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INVESTIGATION OF ILLINOIS SOILS.

(REPORT OF PROGRESS.)

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*Gentlemen of the Advisory Committee from the State Farmers' Institute:*

In a report which I made about one year ago, regarding the investigation of Illinois soils, I stated that plans were then made to begin the investigation of soils of the most important areas in the State. The methods of investigation were to include:

1. Collecting and analyzing representative samples of the most extensive areas of distinct types of soil to be found in the State in order to determine what stock of the different elements of plant food is contained in each type of soil;

2. Conducting pot culture experiments under controlled conditions in the pot culture laboratory at the University, and also plot experiments under natural field conditions in different sections of the State, to determine in terms of productive capacity, or crop yields, the value of the different kinds of soil treatment and the effect of applications of different elements of plant food, to the different soils of the State; and

3. Beginning a detailed survey in which the different soils of the State should be mapped so as to show their exact location, extent, and boundary lines, in which survey we hoped to secure some coöperation from the Bureau of Soils of the United States Department of Agriculture.

I will ask you, then, to keep in mind the fact that we have in progress in Illinois two soil surveys of the State. The first of these we call the general soil survey, and the second the detail soil survey. In the general survey, we are covering practically the whole State almost from the beginning of the work; while with our present facilities and appropriations it will require many years to extend the detail survey over the entire State.

#### GENERAL SOIL SURVEY.

In beginning the general soil survey, we have found that the soils of the State differ markedly according to the time and method of their original or geologic formation. The work on the glacial geology of Illinois which has been done by Leverett and others connected with the geological survey has been of very great value in starting the soil investigations in this general survey work, and this first division of the State into large soil areas, as shown in our general survey soil map, is based largely upon Leverett's glacial map. I hope it will be understood and borne in mind not only that we are studying Illinois soils and not glacial geology, but also that I do not wish to be held strictly to account for the technical geologic exactness of all the divisions or different areas which we make for the purpose of agricultural investigation and regarding some of which, in fact, even geologists differ.

According to geological investigations there have been three different times when glaciers, or ice sheets, have covered more or less of the State of Illinois, in consequence of which nearly all of the surface of the State is covered by soils of glacial formation. The first glacier covered all of Illinois as far south as the Ozark Spurs, excepting a part of what is now called Calhoun County and a small area in the northwest corner of the State. The area where the drift, or debris, left from this first glacier still remains the surface, is called the Illinoisan Glaciation. For our purpose in soil investigation we divide this Illinoisan Glaciation into three areas, because of the marked differences in the agricultural values and properties of the soil. These three areas we call the Lower Illinoisan Glaciation, the Middle Illinoisan Glaciation, and the Upper Illinoisan Glaciation, each of which will be more fully described later.

The second glacier covered only three or four tiers of counties from the north line of the State, but the area did not include the extreme northwest corner of the State. Where the drift from this second glacier is now the surface, it is termed the Iowan Glaciation.

The third and last glacier covered approximately the northeast quarter of the State and this area is called the Wisconsin Glaciation.

According to the formation we have about ten large soil areas in the State, although each of these areas may contain several different types of soil:

1. Unglaciaded soil.
2. Illinoisan Moraines.
3. Lower Illinoisan Glaciation.
4. Middle Illinoisan Glaciation.
5. Upper Illinoisan Glaciation.
6. Iowan Glaciation.
7. Wisconsin Moraines.
8. Wisconsin Glaciation.
9. Areas of deep Loess deposits.
10. Sand, swamp areas, and bottom land.

Because of their evident greater need of immediate investigation, Nos. 1, 3 and 7 have been given rather more study than the other areas.

#### 1. UNGLACIATED SOIL.

The unglaciaded soils of the State are those which have been formed in place from the original rocks and have never been covered by glacial drift. The unglaciaded soil area includes (1) the seven southern counties in the State: Union, Johnson, Pope, Hardin, Alexander, Pulaski and Massac, and parts of the adjoining counties on the north (occupied by the Ozark Spurs and territory south of them, the progress of the glacier toward the south evidently having been stopped by the Ozark hills), (2) most of Calhoun county, and (3) the area in the northwest corner of the State, principally in Jo Daviess county. (This area has evidently been protected from the ice flow by a range of hills lying just north of it in Wisconsin). Our investigations of the unglaciaded soils have been confined chiefly to the so-called red clay hill soils in the extreme southern part of the State. Briefly, I may state that by chemical analysis we have invariably found these old worn hill soils to be markedly acid, or sour, very deficient in nitrogen, and only medium in phosphorus content. Quantitative de-



PLATE I.—From Leverett's Glacial Map of Illinois.

terminations of the acid in the soil show that from 500 to 1,000 pounds of lime per acre are usually required to correct or neutralize the acid in the plowed soil (four to seven inches deep), and that much larger quantities are required to neutralize the acid in the sub-soil. As it is absolutely necessary to grow leguminous crops in order to restore the nitrogen in the soil by the only rational and economical method, that is, by taking it from the free and unlimited supply of the atmosphere, and, as our most important and valuable legumes, such as red clover and alfalfa, cannot be grown successfully on acid soils (and no legumes can be expected to do their best on such soils), the application of some form of lime to these old hill soils seems absolutely necessary for restoring their productive capacity to any satisfactory degree.

Pot culture experiments have shown that liberal applications of nitrogen in available form have produced a remarkable increase in wheat yields on these old worn hill soils. The following table shows the results from a single series of thirteen pot cultures, the first having been filled with virgin soil from a fence row which has never been cultivated, and the remaining twelve numbered pots having all been filled with soil from an old worn field which produced less than five bushels of wheat per acre in 1901, but which, when first cultivated more than seventy-five years ago, frequently yielded 25 bushels of wheat per acre.

In the photographic reproduction of this series of pot cultures (see Plate II), L means lime, N means nitrogen, P means phosphorus, and K (*Kalium*) means potassium (the element contained in potash salts).

Pot No.	Treatment Applied.	Wheat Produced. (grams per pot)
V (Virgin soil)	None	24.40
1 (Old soil)	None	3.00
2	Lime	3.85
3	Lime, Nitrogen	26.00
4	Lime, Phosphorus	3.25
5	Lime, Potassium	3.25
6	Lime, Nitrogen, Phosphorus	34.00
7	Lime, Nitrogen, Potassium	32.80
8	Lime, Phosphorus, Potassium	2.07
9	Lime, Nitrogen, Phosphorus, Potassium	34.40
10	Nitrogen, Phosphorus, Potassium	30.60
11	None	3.00
12	None	3.40

It will be observed that every pot to which nitrogen was applied yielded even more than the virgin soil, and eight to ten times as much as the untreated old cultivated soil; while none of the pots receiving no nitrogen made any appreciable gain over the untreated old soil, although, after nitrogen had been applied, the addition of



PLATE II.—Wheat on Unglaciaded Soil (Pulaski County Hills) Effect of Nitrogen.



phosphorus or potassium further increased the yield. Nevertheless, the supply of potassium in the soil is about equal to that in fertile soils and the supply of phosphorus is by no means exhausted, so that while phosphorus could possibly be applied with profit, it is doubtful if potassium could be, especially after a liberal use of lime and leguminous fertilizers, both of which tend to liberate potassium from the soil.

Let me urge you to keep in mind that, while we have in these experiments bought and used commercial nitrogen in order to save time, the nitrogen should always be secured from the atmosphere by legumes in all practical farm work; and, in this connection, let me state, tentatively, that experiments conducted and now in progress indicate that leguminous crops and leguminous green fertilizers will produce a greater increase in the productive capacity of the soil than heavy applications of commercial nitrogen; and let me express my opinion that no Illinois farmer can afford to purchase a pound of commercial nitrogen for ordinary farming. Probably market gardeners whose lands are too valuable to wait for legumes to grow, and who take off several crops of high market value each season, can well afford to make use of commercial nitrogenous fertilizers, but probably farm-yard manure is the best and cheapest nitrogenous fertilizer they can purchase.

As you know, our field experiments include the use of leguminous crops in improving the soil, and we have an experiment field on this unglaciated hill soil near Vienna in Johnson county, but, of course, we shall require one or two years more before we can secure any results from such rotation work, even this first year's crop not being all harvested at this date (September, 1902).

## 2. ILLINOISAN MORAINES.

The soil area known as *Illinoisan Moraines* includes the broken moraines or hills which rise above the general level of the surrounding prairie land, resulting from glacial drift left in great piles, or ridges, and represent the place where the forward movement of the terminus, or edge, of the glacier was practically counterbalanced by the melting away of ice. Those moraines cover considerable areas in Christian, Montgomery, Fayette, Bond, Clinton and in some adjoining counties, and are also found in Fulton, McDonough, Hancock, Adams, Pike, and to some extent in other counties in that section of the State. As a rule these soils are slightly acid and will be benefited by applications of a few hundred pounds per acre of some form of lime, especially for the growth of clover, alfalfa, and other leguminous crops. As yet we have no

experiment field on this soil, have conducted no pot culture experiments, and our analytical work is only begun. This is because the area is much more limited than many other soil areas in the State.

### 3. LOWER ILLINOISAN GLACIATION.

The soil area which we term the *Lower Illinoisan Glaciation* comprises all or parts of about thirty counties, lying North of the Ozark Spurs, south of the Shelbyville Moraine (the most southern moraine of the Wisconsin Glaciation) and east of the range of broken Illinoisan Moraines which extend from Christian county to St. Clair county. Fayette, Effingham, Jasper, Marion, Clay, Richland, Washington, Jefferson, Wayne, Perry, Franklin, Hamilton, and more or less of all adjoining counties are included in this soil area. Aside from the moraines, which are classed in the area previously described, the soils of this area consist of level upland, broken hill land, and river bottom land. The level upland is by far the largest part of the area and our investigations have as yet been confined chiefly to this type. The soils of the Lower Illinoisan Glaciation are usually very light colored, in places almost white.

The chemical analysis of a considerable number of samples of the common prairie soil, the principal type of this area, shows that it is almost invariably strongly acid and quite deficient in phosphorus. As a rule, it is rather poor in nitrogen and not abundantly supplied with potassium. The soil needs heavy applications of lime. As a rule, it will require a ton of lime per acre to correct the acidity to a depth of 12 or 15 inches, and much larger applications will be required if the acid in the subsoil must also be neutralized. We are conducting experiments to determine to what depth this soil acidity must be corrected for the most profitable improvement of the soil.

Because of the acid condition of this soil, red clover will not grow upon it, and even the less valuable substitute, cow peas, which are killed by the frost and do not live over winter, will not grow nearly so well as they do in other places in the State upon soils which are not acid. We have found that applications of lime to this soil increase the growth of legumes and markedly increase the number of tubercles upon the roots, showing that the power of the plant to secure nitrogen from the atmosphere is enlarged, thus enabling it not only to increase its own growth but to improve the soil. Where we applied lime last spring we now find that the plowed soil to a depth of seven inches is not acid, although it is still strongly acid in an adjoining plot where no lime has been applied.



Understand that we have had only one season to study this problem of the acidity of this great area of southern Illinois soils; that one year ago there was not even a method known to science by which the quantity of acid in soils could be determined, that we have been obliged to work out such a method; and, I am glad to say that we have succeeded, so that we can now tell, not only that a soil is acid, but how acid, and how much lime will be required to correct or neutralize this acid to any depth we choose to take our samples.

We can already see some marked results from applications of lime although we cannot hope for the full benefit of it until at least one year after it has been applied and it has become well incorporated with the soil, and even then we need one or two years more to grow leguminous crops and to follow them by other crops before we can have anything like complete data. I am glad to state, however, that some of the men with whom we have soil experiment fields located on this soil and who have been watching the experiments very closely are already purchasing considerable quantities of lime. For example, Mr. A. A. Hinkley, of DuBois, Washington county, has already applied two car loads of lime to the soil on his farm and will use more this fall.

We are not only trying to determine how much lime must be added and to what depth in the soil the acidity must be corrected, but we are also trying to determine what is the best and most economical form of lime to use for this purpose. We are trying fresh burned lime, air slacked lime, and pulverized limestone, any of which can be obtained in the market in any quantity desired, and any of which will correct the acidity of the soil. The only question is which form can be applied the most economically and give the quickest and most profitable returns.

In our experimental work we are this year using five car loads of lime and three car loads of finely pulverized limestone. In this connection I beg to state that these extensive experiments are only made possible because of the interest taken in the work by the Marble Head Lime Company, of Marble Head, Illinois, the Crystal Carbonate Lime Company, of Elsberry, Missouri (who furnished the pulverized limestone), J. P. Speed & Company, of Milltown, Indiana, the Southern Railway, the Illinois Central Railway, the Big Four Railway and the Wabash, Chester & Western Railway, all of whom have either furnished large quantities of such materials which we have asked for or transported car load lots of it free of charge. You will see that we are not only making use of all the appropriation furnished by the State, but we are doing consider-

ably more than we could do with those funds alone. I may say further that the Armour Fertilizer Works, Union Stock Yards, Chicago, and the German Kali Works, New York, have furnished us large quantities of bone meal (phosphorus fertilizer) and potash salts, respectively, free of charge. And in no case are we experimenting with anybody's brand of fertilizer. These different parties have furnished us exactly what we asked and what we need to use in investigating the needs of Illinois soils for increasing their productive capacity.

Most of the soils of the Lower Illinoisan Glaciation are level prairie land and, in this respect, are equal to any in the State for agricultural purposes, but, while these soils are now producing three-quarters of a ton of timothy hay per acre as the principal crop (aside from apple orchards), and 15 to 25 bushels of corn, and with scarcely a good field of clover to be seen on the principal type of soil in this area, and the land worth \$20 to \$30 an acre,—just a few miles north, in Coles and other counties in the Wisconsin Glaciation, every other field is a clover field, corn yields from 50 to 75 bushels per acre and land is worth \$125. There are other differences in the properties of those two adjoining soil areas, but the principal one is the acid in the soil of the southern area. We expect, within one or two years, to have practical demonstrations on several fields in this soil area to show whether liming the soil will be beneficial for red clover, alfalfa, etc.

As stated above, the soils of the Lower Illinoisan Glaciation are not only markedly acid and consequently require heavy applications of lime, but they are also quite deficient in phosphorus. They are not altogether peculiar, however, in being somewhat deficient in phosphorus, because many of the soils of Illinois are below the normal fertile soil in this element and, furthermore, applications of phosphorus to other soils have produced some markedly beneficial results, as has been shown, for example, in our Bulletin No. 76, "Alfalfa on Illinois Soil."

Our experiments include not only trials to determine the value of applying phosphorus to these Southern Illinois soils, but also trials to determine what form is most economical to purchase. Bone meal containing 20 to 25 per cent of phosphoric oxid (8 to 10 per cent of phosphorus) costs about \$25 a ton, while ground rock phosphate, which is just as rich in phosphorus, costs only \$4 a ton at the mine in Tennessee, or about \$6 to \$8 per ton delivered in Illinois. The phosphorus in the bone meal is more readily available and, consequently, gives quicker returns, but the ground rock phosphate is more lasting; and the question

is, if equal values (not equal quantities) of the two materials are applied, will not the ground rock phosphate prove more profitable in the course of a few years? Probably we shall require at least five years to answer this question.

In a series of pot culture investigations on soil taken from near Odin, Marion county, in the Lower Illinoisan Glaciation, we obtained the following results:

Pot No.	Treatment Applied.	Wheat Produced. (grams per pot)
1.....	None.....	11.0
2.....	Lime.....	11.6
3.....	Lime, Nitrogen.....	9.2
4.....	Lime, Phosphorus.....	13.6
5.....	Lime, Potassium.....	10.3
6.....	Lime, Nitrogen, Phosphorus.....	20.6
7.....	Lime, Nitrogen, Potassium.....	7.2
8.....	Lime, Phosphorus, Potassium.....	13.7
9.....	Lime, Nitrogen, Phosphorus, Potassium.....	26.5
10.....	Nitrogen, Phosphorus, Potassium.....	24.5
11.....	None.....	9.9
12.....	None.....	9.5

It should be borne in mind that applications of lime are especially beneficial for legumes, in that the lime corrects the acidity and thus encourages the development and activity of the nitrogen-gathering bacteria. It is not to be expected that the lime will have any very marked effect on wheat yields unless the wheat follows the legume. Disregarding the lime, it will be observed that phosphorus is the only element which increases the yield of wheat when applied alone (Pot 4), and this yield is not further materially increased by adding potassium to the phosphorus (Pot 8); and, without phosphorus, the addition of both nitrogen and potassium does not increase the yield (Pot 7). Aside from lime (needed for legumes and consequently for the accumulation of nitrogen) the first element needed by this soil is phosphorus (Pot 4); after phosphorus additions of nitrogen are of great value (Pot 6); and, after both phosphorus and nitrogen have been added, applications of potassium further increase the yield (Pots 9 and 10).

To be sure our data is meager yet, but so far both chemical analyses and pot cultures, show that these soils need lime and phosphorus, and after that they need to grow legumes or to have liberal applications of farm-yard manure.

The broken hill land of the Lower Illinoisan Glaciation lies along the streams. The so-called hills are no higher, and usually not quite so high, as the surrounding prairie. They are simply ridges left between the valleys which have been worn out by washing during the time which has passed since the glacial age. The soils of the bottom lands are largely composed of the top soil



PLATE III.—Wheat on Lower Illinoian Glaciation Soil (Marion County Prairies) Effect of Phosphorus.

washed down from the uplands, with occasional sand bars formed by the currents of the streams. Along the larger streams, especially those whose source is in the Wisconsin Glaciation, the lower bottom lands usually contain more or less soil which has evidently been washed down from the Wisconsin Glaciation. These soils are dark colored, practically free from acid, and when not injured by overflow they produce clover and other crops as well as the soils in the Wisconsin Glaciation.

#### 4. MIDDLE ILLINOISAN GLACIATION.

This soil area consists chiefly of Cass, Menard, Logan, Scott, Morgan, Sangamon, Green, and parts of Macoupin, Jersey, St. Clair, Clinton, Bond, Montgomery, Christian and Macon counties. In the area just defined and, in fact, in all of these large soil areas, there are several markedly different types of soil and there is usually no very distinct and continuous boundary between two soil areas. Besides the timber land, the broken or hilly land, and the bottom lands, there are frequently bodies of level prairie land which are unlike the common or principal type in the area, and they may or may not resemble the principal type in some adjoining soil area. An investigation of all these different bodies or types of soil is important and should be carried on, but that is the work of our detail survey (which will be briefly described later), and it cannot be done in our general survey work in which we study only the very largest and most important types in these large soil areas.

The soils of this area are markedly different from those of the Lower Illinoisan Glaciation, the principal type being dark brown in color, and very slightly acid. The subsoils are usually free from acidity, so that a light application of lime (600 to 800 pounds per acre) will entirely correct the total acidity of the soil. That such an application would prove very profitable for increasing the growth of clover and consequently of other crops which follow clover, is practically certain. It would be equally beneficial for growing alfalfa.

The analysis of soils from this area shows that they are not abundantly supplied with phosphorus. In some places where continuous cropping with wheat and other grain crops has been practiced, the nitrogen content is becoming very much reduced. The acidity of the soil is increasing under cultivation as it usually does, as is evidenced by the fact that in many places where clover formerly grew, it is now frequently a failure.

#### 5. UPPER ILLINOISAN GLACIATION.

This area includes the chief part of Henry, Stark, Peoria, and



counties to the southwest of these lying between the Mississippi and Illinois rivers, excepting the unglaciated part of Calhoun county, the Illinoisan Moraines, the loess soils and the river bottom lands, which belong in other soil areas.

The level prairie land in this area constitutes the principal type. The soil resembles somewhat that of the Middle Illinoisan Glaciation but it is darker (almost black) in color and generally deeper to the subsoil. It is but very slightly acid, as a rule, but, in places where it is found difficult to secure good crops of clover, an application of a few hundred pounds of lime per acre should be made, and it is not improbable that on old worn fields of this type applications of phosphorus will increase the yield of crops, although we have no data on this point, except that the analysis of the soils shows a much more abundant supply of potassium than of phosphorus. The broken or hilly lands along the Mississippi and other streams in the Upper Illinoisan Glaciation are usually quite markedly acid and for growing legumes will be greatly benefitted by an application of 1000 to 2000 pounds of lime per acre.

#### 6. IOWAN GLACIATION.

This soil area represents all that is now exposed of the drift material from the second glacier. It includes the counties of Stephenson, W:nnabago, Boone, Carroll and Ogle, and parts of Jo Daviess, McHenry, DeKalb, Lee and Whiteside. Geologists are still in doubt regarding the exact origin of different parts of this section. Probably the western part of the area was not covered by the second glacier and belongs to the Illinoisan Glaciation. The principal type of soil is rolling prairie. The soil is brown or dark brown in color. The basis of this soil is largely silt (a grade of soil particles which are finer than fine sand), with some fine sand. It contains but little plastic clay even in the subsoil. In my judgment this soil where it is not acid will be found admirably adapted to growing alfalfa, although it may sometimes winter kill in places when too much exposed, especially if cut too late in the fall. This area contains a considerable extent of so-called limestone soils, but as a matter of fact the soils have been formed from glacial drift (chiefly pulverized sandstone and granite) with more or less loess on top, and consequently are not limestone soils. In this connection it may be said that the presence of limestone a few feet beneath the surface and even the presence of lime in the well water is not absolute evidence that the surface of an old worn field is not in need of an application of lime. Indeed from the analyses which are in progress of samples from this area we find that



some of the long cultivated soils are already distinctly acid, even where they are underlaid by limestone at a depth of 15 to 20 feet. An application of a few hundred pounds of air slacked or water slacked lime, or probably of the finely pulverized limestone, such as is used extensively in this soil area as a top dressing for stone roads and could be easily obtained by pulverizing the underlying lime rock would prove very advantageous and profitable for leguminous crops and consequently for subsequent crops.

Our chemical analyses of soils from this section are not completed, and our data and exact information regarding the needs of this soil area are as yet very meager.

#### 7. WISCONSIN MORAINES.

While the moraines of the old Illinoian Glaciation have been much eroded and now exist only in broken chains of hills or ridges the moraines of the much more recent Wisconsin Glaciation are as a rule broad and continuous, and represent very large areas of land. Aside from the terminal moraine which was piled up at the outer edge of the glacier and which now marks the south and west border of this soil area, and which extends in a sort of semicircle through the counties of Edgar, Coles, Shelby (most of it is known geologically as the Shelbyville Moraine), Macon, DeWitt, Tazewell, Peoria, Marshall, Bureau, Lee, DeKalb and McHenry, there are many later moraines of large extent, as are found especially in Vermilion, Ford, McLean and Livingston counties, and also in the counties in the northeast corner of the State.

There are several different types of soil on the Wisconsin Moraines. Indeed the types in this soil area vary from beds of gravel, in places along the edges of moraines, to inclosed individual swamps. Nevertheless, the principal type is the rolling prairie soil varying in color from a brown or dark gray to black, with a mottled reddish brown and yellow subsoil usually found at about 14 to 18 inches below the surface. More or less sand and gravel are commonly present, even in the top soil.

The surface soil is frequently distinctly but not strongly acid, while the subsoil is free from acidity. In places, deeper plowing than commonly practiced will bring sufficient lime from the sub-surface soil to correct the acidity of the top soil, but, as a rule, an application of 400 to 500 pounds of lime per acre will greatly benefit the soil. This soil is not rich in phosphorus and with some crops and crop rotations it seems very evident that phosphorus can be applied with marked profit. The growth of leguminous crops

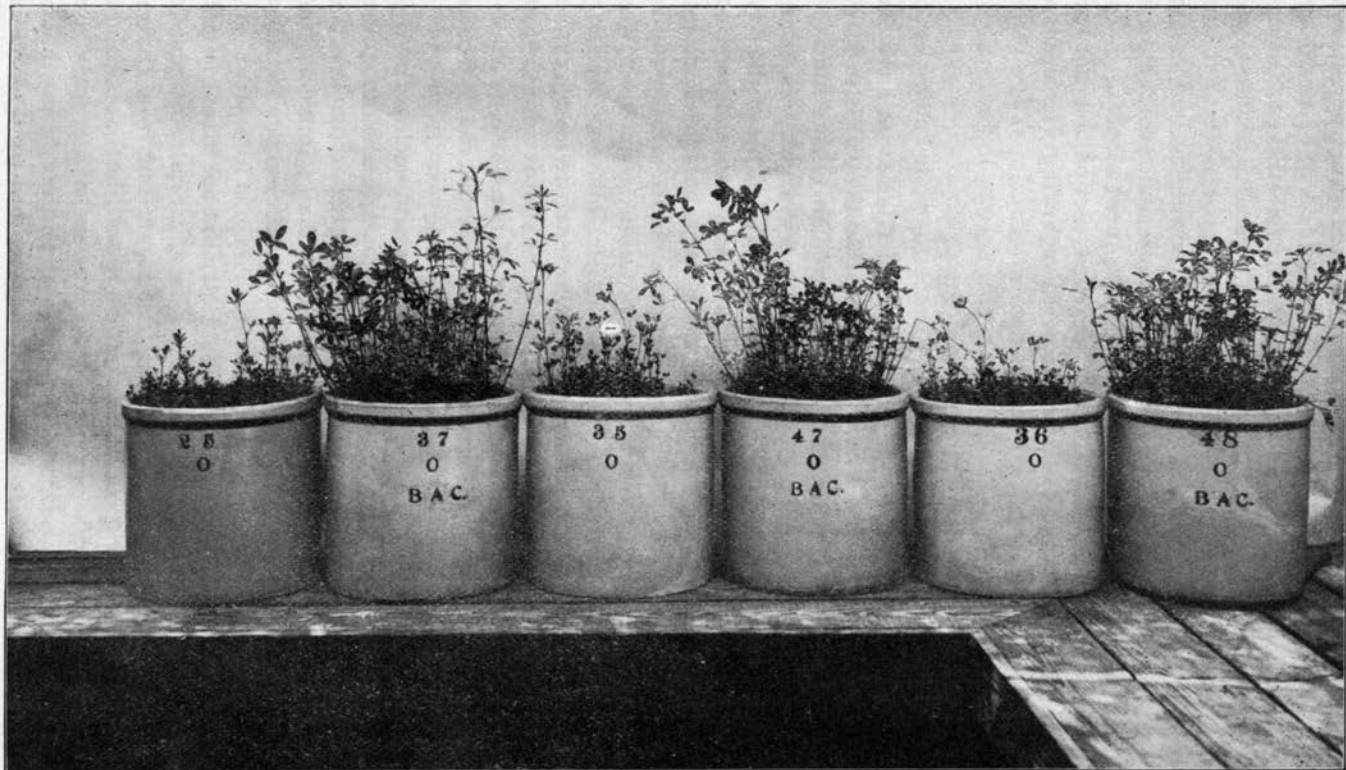


PLATE IV.—Alfalfa on Wisconsin Moraine Soil (Champaign County Rolling Prairie) Effect of Bacteria.

and the use of leguminous green fertilizers are of great benefit to succeeding crops of corn on this soil.

Several analyses have been made of this soil from different places, pot cultures have been conducted and field experiments are in progress. Nearly all results obtained show the need of light applications of lime and the great value of growing legumes (the nitrogen content is below normal) or of making liberal use of farm yard manure. The experiments already reported in our Bulletin No. 76, "Alfalfa on Illinois Soil," give some exact data regarding this type of soil, and I will not take more time to discuss it here.

#### 8. WISCONSIN GLACIATION.

While this term in its strict geological sense really includes the total area covered by the latest glacier, it is here used principally to designate the ordinary level or very slightly rolling prairie soil of this area. This is a black prairie soil, the commonest type of soil in DeKalb, Bureau, LaSalle, Grundy, Kankakee, Iroquois, Putnam, Marshall, Woodford, Livingston, McLean, DeWitt, Macon, Piatt, Champaign, Moultrie, Douglas, Coles and Edgar counties, and it is found more or less abundant in about a dozen other adjoining counties. It is a soil which apparently is not in so great need of immediate investigation as many other types, and as yet it has received but little attention. One of our regular series of pot cultures was conducted upon this soil, but no treatment applied seemed to effect the yield very markedly. When well drained and well cultivated, this soil produces from 60 to 80 bushels of corn in favorable seasons. It grows clover well. Broom corn is grown very extensively on this type of soil in Douglas, Coles and Edgar counties. Some representative samples of this soil have been collected and will be analyzed during the coming year.

#### 9. AREAS OF DEEP LOESS DEPOSITS.

This type of soil is of more recent formation than the Illinoian Glaciation (which is, itself, usually covered with more or less loess) but evidently it is older than the Wisconsin Glaciation. It occupies long, narrow strips of land bordering the Wabash, Illinois and Mississippi rivers. The loess deposit consists of very fine sand and of the still finer material, silt, together with some proportion of clay. It varies in thickness from a few feet to more than 50 feet. It has evidently been transported and deposited by winds, at least to some extent. It frequently contains light shells of lime carbonate. The surface of the soil on old cultivated

fields is usually distinctly acid, but at a depth of a few feet the acid disappears and lime carbonate is found, frequently in the form of small concretions of varying size and of odd and curious shapes. Evidently these concretions have all been formed in place since the loess deposit was made, the carbonic acid and other acids of the soil having dissolved the lime in the surface soil and carried it to lower depths where it has solidified and filled cracks and cavities in the earth.

In many places (especially upon old cultivated land) clover is a very uncertain crop on this soil. A field of it usually presents a "patchy" appearance. Along the brow of slopes and even on the slopes themselves the clover and also the crops which follow are frequently as good or better than on the level land. This is due to the fact that the surface soil on the level is acid, while the hill-side soil where the original surface has been washed off contains lime. This loess soil has no true subsoil. Aside from the larger quantity of organic matter contained in the surface, the texture is quite uniform to considerable depths, although at a depth of 40 to 50 feet the material is somewhat coarser, consisting chiefly of fine and medium sand. The loess soil is usually quite rich in potash, but it is not well supplied with phosphorus. It should be given an application of about 1,000 pounds of lime per acre, and then be improved by legumes or manure. If this is to be done, applications of phosphorus will greatly assist in improving the productive capacity of the soil and will undoubtedly prove profitable.

#### 10. SAND, SWAMP AREAS AND BOTTOM LANDS.

This soil area comprises all of the most recently formed soils in the State, and includes many of the markedly different types, such as the almost pure sand of the sand dunes or sand hills (where in places the sand is still blown or drifted by the wind), the alluvial sands or sandy loams of the river bottoms, the heavier loam and clay loam bottom lands, the plastic clay soils of drained and undrained river marshes, and even the swamp and peat soils which are found in the State.

These soils are widely scattered over the State and nowhere occupy such compact territory as many of the areas above described.

(a) *Sand Soils.*—The sand soils are chiefly in Tazewell and Mason, and in Lee, Whiteside, Bureau and Henry counties, and along the principal river bottoms. The lighter drifting sand soil is very deficient in all elements of plant food. It is apparently best adapted for some form of fruit, such as peaches (if they would not be winter killed). When heavily manured, it is well adapted

to growing melons, sweet potatoes, etc. We have an experiment field near Green Valley, Tazewell county, on this type and have some hopes of growing alfalfa and possibly some other deep rooting legumes on this soil.

(b) *River Bottom Soils.*—The river bottom soils are exceedingly variable, depending much upon the source of the material from which they are made. We are accumulating considerable information regarding several types of bottom land, but I shall not try to give details regarding it at this time.

(c) *Swamp Soils.*—The swamp soils of the State are quite extensive and greatly in need of investigation and we are giving them considerable attention. We have a University soil experiment field in Whiteside county and another in Kankakee county on swamp soils. The chemical analyses, the pot cultures, and the field experiments show that, as a rule the swamp soils are deficient in potassium, and that applications of potash salts are very profitable on most of those soils.

The following results secured the present season from our experiment field near Tampico, Whiteside county, on swamp soil which is known as "poison land" because it will not produce crops well, illustrates the need and value of applying potassium to that soil. Each plot under experiment is exactly one-tenth of an acre and contained 400 hills of corn. The exact yields per acre are given in bushels of ear corn (80 pounds per bushel) and pounds of corn stover:

Plot No.	Treatment Applied.	Ear Corn (bushels)	Stover (pounds)
1.....	None .....	None .....	1000
2.....	Lime .....	None .....	800
3.....	Lime, Nitrogen .....	None .....	1200
4.....	Lime, Phosphorus .....	None .....	2000
5.....	Lime, Potassium .....	36.3 .....	3600
6.....	Lime, Nitrogen, Phosphorus .....	None .....	1400
7.....	Lime, Nitrogen, Potassium .....	40.0 .....	3500
8.....	Lime, Phosphorus, Potassium .....	37.5 .....	3100
9.....	Lime, Nitrogen, Phosphorus, Potassium .....	60.0 .....	4400
10.....	Nitrogen, Phosphorus, Potassium .....	52.5 .....	4750

It will be observed that no ear corn was produced on any plot to which potassium was not applied. As a rule the plants on the plots not receiving potassium grew only two or three feet in height, while with an application of 160 pounds per acre of "muriate of potash" (potassium chlorid) the corn grew quite normally and produced a fair yield of grain.

Another special difficulty with many of the swamp soils is that they contain too much magnesia and in some cases probably too much lime. We are now conducting pot culture experiments



to try to determine how much magnesia plants can tolerate in the soil; that is, what percentage may exist without producing a poisonous or injurious effect. We are also trying to discover if there is any practical method by which the poisonous effect of magnesia can be corrected.

Recently drained swamp soils are frequently lacking in soil bacteria, especially those bacteria which have to do with the de-

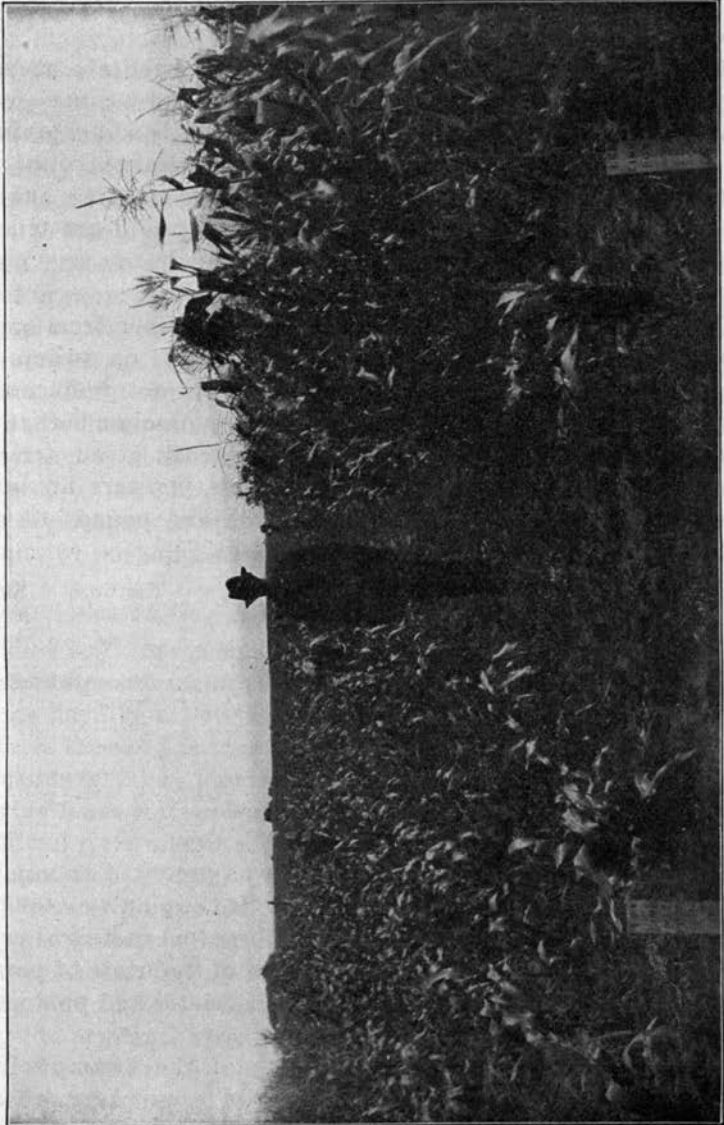


PLATE V.—Corn on Swamp Soil (Whiteside County "Poison" Land) Effect of Potassium.



composition, oxidation and nitrification of organic matter of soils and the consequent liberation of plant food from the soil. Because of this the growing crops practically starve, although the soil may be rich in all essential elements of plant food. The bacteria can be supplied by light applications of normal cultivated soil or earth. The same results may be accomplished by light applications of manure, particularly of horse manure, which is usually so thoroughly infected with bacteria that it not only rapidly decomposes itself but it greatly increases the rate of decomposition of the organic matter of the soil. In this connection it may be well to call your attention to the fact that even ordinary fertile soils do not contain in solution at any one time sufficient plant food to produce a single crop, but that during the growing season the plant food is liberated gradually from the soil and chiefly by the action of the soil bacteria.

(d) *Peaty Soils.*—The peaty soils are of limited areas. Those we have studied are chiefly in Tazewell and Mason counties. They are found to be very rich in nitrogen and fairly well supplied with phosphorus, but very deficient in potassium. Applications of potash salts are proving of great value and profit on these soils, and they are now being used by the farmers over the principal areas of peaty soils.

Now, of course, I have given you only an outline or summary of the work we are carrying on in our general survey of Illinois soils. With the assistance of my associates in this work we shall soon have ready for publication in bulletin form much more complete information regarding the progress and results of these investigations than I could include in this report. In general I may add that the field experiments of the present season are as successful as we could reasonably expect them to be. In some places in southern Illinois, dry weather has greatly injured our crops, while in places in the north-central part excessive rains and overflows have been injurious and will prevent our securing the most reliable and useful results. Because of such seasonable injuries or damages and uncontrolled influences, field experiments usually require a much longer time than pot cultures to yield reliable information, although the field experiments have the advantage of being under the outside natural conditions and they also serve as practical demonstrations in the section where they are conducted.

#### DETAIL SOIL SURVEY.

In beginning the detail soil survey, we first selected two differ-

ent areas, one (Tazewell county) in the north-central part of the State, and the other (Clinton and St. Clair counties) in the south-central part of the State. Each of these areas was selected by us because of the large number of different types of soil which they were known to contain. The terminal moraine of the Wisconsin Glaciation crosses Tazewell county, so that the west part of the county contains two of the distinct types of soil of the Wisconsin Glaciation; first the terminal moraine soil occupying the level tops or sloping sides of the hills or ridges; second the level or gently rolling upland prairie soil. Some soil materials of the Wisconsin Glaciation have also been washed beyond the terminal moraine across the central part of the county and this reworked material has formed some distinct types of soil overlying the till plain of the older glacial drift. The southern part of the county extends into the area of the Middle Illinoian Glaciation, while the western part of the county contains gravel beds, sand dunes, river bottoms, swamp lands and peat bogs. Thirteen distinct types of soil have been found in the detail survey of Tazewell county, which will serve as a basis for extending the survey in different directions where several of the types established in Tazewell county extend over very much larger areas.

In working out the detail survey a field party goes over the entire area, fixing soil types and locating, as definitely as it is possible to do, their exact boundary lines. Soil maps are made of the entire area surveyed which show the extent, location and boundaries of each different type of soil. The aim is to have this soil map made to show areas as small as 10 acres. The soil is examined by boring with augers, regularly to a depth of 40 inches, but if necessary, to much greater depths. A soil to be mapped under a given type must possess some uniform characteristics in texture (both in surface and subsoil), in color, in productive capacity (as determined by observed and reported crop yields), and in other properties which can be recognized by one who has become expert in distinguishing and correlating soil types. Ultimately the soils which are classed as a type must stand the test of chemical and physical analysis, pot culture tests and field experiments.

During the first half of the season our field party in the detail survey work consisted of two of our own men and two men from the Bureau of Soils. Since June we have furnished three men and the Bureau of Soils one man. The work has been under the joint direction of the Chief of the Bureau of Soils and myself, but one of the most experienced government men has been in direct charge of the field party.

St. Clair and Clinton counties were selected by us for detail survey because they contain all the types of soil between the Mississippi River bottom and the center of the Lower Illinoisan Glaciation, or white soil area. After both of the selected areas were completed, the field party was placed in Clay county and this has also been completed; so that we now have finished the detail survey of four counties in the State. Representative samples of soil have been taken from each of the different types of soil in all of the detail survey and these will be analyzed as rapidly as possible. We also hope in the near future to carry on pot culture experiments with all these different types of soil and, as far as possible and advisable to conduct field experiments upon each type. The soil maps will never become of the greatest possible value till we have exact information regarding each of the types of soil which are located and defined by the map.

In conclusion let me say that it is not now possible, and probably never will be practical or possible, for the Experiment Station to investigate and analyze soils which represent only one man's field or farm. You will readily understand this from the fact that the present total annual appropriation for soil investigation amounts to less than five cents for each quarter section of Illinois land, while the cost of only analyzing a single sample of soil amounts to about \$25.

I am very glad to report to you that we have made no analyses and have carried on no investigations of soils which are of only local or private interest and, with very few exceptions, there has been no demand upon us by Illinois citizens for such private work at public expense. Analyses of miscellaneous samples of soils collected by unauthorized and untrained persons, by inaccurate and non-uniform methods, usually imperfectly representing a mere patch of ground and frequently little more than the hole it is taken from, are of very little value even to the owner of the piece of land and certainly of very little value to the agriculture of a State. On the other hand it is possible to classify the soils of the State, first, into large soil areas according to their principal soil types, and finally to map all of the different types in detail and to investigate them carefully, ultimately to secure exact and reliable and most valuable information not only regarding the principal types in large soil areas (as we have already done and are doing) but also regarding the distinctly different types of soil even of more limited extent within these larger areas (as we plan and expect to do).

Is it my duty to add that the appropriation of \$10,000 per annum, made by the last General Assembly for beginning an investigation of Illinois soils, has made a beginning?

It has discovered that nearly one-third of the soils of the State are strongly acid and consequently will not grow red clover and other legumes successfully until treated with lime, and that some other soils of the State are slightly acid and will be greatly benefited by light applications of lime.

It has discovered that the old worn red clay hill soils, abundant in seven counties in the extreme southern part of the State, are still well stocked with potassium and fairly well supplied with phosphorus. but that they are exceedingly deficient in nitrogen, and that, if treated with lime and cropped with nitrogen gathering legumes, their productive capacity may be greatly increased.

It has discovered that the great white soil area in Southern Illinois is deficient in phosphorus, and that an intelligent use of phosphorus in connection with lime and legumes will undoubtedly largely and profitably increase the productive capacity of thirty counties of Illinois soil.

It has discovered that not only the peaty soils of Tazewell and Mason counties, but also very extensive swamp areas in north-central Illinois are very deficient in potassium, and that moderate applications of potash salts greatly increase the productive capacity of those soils.

It has discovered that the alfalfa bacteria are not generally present in Illinois soils, in consequence of which alfalfa has been pronounced a failure in Illinois for the past twenty years, but that these bacteria can be easily and profitably added to our soils and that then, under favorable conditions, alfalfa thrives in Illinois and has been made to produce from 8 to 10 tons of alfalfa hay per acre in several places in the State during the past season.

Gentlemen, there are other results, but let me say that I firmly believe any one of the discoveries mentioned above is worth to Illinois agriculture and to the commonwealth at least a hundred times the total appropriation which has been made for the investigation of her soil.

But, remember that only a beginning has been made. We need to do more. We need to extend the general soil survey at once to all of the large soil areas in the State; we need more soil analyses and more soil analysts; we need more apparatus; we need more room and facilities for pot culture experiments; we need more experiment and demonstration fields on different soil areas



and in different sections of the State; we need to follow up the detail soil survey, not only of the four counties which we have covered, but of the entire State of Illinois. In my judgment, Gentlemen, there is needed, and could be used to the advantage of this great State, at least \$25,000 per annum for the investigation of Illinois soils. The appropriation made by the last General Assembly was the first which has ever been made by the State of Illinois for an investigation of her soils. For the tremendous magnitude of the task, the appropriation was exceedingly small; but even great undertakings are probably best begun on a small scale and by safe and well tried methods that the appropriation may all be well used and none wasted; and the funds which were appropriated were all you asked for and they have made a good beginning; but, in my judgment, the actual needs of this great State demand that you should ask for larger appropriations from the next General Assembly for this great work. Illinois has a dairy section; she has a fruit section; she has an apple belt and a corn belt; but Illinois has no soil belt. As agriculture is the support of the State and the nation, so the soil is the support of agriculture. "The wealth of Illinois in her soil, and her strength lies in its intelligent development." All of the people are interested in Illinois soils, in the maintenance of her soil fertility, in increasing the productive capacity of Illinois lands; and they are desirous of learning as quickly as possible the most reliable and economic means of bringing about these results. Strictly speaking these investigations are an investment rather than an experiment. It is largely a question of work. With the continuation of the present appropriations, it will require about 30 years to cover the entire State. If the appropriations can be increased from \$10,000 to \$25,000 per annum the work can be done in 10 or 12 years; that is in time to be of real service to the people who are now living; and I frankly assert that any thoughtful man will agree that the appropriation suggested is exceedingly small compared with the interests involved. Consider, if you please, that an amount equal to that already appropriated by Illinois for an exhibit at the Louisiana Purchase Exposition (\$250,000) would make \$25,000 a year for 10 years, which would probably enable us to extend these investigations to every quarter section of Illinois soil. Seventy-five years ago these investigations and demonstrations could not have been made, because the exact and scientific methods of work which we now have at our command were not known then. Indeed, during the time of your own past lives, the sciences fundamental to agriculture have been really worked out and developed to their

present state of usefulness. The great sciences of geology, physics, chemistry and bacteriology are now the servants of agriculture. They stand before us, as it were, with bowed heads and bared arms ready to serve in the investigation of Illinois soils, and surely the present and future interests of Illinois and Illinois agriculture require much more exact and abundant information than we now possess regarding the various soils of the State.

I speak earnestly in this matter, solely because I appreciate the great needs of the work and believe in the practical and profitable results to the State I serve. Even though it is out of place it may not be without result for me to say that I could ask for or expect nothing for myself, my personal salary having already practically reached the limit which is paid to teachers and investigators in the University of Illinois. Larger appropriations for the investigation of Illinois soils mean larger responsibilities and larger opportunities for useful and much needed work.

But I make no request; I ask for nothing. That is your privilege, not my duty. I simply submit to the Illinois State Farmers' Institute the facts and opinions which I possess relating to the investigation of Illinois soils. I assume if the appropriation for soil investigation is increased by the next General Assembly, it will be because it is desired and requested by the Illinois State Farmers' Institute, the same organization which urged the last General Assembly to make the initial appropriation for these investigations.