station for the investigation of Illinois soil, in accordance with the request of the State Farmers’ Institute. The annual appropriations secured for the purpose were $10,000 for the first two years, $25,000 for the next six years, and $60,000 per annum for the current biennium. Stated in another way, ten years ago the yearly appropriation for soil investigations amounted to 1 cent for each 36 acres of land in the state; while at the present time it amounts to 1 cent for each 6 acres of Illinois land.

At the present rate it will require about 20 years to complete the work in all the counties of the state, and it seems appropriate to review at this time the general plans and methods that have been followed, to report briefly some measure of the results secured, and to point out the future possibilities and duties, as revealed by facts and data thus far accumulated, even though, to some, such a report may be more instructive than entertaining.

Three distinct but closely related lines of work have been carried on: (1) by soil surveys, (2) by soil analyses, and (3) by culture experiments.

The soil surveys were designed, first, to ascertain what extensive soil types exist in the great soil areas of different ages or formation into which the state as a whole is naturally divided; and, second, to locate and map in detail all of the soil types on every farm in every county. The first is known as the general or state soil survey, and the other as the detail or county soil survey.

The general survey of the State was completed in 1907 and the report published in February, 1908, as Bulletin 123, “The
Fertility in Illinois Soils.” This bulletin contains a colored soil map of Illinois, showing the fourteen great soil areas of the state, and gives an invoice of the stock of fertility contained in twenty-five of the most important and most extensive types of soil in these great areas; also the results of field experiments conducted on the more extensive soil types to ascertain and demonstrate the possibility and practicability of different methods of soil improvement.

The information secured, and published in Bulletin 123, can be applied to more than half of all the soils of the state; and this information is already serving as the basis for systems of positive soil improvement which many progressive farmers and landowners are already adopting on the more common extensive soil types investigated in the preliminary or general soil survey. To utilize this information requires some general knowledge and a good deal of study even on the part of those farmers whose farms include more or less of the most common soil types.

On the other hand, the detail or county soil survey discovers and locates every different kind of soil on every farm in every county, even down to five-acre lots; and, when this is published, every farmer in the state will thus have, in easily available and simple form, definite information concerning every kind of soil on his field, with the boundaries between the different soil types shown on a colored map of his own farm.

The analysis of soils is applied to composite samples collected by uniform methods and representing different strata of the established soil types, only the most extensive types being investigated in the general survey, while all types of both great and small extent are sampled for analysis in the detail survey. By this analysis an absolute invoice is taken of the total stock on hand of the different essential elements of fertility contained in the surface or plowed soil, and also in the subsurface and subsoil strata to definite depths.

The culture experiments are conducted on plotted fields in different parts of the state, and to some extent in culture pots filled with soil carefully collected to represent the actual soil types found in different sections of the state.

On the experiment fields both grain farming and live-stock farming are represented, and systems have been developed under which the fertility of the grain farms as well as that of the live-stock farms can be profitably increased and permanently maintained.
The accompanying map of the state shows that the detail soil survey has already been made in thirty-one counties; that when two other counties, DuPage and Jersey, are completed then every remaining county in the state will join at least one surveyed county; and that the completion of fourteen other counties now agreed upon will leave every unsurveyed county joining two surveyed counties.

When the detail soil survey of a county is completed, then trustworthy soil samples are collected to fairly represent every different kind of soil in the county, several samples being taken of the more extensive soil types and fewer samples of those types of small area. The analyses have now been completed of all the samples from seven counties, thus furnishing an accurate invoice of the stock of fertility contained in every different kind of soil in those counties. Samples from other surveyed counties are now being analyzed as rapidly as possible with the force and facilities afforded.

Several soil experiment fields were established in different parts of the state in the summer and fall of 1901, and during the next six years the number was increased to about twenty. These were regularly located upon uniform tracts of representative land that was rented for the purpose for a term of years. In the beginning most farmers had little confidence or interest in the work, and it was sometimes difficult to secure suitable land for experiment fields even by paying a fair cash rent for a specified term of years. As the work progressed, however, the value of the experiment fields became more and more apparent to the local communities, not only for purposes of investigation, but also as constant demonstrations of the markedly better results secured from systems of farming based upon definite knowledge of the needs of the soil.

During the last two years the number of soil experiment fields was increased to more than thirty, and in every case these newly established fields are located upon land which has been permanently donated to the State University, to the value of about $50,000.

As a rule these experiment fields comprise about 20 acres of land selected because of its suitability for the purpose by a soil specialist from the University. The more essential requirements are, that the land must be uniform, truly representative of an extensive soil type, and easily accessible to visitors, so that the results secured from different systems of farming and methods of soil treatment shall be trustworthy and applicable to the common soil of the section, and so that people who come by train or trolley
PLATE 6. THE THIRTY-ONE SHAD ED COUNTIES HAVE BEEN SURVEYED.
PLATE 7. THE STAR (*) INDICATES THE LOCATION OF AN EXPERIMENT FIELD.
line from the surrounding territory may be able to reach the experiment fields by a reasonable walk from the depot without the expense of money and time that would be required to drive several miles into the country.

The accompanying map of Illinois shows the location and wide distribution of the soil experiment fields.

The older fields which are still being operated on land leased temporarily are as follows:

<table>
<thead>
<tr>
<th>County</th>
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<tbody>
<tr>
<td>Rockford, Winnebago</td>
<td>Sibley, Ford County</td>
</tr>
<tr>
<td>Antioch, Lake County</td>
<td>Bloomington, McLean County</td>
</tr>
<tr>
<td>Union Grove, Whiteside County</td>
<td>Virginia, Cass County</td>
</tr>
<tr>
<td>Momence, Kankakee County</td>
<td>Auburn, Sangamon County</td>
</tr>
<tr>
<td>Magnolia, Putnam County</td>
<td>Edgewood, Effingham County</td>
</tr>
<tr>
<td>Galesburg, Knox County</td>
<td>Mascoutah, St. Clair County</td>
</tr>
<tr>
<td>Manito, Mason-Tazewell County</td>
<td>DuBois, Washington County</td>
</tr>
</tbody>
</table>

The various crops are necessarily grown on each of these widely separated soil experiment fields, and in several cases for the special purpose of crop experiments. There are additional experiment fields on leased land at DeKalb in DeKalb county, and at Fairfield in Wayne County, which are operated primarily for crop investigation, but on which some soil experiments are also in progress.

Soil experiment fields were conducted for some years on leased land at Myrtle, Ogle County; Tampico, Whiteside County; at Green Valley, Tazewell County; and at Lincoln, Logan County; but these have been discontinued, usually because the lease expired and could not be renewed. While some perpetual leases have been secured for a few of the old fields (Odin, Marion County; Cutler, Washington County; and Vienna, Johnson County), and others may possibly still be secured, it is evident that in some cases these experiments must likewise be discontinued at some future time because of the impossibility of securing permanent control of the land.

Permanent possession without rental expense in now assured of the following experiment fields so long as the land is used by the University for purposes of agricultural experimentation or demonstration:

Mount Morris Experiment Field, immediately adjoining the residence district on the south side of Mount Morris, Ogle County. The land was purchased and donated by Mount Morris College and citizens of Mount Morris and vicinity.
Dixon Experiment Field, lying on the north side of the Interurban Railroad about two miles west of Dixon, Lee County. The land was purchased and donated by the citizens of Dixon and vicinity.

La Moille Experiment Field, lying about one mile south of the corporate limits of La Moille, Bureau County. The land was donated by Mrs. Anna Norris Kendall, and was a part of the farm on which her own residence ("Elizabeth Cottage") is located.

Minonk Experiment Field, lying one mile west of Minonk, Woodford County. This land was donated by Mr. and Mrs. Bela M. Stoddard, of Minonk.

Urbana Experiment Field, situated on the University farm. Part of this field has been under continuous experiment for thirty-two years. So far as known, it is the oldest experiment field in the United States on which the originally planned experiments are still being continued. Unquestionably it is the most valuable land within the borders of the state, considering the annual lesson it now presents to the agricultural world.

Aledo Experiment Field, lying about one-half mile west of the depot at Aledo, Mercer County. The land was purchased and donated by the business men and landowners of Aledo and vicinity, in part through the efforts of William and Vashti College.

Carthage Experiment Field, situated within the corporate limits of Carthage, Hancock County, about five blocks south of the Court House. The land was purchased and donated by the business men and landowners of Carthage and vicinity, in part because of their interest in Carthage College.

Clayton Experiment Field, adjoining the town of Clayton, Adams County, about five blocks from the depot on the southeast, and reached by a cement sidewalk. The land was donated by the citizens of Clayton and vicinity.

Carlinville Experiment Field, part of an eighty-acre tract on which Blackburn College is located in Macoupin County. The permanent possession and use of the land was a direct donation from Blackburn College.

Lebanon Experiment Field, situated five blocks south of the main street of Lebanon, St. Clair County. The land was purchased and donated by McKendree College, the purchase price being contributed for the purpose by Governor Charles S. Deneen, an alumnus and trustee of McKendree, and an ex-officio trustee of the University of Illinois.

Ewing Experiment Field, about one-half mile northeast of the village of Ewing, Franklin County. The land was purchased and donated by Ewing College, with the assistance of friends of that institution.

Raleigh Experiment Field, located one-half mile south of Raleigh, Saline County, on land purchased and donated by citizens of Raleigh, Galatia, and vicinity.

Vienna Experiment Field, lying about one mile south of Vienna, Johnson County. This field is on rolling hill land and is devoted
to a special study of surface washing and methods of prevention. (This tract is in addition to the leased land mentioned in a former list.) On part of the field destructive erosion is permitted to continue, as an object lesson; and because of this the land was purchased for the purpose several years ago. It cost the University $20 an acre.

Brookport-Unionville Experiment Field, adjoining the village of Unionville, five miles east of Brookport, Massac County, on land purchased and donated by citizens of Massac County and southern Pope County. This experiment field is located on the most southern table land in the state. It is within five miles of the Tennessee River, which flows northward from Alabama and is said to modify appreciably the temperature of the Ohio River below Paducah and Brookport.

Many other tracts of land have been offered, and several of them should be accepted as soon as adequate provision is made by the state for extending the work of soil investigation.

The Illinois experiment fields are divided into uniform plots arranged in series and treated in accordance with the needs of the soil, check plots being retained so as to determine the effect of every kind of soil treatment applied.

Among the common crops represented in the rotation practiced on these fields are wheat, corn, oats, barley, clover, alfalfa, cowpeas, soybeans, vetch, timothy, and potatoes; and the soil treatment applied deals largely with the use of natural materials, such as farm manure, legume crops, crop residues, ground limestone, ordinary and dolomitic (both of which are found in abundance in Illinois), steamed bone meal (really a farm product), and ground natural rock phosphate.

Purchased nitrogen, manufactured acid phosphate, potassium salts, and other expensive commercial products are used in comparative experiments, and in some cases on abnormal soils.

 Aside from Bulletin 128, a second edition of which is now in press, and which contains the general soil survey map and much information concerning the stock of fertility found in the most extensive soil types and the important results of some of the most valuable field experiments, the publications already issued relating to the investigation of Illinois soil include nine other experiment station bulletins and twenty-six circulars.

Some of these publications relate to certain sections of the state, such, for example, as Bulletin 93, "Soil Treatment for Peaty Swamp Land"; Bulletin 99, "Soil Improvement for the

Other publications relate to general principles of soil fertility and soil preservation; such as Circular 68, "Methods of Maintaining the Productive Capacity of Illinois Soils"; Circular 82, "The Physical Improvement of Soils"; Circular 109, "Washing of Soils and Methods of Prevention"; and Circular 141, "Crop Rotation for Illinois Soils."

To some extent it has seemed wise and necessary for Illinois to defend well established truth against unproven theories or widely disseminated erroneous teaching; and this has called forth the publication of Circular 86, "Science and Sense in the Inoculation of Legumes"; Circular 105, "The Duty of Chemistry to Agriculture"; Circular 123, "The Status of Soil Fertility Investigation"; Circular 127, "Shall we Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"; and Circular 142, "European Practice and American Theory Concerning Soil Fertility".

Aside from the great major lines of purely local work laid upon the Experiment Station to survey the soils in every locality of the state, to determine the stock of fertility in each, and to ascertain and demonstrate by actual field experiments practical methods for their improvement and preservation,—aside from these definite lines of work, the principal soil investigations have been in soil biology, especially in the relation of legume crops and organic matter to the supply and liberation of plant food. Among the publications that have resulted from these investigations are Bulletin 76, "Alfalfa on Illinois Soils", of which four editions have already been required to meet the demand for it; Bulletin 94, "Nitrogen Bacteria and Legumes", now in the third edition; and Bulletin 145, "Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils".

These investigations discovered the general need for the inoculation of Illinois soils for alfalfa, and they added to the sum of human knowledge the facts that the bacteria of alfalfa and sweet clover are interchangeable, and that similar relations exist between
the bacteria of cowpeas and the native partridge peas. They also furnished the first definite measure of the amounts of atmospheric nitrogen utilized by infected legume plants when grown under normal conditions in the field. Of equal importance, perhaps, is the rapidly accumulating information bearing upon the scientific problem, and the economic agricultural practice, of liberating mineral plant food by biochemical agencies, such as the decomposition products of organic matter acting upon the potassium in the enormous supply of insoluble potash compounds naturally present in all normal soils and upon the phosphorus in the low-priced insoluble rock phosphate, instead of purchasing high-priced soluble commercial salts of those elements.

Aside from the publication of Experiment Station bulletins and circulars, and numerous articles contributed to the agricultural press, the soil investigators have given many lectures on soils every year at farmers’ institutes and have also lectured to more than a hundred thousand people on ten “Seed and Soil Lecture” trains that have been run with the co-operation of nearly every important railroad company in the state. (These include the Chicago, Burlington & Quincy—two trains; the Illinois Central; the Wabash; the Chicago & Alton; the Cincinnati, Hamilton & Dayton—two trains; the Chicago & Eastern Illinois; the Vandalia; the Toledo, Peoria & Western; the Cleveland, Cincinnati, Chicago & St. Louis—Big Four; and the Baltimore & Ohio Southwestern.)

Another line of work and influence which absorbs much time and energy and requires the best thought, and we believe accomplishes much good, is the specific information given by individual letters in reply to inquiries that come directly from farmers and landowners. During the first two years of the decade just closed the letters written by our Agronomy Department alone in reply to inquiries for information concerning soils and crops, filled four letter copy books of 500 pages each, making about 2000 letters, and the number has increased in succeeding biennial periods as follows:

1901-1902 ................. 2,000 letters
1903-1904 .................. 5,500 letters
1905-1906 .................. 7,000 letters
1907-1908 .................. 9,000 letters
1909-1910 .................. 12,500 letters
PLATE 8 LETTER COPY BOOKS FOR FIVE BIENNIAL PERIODS.
The accompanying illustration, showing the books in which copies of these letters are preserved on tissue paper, will help one to appreciate to some extent the magnitude of this line of work.

In addition to all this, we have had one man in the field work for a year (and now have four men for the winter months) encouraging farmers on the acid soils of southern Illinois to begin the adoption of permanent systems of soil improvement, including first of all the use of limestone for the special benefit of clover and other legume crops. If one shoe company of St. Louis can afford 126 traveling men to introduce their shoes, and if another shoe company in the same city can afford 108 traveling men for the same purpose, it seemed to us that the great State of Illinois could afford one or more field men to go among the farmers and landowners and help introduce the use of limestone in systems of soil improvement. The results already secured amply justify the conclusion that not one but several such men should be in the field; and we hope largely to extend this line of effort.

To those upon whom has been placed the responsibility for the investigation of Illinois soils and the dissemination of information relating thereto it seemed that our duty was not performed unless we furnished information not only as to what the soils need, but also as to how to supply the needs in the most practical manner.

Thus, when the fact was clearly established by soil analysis and field experiment that potassium is necessary and profitable for the improvement of peaty swamp lands, we ascertained its most economical form and source and encouraged its liberal use, with the result that the yield of corn was increased from 10 or 20 bushels per acre on unfertilized land to 50 or 60 bushels on thousands of acres where potassium is now regularly used on such lands in parts of Kankakee, Iroquois, Mason, Whiteside, and several other counties in north-central and northern Illinois.

When we learned that millions of acres of Illinois land are sour, or acid, we found that abundant information existed to show that ground natural limestone is the safest, and, if economically prepared, also the cheapest material with which to correct soil acidity. As a result of these investigations and of the information thus furnished, the Southern Illinois Penitentiary, under the direction of the Governor of Illinois and the Board of Prison Industries, installed machinery for grinding limestone; and again
the railroad companies co-operated with the Experiment Station and with the State by at once acting upon the suggestion made by us that a uniform freight rate of one-half cent per ton per mile be made for ground limestone over all the railroad lines of Illinois, the minimum carload being fixed at 30 tons and 25 cents per ton fixed as the minimum charge by each road handling the car.

While the first carloads of ground limestone ever applied to Illinois soils were used on the experiment fields less than ten years ago, the records from the Southern Illinois Penitentiary already show shipments to Illinois farmers as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1906</td>
<td>122 tons</td>
</tr>
<tr>
<td>1907</td>
<td>1,520 tons</td>
</tr>
<tr>
<td>1908</td>
<td>2,128 tons</td>
</tr>
<tr>
<td>1909</td>
<td>4,846 tons</td>
</tr>
<tr>
<td>1910</td>
<td>14,135 tons</td>
</tr>
</tbody>
</table>

In addition there are now more than a dozen private companies furnishing ground limestone to Illinois farmers. Several of these companies furnished more limestone in 1910 than the Penitentiary furnished in 1908; and, so far as I can learn, all of them are expecting and preparing to furnish still larger amounts in the future.

The total amount of limestone used in soil improvement in this state should rapidly increase until it reaches more than a hundred times the present demand, for the simple reason that limestone is one of the necessary materials that must always be supplied for the highest improvement and permanent maintenance of Illinois soils, and also because at reasonable prices for limestone and farm produce, it can be used with sufficient profit to justify its application. Even the landowner who receives only one-half of the crops produced can afford to pay for the limestone when needed, and a share of the increased crops will likewise well pay the tenant for the hauling and spreading.

As soon as we had secured the positive information that most Illinois soils are becoming deficient in phosphorus when measured by the requirements of large crops we began to gather information as to the sources and possible supply of that element. Investigation soon revealed the fact that most of the bone which leaves the farms is lost from the land, as when used for manufacturing buttons, toilet articles, cutlery, etc., and that only
the scrap, constituting perhaps 10 percent of the total, is returned to the farm in bone meal, and that more than ten times this should go back to the live-stock farms alone. The iron ores used in the Illinois steel works were found too poor in phosphorus to justify grinding the basic slag as a phosphorus fertilizer; and the extensive natural deposits of rock phosphate proved to be the only adequate sources of phosphorus for general use in soil improvement.

A compilation of the world's information on this subject, confirmed by our own experiments, furnished very complete evidence that the fine-ground natural rock phosphate is the most economic and profitable form of phosphorus to use in general farming in rational systems of permanent soil improvement; and again most of the railroad companies complied with the request to make and maintain such freight rates upon phosphate as would permit it to be used liberally and with some profit on Illinois soils.

Here, too, the first carloads of rock phosphate ever applied to Illinois land were on the University experiment fields less than ten years ago, but at the present time I rarely find a neighborhood where one or more carloads have not been used, and in many places the carloads of phosphate applied annually to the land of the neighborhood are numbered by the dozen, and on many farms in Illinois the phosphorus thus returned to the soil positively equals or exceeds the amount sold from the farm in grain and live-stock products; altho more than nine-tenths of the land in Illinois is still being depleted of phosphorus with practically no return.

"If any question pertaining to the science and practice of agriculture is settled, it is this,—that the atmosphere is the most economical source of nitrogen for all general farming."

This statement was made in an address to the Illinois State Farmers' Institute eight years ago this month, and our subsequent investigations have added much concrete information concerning the amounts of nitrogen secured from the air by legume crops and the amounts that can and must be returned to the soil, either by plowing under legume crops and crop residues in grain farming, or by saving and using farm manure in live-stock farming, in order to establish permanent systems of agriculture with respect to the increase and maintenance of nitrogen and organic matter. The result has been a better knowledge of the effect and true value of crop rotations, a more intelligent understanding of
the value and of the limitations of farm manure, and on many
farms the adoption of definite and positive methods based upon a
clear knowledge of the facts involved, in which every essential
factor of soil fertility is under the intelligent control of the
landowner.

The detail soil survey is slowly revealing the exact location
and extent of every kind of soil in the state, including the normal
soils which require limestone, phosphorus, and nitrogenous
organic matter; some in this order and some in a different order,
depending upon the supply or extent of depletion; and, also the
abnormal soils, some of which are exceedingly rich in all essen-
tials but unproductive because of some injurious substance which
requires removal or correction; while others, like the peaty soils,
are so abnormally poor in one element that the addition of potas-
sium, for example, may change a total crop failure to a yield of
80 bushels of corn per acre, as was the case in 1910 with such land
on the farm of L. H. Klaas of Maple Park, on a farm located just
north of La Salle County. The accompanying illustrations were
furnished by Mr. Klaas.

The census of 1910 reports that the value of artificial fertil-
izers used in Illinois was $571,000, compared with $831,000 ten
years before. From correspondence with Director Durand of the
Bureau of Census, I learn that in 1900 some census takers in-
cluded under this heading manure purchased from the city stock
yards or elsewhere; and, while these reports were eliminated so
far as discovered, there is still some question as to the fairness
of the comparison showing this decrease; but the fact remains
that Illinois farmers are now purchasing about as much phos-
phorus for $200,000 in fine-ground natural rock phosphate as could
be secured for $2,000,000 in high-priced, acidulated highly manu-
factured artificial fertilizers.

On the other hand, it is no credit to the land owners of this
state that Illinois is returning to her farm lands, as an average,
only two cents' worth of fertility per acre in purchased fertilizers,
while the farmers of New Jersey are expending $2.33 per acre
per annum on their farms for commercial plant food.

I shall not attempt in this paper to give you the present
status of the invoice of Illinois' stock of fertility, taken by ten years
of analytical work, nor the detailed results thus far secured from
thirty soil experiment fields, several of which have been operated
for nine seasons, and on most of which there are more than forty
PLATE 9. TREATMENT 200 Lb. POTASSIUM CHLORID.  
TREATMENT none.  
TREATMENT 15 TONS HORSE MANURE.

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>YIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 Lb. Potassium Chlorid</td>
<td>80 Bushels of Corn Per Acre</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>15 Tons Horse Manure</td>
<td>65 Bushels of Corn Per Acre</td>
</tr>
</tbody>
</table>
separate plots whose individual records are taken every year; but you will perhaps permit me to call your attention to the increase produced in 1910 by phosphorus and limestone upon the yield of clover as the best key to permanent systems of agriculture on our normal soils, both in grain farming and in live-stock farming.

As an average of 16 different trials, most of which include several tests, the yield of clover was increased from 1.74 tons to 2.87 tons of hay per acre, making an average increase of 1.13 tons, or 65 per cent. On ten of these fields where live-stock farming is practiced, the average increase was slightly more than 1 ton of clover per acre above the yields secured with manure alone; and on six fields in grain farming the increase was 1½ tons above what was secured without phosphorus and limestone. Of course, more clover means more corn to follow, whether utilized in green manure or in farm manure.

On a few of these fields, especially in southern Illinois, the chief effect on clover is due to the limestone, but on all of them phosphorus produced some benefit, and usually a marked benefit, even when used in addition to limestone.

The general conclusion that may be drawn from the definite information secured and already widely disseminated is, that the productive power of our normal well drained and well cultivated land depends almost wholly upon the power of the soil to feed the crop; that, because of deficiencies in the soil itself, as well as poor methods, Illinois is producing as an average only half a crop; that what Illinois agriculture needs above everything else is not more work, but more thought, more knowledge, more use of established farm science; that even with the seed we now have, with the same amount of work, and with our normal rainfall and sunshine, the average yield of corn, oats, wheat, and hay in the great State of Illinois could be doubled in a dozen years if the absolute knowledge now available, or easily to be secured during that time, were to be applied to the positive and profitable improvement of Illinois soils.

It is encouraging that some progress has already been made in the agriculture of this state since the experiment station began to experiment, to investigate, to secure and disseminate definite information concerning the selection of seed, the improvement in methods of cultivation, and the rotation of crops; all of which relate not at all to soil improvement, but to more rapid soil depletion,—to getting out of the soil the fertility which it contained.
During the last ten years, however, some efforts have been made towards positive soil improvement, especially in the wheat belt of southern Illinois.

The Illinois Agricultural Experiment Station was established in 1887, and began to disseminate information extensively about 1890. The average yield of corn in Illinois during the 20 years since 1890 is more than 5 bushels per acre higher than during the previous 25 years, the increase being placed at 5.4 bushels by the federal crop reports, and at 5.3 bushels by the report of the State Board of Agriculture. A comparison of the last two decades and the previous 25 years average is shown in the accompanying table.

**YIELD PER ACRE OF ILLINOIS FOOD GRAINS**

1st. Data from U. S. Department of Agriculture

<table>
<thead>
<tr>
<th>Average</th>
<th>Wheat*</th>
<th>Corn*</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Years (1866 to 1890)</td>
<td>12.7 Bu.</td>
<td>28.4 Bu.</td>
</tr>
<tr>
<td>10 Years (1891 to 1900)</td>
<td>13.3 Bu.</td>
<td>32.9 Bu.</td>
</tr>
<tr>
<td>10 Years (1901 to 1910)</td>
<td>15.7 Bu.</td>
<td>34.7 Bu.</td>
</tr>
<tr>
<td>Increase</td>
<td>3.0 Bu.</td>
<td>6.3 Bu.</td>
</tr>
</tbody>
</table>

2nd. Data from Illinois State Board of Agriculture

<table>
<thead>
<tr>
<th>Average</th>
<th>Wheat</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Years (1866 to 1890)</td>
<td>13.2 Bu.</td>
<td>29.5 Bu.</td>
</tr>
<tr>
<td>10 Years (1891 to 1900)</td>
<td>13.4 Bu.</td>
<td>34.2 Bu.</td>
</tr>
<tr>
<td>10 Years (1901 to 1910)</td>
<td>16.3 Bu.</td>
<td>35.3 Bu.</td>
</tr>
<tr>
<td>Increase</td>
<td>3.1 Bu.</td>
<td>5.8 Bu.</td>
</tr>
</tbody>
</table>

3 bushels wheat on 1,500,000 acres............ 4,500,000
6 bushels corn on 7,500,000 acres............ 45,000,000

Value of wheat at 80 cents........................ $3,600,000
Value of corn at 40 cents........................ $18,000,000

Value of increase.............................. $21,600,000

The figures for wheat, compared with the 25-year average before 1890, show for the first ten years of experiment station work, 1891 to 1900, only 0.2 bushel increase by state data and 0.6 bushel by the federal report; but the last 10 years (which include all of the time of the soil and crop experiments in the wheat belt of southern Illinois) show a gain of 3.1 bushels by the State report and 3.0 bushels by the federal report, compared with the 25-year record before 1890.

As an average of these two independent sources of information, the Illinois yields of the last ten years have been 6 busheles more corn and 3 bushels more wheat than during the 25-year period.

*The Experiment Station work and influence were confined to the corn belt till 1900, after which the investigations were extended into the great wheat belt of southern Illinois.*
before the information from the experiment station investigations began to influence the agricultural practice of the state.

The value of increased yields for the two great food-grains amounts to more than 20 million dollars a year for this state; and every citizen of the state is justified in assuming that with adequate support for investigation, instruction, and dissemination, by the Experiment Station, the College of Agriculture, and the Farmers' Institute, and with the continued co-operation of the agricultural press, the newspapers, the schools, the railroads, and commercial organizations, these crop yields can not only be doubled, but the agriculture of Illinois can be placed upon a truly permanent basis.

In conclusion, I only ask your attention to the accompanying illustration showing the result at the end of five years where one ton of natural rock phosphate and two tons of natural limestone, per acre, are applied every four years on the 40-acre experiment field at Fairfield on the common prairie land of southern Illinois, where to-day exists possibly the best opportunities America affords for investment in land and farm science, where the land is

PLATE 10. CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. MANURE ALONE ON LEFT; MANURE, LIMESTONE AND RAW ROCK PHOSPHATE ON RIGHT. (CLOVER SEEDED ALIKE ON BOTH SIDES.)
relatively low in price, and where all of the materials really needed for the improvement of the soil are already within reach delivered at a cost which is not prohibitive, thanks to the co-operative efforts of the railroad companies with the Experiment Station and the State government.

NOTES

NATURAL ROCK PHOSPHATE

Fine ground raw rock phosphate, containing from 10 to 14 percent of phosphorus, can be obtained from the Mt. Pleasant Fertilizer Co., Mt. Pleasant, Tenn.; from Robin Jones, Nashville, Tenn.; from the N. Y. & St. L. Mining & Mfg. Co., St. Louis, Mo.; from the Natural Phosphate Co., Nashville, Tenn.; the Farmers Ground Rock Phosphate Co., Mt. Pleasant, Tenn.; John Ruhm, Jr., Mt. Pleasant, Tenn.; H. D. Ruhm & 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.; or from the Central Phosphate Co., Mt. Pleasant, Tenn., delivered in bulk on board cars at the mines in Tennessee for $2.50 to $5.00 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, but 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, even though it costs him $2.00 or $3.00 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 12% 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 $6.00, a difference in value of $1.50 per ton, which amounts to $45 on a 30-ton car of rock phosphate.

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

As a rule it is most satisfactory to purchase in bulk rather than in bags (see page 15 in Circular 110, "Ground Limestone for Acid Soils").

BONE MEAL

A good grade of steamed bone meal (about 12% percent phosphorus) can be obtained delivered in Illinois for about $25.00 a ton, from the local agents of Morris & Co., Swift & Co., Armour & Co., the American Glue Co., Chicago, Ill., or from the Empire Carbon Works, National Stock Yards, Ill.
POTASSIUM SALTS

Potassium chlorid (so-called "muriate of potash"), containing about 42 percent of potassium, can be obtained for about $50.00 a ton from Armour & Co., Swift & Co., Darling & Co., Union Stock Yards, Chicago, Ill., from the Nitrate Agencies Co., Chicago, Ill., from A. Smith & Bro., Tampa, Ill., or from American Agricultural Chemical Co., New York, N. Y.; and kainit, containing about 10 percent of potassium in the form of potassium sulfate, together with some magnesium sulfate, magnesium chlorid, and sodium chlorid, can also be obtained from Armour & Co., Darling & Co., Swift & Co., Hirsch, Stein & Co., or the Chicago Fertilizer Works, Chicago, Ill., or from German Kali Works, Baltimore, Md., for about $15.00 a ton.

GROUND LIMESTONE


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 wheat grains. In carload lots the price on board cars at the plant varies from 50 cents to $1.00 a ton according to the 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 $1.00 and $2.00 a ton. The quickest action will probably be secured by using the finer material and mixing it most thoroughly with the soil, but 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 wheat grains, at no greater expense than would be required for one ton of fine-ground stone containing no coarser particles. The coarser particles will last in the soil longer than the finer material, which is rapidly lost by leaching; and, if the product will all pass through a sieve with 10 or 12 meshes to the linear inch, and if it contains all of the fine dust produced in the process of crushing or grinding, it is very satisfactory.

Portable machines for crushing and grinding limestone, using threshing engines for power, can be obtained from Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.; or from Eureka Stone and Ore Crusher Co., Cedar Rapids, Iowa.