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SOIL REPORT NO. 5

LA SALLE COUNTY SOILS

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INTRODUCTION

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, Sangamon, La Salle, and other subsequent reports are sent only to the residents of the county concerned and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles to help the farmer and landowner to understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix, but if necessary it should be read and studied in advance of the report proper.

La Salle county is located in the north-central part of the early Wisconsin glaciation. The soils of the county are divided into five classes as follows:

(1) Upland prairie soils, rich in organic matter. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat prairie land contains the higher amount of this constituent because it was largely preserved from decay by the presence of water.

(2) Upland timber soils, including those zones along stream courses over which forests once extended. The timber land contains much less organic matter because the large roots of dead trees and the surface layer of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay.

(3) Terrace soils, or second bottom land, representing the soils formed on fills of either silt or gravel or the flood plain of a stream when it flowed at a higher level than at present.

(4) Swamp and bottom lands, which include the lands that overflow along streams and a few small areas of swamps on the upland.

(5) Residual soils, formed by the decomposition of rocks in place. The entire area of this class is only $2\frac{1}{2}$ square miles.

The general topography of the county is undulating or slightly rolling. There are, however, some very flat areas; also belts of very rolling or hilly land along the larger streams, and considerable areas of terraces and bottom lands. The difference in topography is due mainly to two causes—glacial action and stream erosion. Like most of the state, this county was covered by a glacial ice sheet during what is known as the glacial period. During this time, snow and ice accumulated in the vicinity of Hudson Bay to such an amount that it flowed southward until a point was reached where the ice melted as rapidly as it advanced.

In moving across the country, the ice gathered up all sorts and sizes of earthy material, including pebbles, boulders, and even large masses of rock. Many of these were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, all of this material would accumulate in a broad, undulating ridge, or moraine. When the ice melted away more rapidly than it advanced, the terminus of the glacier would recede and leave a moraine of boulder clay to mark the outer limit of the ice sheet.

The ice made many advances, and with each advance a terminal moraine was formed. This has left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is vertically much less but longer and more gradual. The inter-morainal tracts are occupied chiefly by the broad areas of level or undulating prairies.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and this ice sheet may have been thousands of feet in thickness.

The materials pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Ridges and hills were rubbed down and valleys filled, and the surface features changed entirely.

A deposit of boulder clay covered the entire upland of the county to a depth varying from 5 to 300 feet, with an average of about 100 feet; but this was later covered by a deposit of loess, as hereinafter explained.

PHYSIOGRAPHY

The altitude of La Salle county varies from 430 feet in the Illinois-river valley to 930 feet on the Bloomington moraine north of Mendota. Other high altitudes are in the southwest and southeast parts of the county, but about four-fifths of the entire county is less than 700 feet above sea level.

The valley of the Illinois river is from 200 to 300 feet below the general upland. This has permitted considerable erosion, and as a result the land adjacent to the bottom land of the larger streams is cut up into hills and valleys unsuited for ordinary agriculture. Before the land was put un-

der cultivation, forests had extended their way up the smaller streams and were slowly invading the adjoining prairies. The influence of the prevailing southwesterly wind may be seen in the greater extension of the forests to the north and east of the protecting streams, as shown in the soil types.

The early Wisconsin glacier is responsible for three moraines: one, a very distinct ridge, known as the Bloomington moraine, crosses the northwest corner of the county; another, less distinct, crosses the Illinois river at Utica and extends northeast and southeast from this point, the north arm terminating near Earlville and the south arm coalescing with another moraine in the southeast part of the county; the third, the Marseilles moraine, enters the county northeast of the town of Marseilles, extends southwest across the Illinois river and thence southward into Livingston county. Between these moraines are broad inter-morainal areas of gently rolling prairie land with many flat areas of poor drainage. The old drainage system was almost completely filled and destroyed by the glacial drift, but gradually a new system has been developed. The large streams have eroded valleys from 5 to 250 feet deep and in some cases have formed narrow flood plains. Small streams tributary to the large ones have formed valleys extending back from the bluffs, and along the larger streams there gradually has been formed a zone of broken to hilly land. The time elapsed since the glaciers, however, has not been sufficient to develop a complete natural drainage system for the county, and it therefore has been necessary to supplement the work of nature by artificial means, with the result that the entire upland of the county is now well drained. The Illinois river flowing thru the central part of the county from east to west furnishes a good outlet for the half dozen streams with their tributaries that drain the county.

Bench lands, or terraces, are found along the larger streams; namely, the Illinois, Fox, and Vermilion rivers, and Indian creek,—a fact which indicates that these streams formerly carried a larger volume of both sediment and water.

TOPOGRAPHY AND FORMATION

The topography of the bottom lands is modified somewhat by deformation. All limestones, sandstones, and shales were formed in large bodies of water, from material deposited in almost horizontal strata. Usually when this became dry land, the strata still remained horizontal. Sometimes long fissures would occur in these rocks and one side would push up or drop down so that the rocks on the opposite sides would not correspond. This formation is called a *fault*. Sometimes the strata of rock would be pushed up into arches, or even into folds, as the earth contracted, forming what are known as *anticlines*.

The La Salle anticline (arch) has a steep slope to the southwest, while the slope to the northeast is more gradual. This anticline enters the state from Wisconsin near Winslow (Stephenson county), passes near Grand Detour, La Salle, Tuscola, and Bridgeport (Lawrence county), and is responsible for the oil fields (which lie beneath the arch) in the southeastern part of the state. This anticline does not seem to affect the topography of the upland in La Salle county, but in the valley of the Illinois river its effect is very striking. West of the anticline the bottom land all overflows, and is what is commonly called *first bottom*; while east of the anticline the overflow land is of small extent and in many places is either entirely absent or is replaced by second bottom, or bench lands. Most of these lands are un-

derlain by rock at no great depth; in fact, the rock frequently comes too near to the surface to permit tillage. The underlying rock is mostly sandstone. In some cases it even gives rise to a residual soil type (No. 060.5), and it also modifies the more common brown sandy loam on rock (No. 1560.5).

SOIL MATERIAL, AND SOIL TYPES

The early Wisconsin glacier covered La Salle county and left a thick mantle of drift, completely burying the old soil that preceded it. Later other ice invasions of Illinois occurred, but they covered only the north-eastern part of the state. (See state map in Bulletin 123, late Wisconsin glaciation.) These ice sheets did not reach La Salle county, but finely ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains, where it was picked

TABLE 1.—SOIL TYPES OF LA SALLE COUNTY

Soil type No.	Name of types	Area in square miles	Area in acres	Percent of total area
(a) Upland Prairie Soils (page 20)				
926 } 1126 }	Brown silt loam	922.16	590182.4	79.7143
1126.3 } 1120 }	¹ Brown silt loam on till	6.40	4096.0	.5532
1125 }	Black clay loam.....	17.39	11129.6	1.5032
1160 }	Black silt loam.....	.02	12.8	.0017
(b) Upland Timber Soils (page 23)				
934 } 1134 }	Yellow-gray silt loam	94.56	60518.4	8.1741
935 } 1135 }	Yellow silt loam	41.12	26316.8	3.5545
1199 }	Rock outcrop.	2.40	1536.0	.2074
(c) Terrace Soils (page 27)				
1526 }	Brown silt loam	10.26	6566.4	.8869
1526.4 }	Brown silt loam on gravel ² .....	.13	83.2	.0112
1526.5 }	Brown silt loam on rock.....	.06	38.4	.0052
1527 }	Brown silt loam over gravel ²	5.12	3276.8	.4426
1534.4 }	Yellow-gray silt loam on gravel.....	.02	12.8	.0017
1536 }	Yellow-gray silt loam over gravel.....	6.68	4275.2	.5774
1560 }	Brown sandy loam.....	4.80	3072.0	.4157
1560.4 }	Brown sandy loam on gravel.....	.30	192.0	.0259
1560.5 }	Brown sandy loam on rock.....	5.73	3667.2	.4953
1564 }	Yellow-gray sandy loam .....	.01	6.4	.0008
1581 }	Dune sand.. ..	.04	25.6	.0034
1590 }	Gravelly loam.....	.47	300.8	.0406
(d) Swamp and Bottom-Land Soils (page 31)				
1401 }	Deep peat .....	.57	364.8	.0492
1402 }	Medium peat on clay .....	.13	83.2	.0112
1426 }	Deep brown silt loam.....	11.48	7347.2	.9923
1454 }	Mixed loam	16.76	10726.4	1.4487
(e) Residual Soils (page 33)				
060.5 }	Brown sandy loam on rock	2.38	1523.2	.2057
083 }	Residual sand.....	.11	70.4	.0095
(f) Miscellaneous				
	Shale pits .....	.54	345.6	.0467
	River.....	7.19	4601.6	.6216

¹See map and text for area.

²"On" signifies that the gravel or rock is less than 30 inches below the surface; "over," more than 30 inches.

up by the wind, carried forward, and deposited upon the surface, burying the drift material of the early Wisconsin glaciation to a depth of 2 to 10 feet or more. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed.

After the loessial material was deposited over the surface of the country, vegetation developed, and organic matter became incorporated with the loess to a greater or less extent, thus gradually changing it into normal soil. Surface washing has made additional modifications.

Table 1 shows the area of each type of soil in the county and its percentage of the total area.

It will be noted that four-fifths of the entire county is covered with the common prairie soil, known as brown silt loam, while the black silt loam and black clay loam (sometimes called "black gumbo"), occupying the flat upland prairie, aggregate only 2 percent.

About 8 percent of the county consists of yellow-gray silt loam, the undulating upland soil once covered with timber. The more rolling yellow silt loam, also timber upland, is nearly half as extensive.

The terrace types cover 3 percent of the area of the county and the bottom lands and rivers also about 3 percent.

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about $6\frac{2}{3}$ inches deep). In addition, the table shows the amount of limestone present, if any, or the amount of limestone required to neutralize the acidity existing in the soil.¹

THE INVOICE AND INCREASE OF FERTILITY IN LA SALLE COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

¹The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations made, with the exception of the acidity or the limestone present in two soil types. As a rule, the brown silt loam is slightly acid in the surface and subsurface, and sometimes the acidity extends to the subsoil, but where samples were taken from the heavier phase of this type (near old draws or perhaps near the shore lines of what may once have been ponds) an abundance of lime carbonate was usually found in the subsoil and, in a few cases, even in the surface and subsurface, as is shown in the tables. The other exception occurred with one sample of subsoil of the yellow-gray silt loam, which showed the presence of limestone, but this stratum, as well as the surface and subsoil, is usually acid, and consequently this exceptional result was not included in the average.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even the plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

As stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil,¹ which corresponds to an acre about $6\frac{2}{3}$ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point, then the strong, vigorous plants will have power to secure more plant food from the sub-surface and subsoil than would weak, shallow-rooted plants.

By easy computation it will be found that the most common prairie soil of La Salle county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for twelve rotations; while the upland timber soils contain, as an average, less than one-half as much nitrogen as the prairie land.

¹In all strata the weight of peat is figured at $\frac{1}{2}$ and that of sand at $1\frac{1}{4}$ the weight of normal soils.

TABLE 2.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6½ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
Upland Prairie Soils									
1126	Brown silt loam	71390	6102	1384	33474	9567	15158	rarely	often
1126.3	Brown silt loam on till	42200	4360	1180	38520	11200	8420		40
1120	Black clay loam	81460	7020	1780	36440	13480	20300	1960	
1125	Black silt loam	74660	6850	1970	34980	13380	21270	14850	
1160	Brown sandy loam.	33100	2820	1160	28720	5480	7400		40
Upland Timber Soils									
1134	Yellow-gray silt loam	32673	2527	1033	38580	7053	8227		87
1135	Yellow silt loam	23967	2093	773	39033	7560	7100		200
Terrace Soils									
1526	Brown silt loam	65520	5720	1860	56260	16667	12000	2620	
1526.4	Brown silt loam on gravel. . .	42760	3880	1100	33740	7120	8720		40
1526.5	Brown silt loam on rock.	135800	11460	4900	46380	14680	21880	2780	
1527	Brown silt loam over gravel. . .	40440	3700	1020	35680	7940	8920		60
1534.4	Yellow-gray silt loam on gravel	29120	2740	980	35560	6280	9020		40
1536	Yellow-gray silt loam over gravel.	29080	2700	980	37900	6500	8380		60
1560	Brown sandy loam.	29240	2480	1210	19110	3560	5430		80
1560.4	Brown sandy loam on gravel	25700	2260	1360	25980	4760	4740		80
1560.5	Brown sandy loam on rock. .	52780	5000	1240	13120	5840	11920	9900	
1564	Yellow-gray sandy loam over gravel. .	19120	1560	740	30480	4600	8980	4300	
1581	Dune sand.	13500	1300	780	23530	4000	5880		80
1590	Gravelly loam. . .	64560	5960	1920	25580	11220	17420	11460	
Swamp and Bottom-Land Soils									
1426	Deep brown silt loam.	52460	4440	2020	37960	30000	62760	209500	
1454	Mixed loam (small streams)	42740	4440	1260	33500	27420	46880	161900	
1401	Deep peat.	177540	16080	1310	8210	8370	129900	285850	
1402	Medium peat on clay.	212320	19600	970	10730	5140	16270		90
Residual Soils									
060.5	Brown sandy loam on rock. .	26400	2220	880	25880	4480	1800		20
083	Residual sand. . .	16380	850	700	7900	2530	2650	4530	

With respect to phosphorus, the condition differs only in degree, nine-tenths of the soil area of the county containing no more of that element than would be required for eighteen crop rotations if such crop yields were secured as are suggested in Table A of the Appendix. In the case of the

cereals it will be seen from the same table that about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 400 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2500 and 600 years for magnesium, and about 15,000 and 350 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with these elements we must also consider the heavier loss by leaching.

These general statements relating to the total quantities of plant food in the plowed soil certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different soil types with respect to their content of important plant-food elements is also very marked. Thus, the prairie soils contain from two to three times as much nitrogen as the timber lands of the same topography; and the richest prairie land contains twice as much phosphorus as the common upland timber soils.

On the other hand, the most significant fact revealed by the investigation of the La Salle county soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than three-fourths of the entire county. The market value of this land is about \$200 an acre, and yet an application of forty dollars' worth of fine-ground raw rock phosphate would double the phosphorus content of the plowed soil, and, if properly made, would in the near future double the yield of clover on the normal and lighter phases. If the clover was then returned to the soil, either directly or in farm manure, the combined effect of phosphorus and increased nitrogenous organic matter, with a good rotation of crops, would in time double the yield of corn on most farms.

With 6,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 34,000 pounds of potassium in the same soil and with practically no acidity, the economic loss in farming such land with only 1300 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that the crop yields could ultimately be doubled by adding phosphorus,—without change of seed or season and with very little more work than is now devoted to the fields.

Fortunately, some definite field experiments have already been conducted on this most extensive type of soil, not in La Salle county, but on similar soil in several other counties, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced) and had then been cropped with clover and grass on one field, oats on another, and oats, cowpeas, and corn on the third field, until 1901.

As an average of the first three years (1902-1904) phosphorus increased the crop yields per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats.

During the second three years (1905-1907) it produced average increases of .79 ton of clover, 13.2 bushels of corn, and 11.9 bushels of oats.

During the third course of the rotation (1908-1910) it produced average increases of 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats.

For convenient reference the results are summarized in Table 3 (page 10).

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the four years 1908 to 1911, raw



PLATE 1. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

TABLE 3.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

Rotation	Years	Corn, bu.	Oats, bu.	Clover, tons	Value of increase	Cost of treatment ¹
First.....	1902,-3,-4	8.8	1.9	.68	\$ 7.73	\$7.50
Second.....	1905,-6,-7	13.2	11.9	.79	12.93	7.50
Third.....	1908,-9,-10	18.7	8.4	1.05	15.37	7.17

¹Prices used are 35 cents a bushel for corn, 30 cents for oats, \$6 a ton for clover hay, 10 and 3 cents a pound, respectively, for phosphorus in bone meal and in rock phosphate.

rock phosphate (with no previous application of bone meal) increased the yield of wheat by 10.3 bushels per acre. Here too, as an average of the four years, the phosphorus applied paid back about twice its cost.



PLATE 2. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

Wheat has also been grown on the North Farm during the last two years, and the average increase produced by phosphorus (part in bone meal and part in raw phosphate) has been 11 bushels per acre.

In the grain system of farming, the yield of wheat in 1911 was 35.2 bushels per acre where cover crops and crop residues are plowed under without the use of phosphorus; but where rock phosphate is used the average yield was 50.1 bushels. (See Plates 1 and 2.)

In the live-stock system, the yield of wheat in 1911 was 34.2 bushels where manure and cover crops are used without phosphate, and 51.8 bushels, as an average, where rock phosphate is used in addition. (See Plates 3 and 4.)

These results emphasize the cumulative effect of permanent systems of soil improvement.



PLATE 3. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
AVERAGE YIELD, 34.2 BUSHELS PER ACRE

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 4 gives the results obtained during the past eleven years from the Sibley soil experiment field located in Ford county on typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitrogen without phosphorus produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in the corn in 1907 having



PLATE 4. WHEAT IN 1911 ON URBANA FIELD
COVER CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None.....	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4
102	Lime.....	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6
103	Lime, nitrogen..	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3
105	Lime, potassium.	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1
106	Lime, nitrogen, phosphorus...	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2
107	Lime, nitrogen, potassium.....	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6
108	Lime, phosphorus, potassium.....	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7
109	Lime, nitrogen, phos., potas...	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2
110	Nitro., phos., potassium....	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1

Average Increase: Bushels per Acre

For nitrogen.....	-1.7	3.4	.7	6.4	14.1	23.6	19.3	.1	6.4	1.6	-40.1
For phosphorus.....	1.7	12.1	10.7	9.2	16.5	15.7	6.4	8.1	16.3	12.0	5.4
For potassium.....	-3.0	-2.9	-5.1	2.4	-1.5	1.0	3.0	-.2	2.7	-.6	7.5
For nitro., phos., over phos.....	-4.0	6.8	-4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	-50.1
For phos., nitro. over nitro.....	-2.7	14.8	10.9	12.4	26.8	24.2	9.3	14.3	26.6	12.9	16.9
For potas., nitro., phos. over nitro., phos....	1.4	-3.2	-5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None ..	\$ 172.73	
102	Lime	184.75	\$ 12.02
103	Lime, nitrogen	167.42	— 5.31
104	Lime, phosphorus.	214.50	41.77
105	Lime, potassium.	173.22	.49
106	Lime, nitrogen, phosphorus.....	233.15	60.42
107	Lime, nitrogen, potassium.....	188.19	15.46
108	Lime, phosphorus, potassium.....	200.37	27.64
109	Lime, nitrogen, phosphorus, potassium.....	244.62	71.89
110	Nitrogen, phosphorus, potassium.....	233.51	60.81

Average Value of Increase per Acre in Eleven Years

	Cost of increase
For nitrogen..	\$ 15.14
For phosphorus.....	44.76
For potassium.....	1.65
For nitrogen and phosphorus over phosphorus.....	18.65
For phosphorus and nitrogen over nitrogen.....	65.73
For potassium, nitrogen, and phosphorus over nitrogen and phosphorus	11.47
	\$ 165.00
	27.50
	27.50
	165.00
	27.50
	27.50

been 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the yield of the highest-producing plot exceeded that of 1902, while the untreated land produced less than half as much as was produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment is seen. Phosphorus appears to have been the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results.

In the lower part of Table 4 are shown the total values per acre of the eleven crops from each of the ten different plots, the amounts varying from \$167.42 to \$244.62; also the value of the increase produced in crop yields above the value of the yields from the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents. Phosphorus without nitrogen produced \$29.75 in addition to the increase by lime; but, with nitrogen, it produced \$65.73 above the crop values where only lime and nitrogen were used. The results show that in 25 cases out of 44 the addition of potassium decreased the crop yields. Even under the most favorable conditions, and with no effort to liberate potassium from the soil by adding organic matter, potassium paid back less than half its cost.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that the average increase produced by lime was \$11.55, or more than \$1 an acre a year. Altho this increase may have been above normal on these plots because of the "condition" of the soil at the beginning, it suggests that the time is here when limestone must be applied to some of these brown silt loam soils. While nitrogen produced an appreciable increase, especially when phosphorus was provided, the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 5, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the eleven years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen on the Bloomington field after 1905, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced an even larger increase (\$89.92) than was produced by phosphorus over nitrogen (\$65.73) on the Sibley field (see Plots 103 and 106).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the oppo-

site side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 5 are considered reliable. They not only furnish much information in themselves but also instructive comparisons with the Sibley field.

Wherever nitrogen was provided, either by direct application or by the use of legume crops, the addition of the element phosphorus produced very marked increases, the average value for the two fields being \$7.07 an acre a year. This is \$4.57 above its cost in 200 pounds of steamed bone meal, the form in which it was applied to the Sibley and Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying the nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots, 160 pounds per acre of phosphorus, as an average, were removed in the eleven crops. This is equal to more than 13 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus was applied, the crops removed only 107 pounds of phosphorus in the eleven years, which is equivalent to only 9 percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902). The total phosphorus applied from 1902 to 1912, as an average of all plots where it was used, amounted to 275 pounds per acre and cost \$27.50. This paid back \$84.91, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, paid back only \$1.59 per acre in the eleven years, or less than 6 percent of its cost. Are not these results to be expected from the composition of the soil and the requirements of crops? (See Table 2, page 7, and also Table A in the Appendix.)

Nitrogen was applied to this field in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a catch crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil is already appreciable (an average increase of 4.4 bushels of wheat in 1910 and 7.9 bushels of corn in 1911) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the eleven years drew their nitrogen very largely from the natural supply in the organic matter of the soil.

The clover roots and stubble contain no more nitrogen than the clover crop takes from the soil, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106 and between Plots 108 and 109, in the yields of grain crops.

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover ² 1910	Wheat 1911	Corn 1912
Plot	Soil treatment applied	Bushels or tons per acre										
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.6	47.9
103	Lime, crop res. ¹ ...	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5
104	Lime, phosphorus...	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5
105	Lime, potassium...	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8
106	Lime, residues, ¹ phosphorus.....	43.9	77.6	85.3	50.9	°	78.9	45.8	72.5	(1.67)	60.2	86.1
107	Lime, residues, ² potassium.....	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9
108	Lime, phosphorus, potassium.....	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2
109	Lime, res., ¹ phos., potassium.....	52.7	80.9	90.5	51.9	°	88.4	58.1	64.2	(.42)	60.4	83.4
110	Res., phosphorus, potassium.....	52.3	73.1	71.4	51.1	°	78.0	51.4	55.3	(.60)	61.0	78.3

Average Increase: Bushels or Tons per Acre

For residues	1.4	3.1	11.4	5.9	-.96	1.3	-1.1	3.7	-1.64	4.4	7.9
For phosphorus.....	9.5	17.8	14.8	14.4	.41	18.8	18.0	15.1	1.51	33.9	24.0
For potassium.....	5.8	.2	.3	.7	.25	2.4	4.2	-4.8	-.63	-.6	2.1
For res., phos. over phos.	2.2	4.6	12.6	11.7	-.65	-3.2	-1.7	8.7	-2.25	2.6	11.6
For phos., res. over res.	8.8	18.1	15.5	20.4	-1.46	14.6	8.9	23.1	.84	34.6	23.6
For potas., res., phos. over res., phos.....	8.8	3.3	5.2	1.0	.00	9.5	12.3	-8.3	-1.25	.2	-2.7

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None	\$167.22	
102	Lime	165.52	-\$1.70
103	Lime, residues	173.17	5.95
104	Lime, phosphorus	255.44	88.22
105	Lime, potassium	169.66	2.44
106	Lime, residues, phosphorus	251.43	84.21
107	Lime, residues, potassium	170.57	3.35
108	Lime, phosphorus, potassium	256.92	89.70
109	Lime, residues, phosphorus, potassium	254.76	87.54
110	Residues, phosphorus, potassium	236.66	69.44

Average Value of Increase per Acre in Eleven Years

	Cost of increase
For residues.....	\$.60
For phosphorus.....	84.91
For potassium.....	1.59
For residues and phosphorus over phosphorus.....	-4.01
For phosphorus and residues over residues.....	78.26
For potassium, residues, and phosphorus over residues and phosphorus.....	3.33
	?
	\$27.50
	27.50
	?
	27.50
	27.50

¹ Commercial nitrogen was used 1902-1905.² The figures in parentheses mean bushels of seed; the others, tons of hay.³ Clover smothered by previous wheat crop.

In Plate 5 are shown graphically the relative values of the eleven crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. As an average, Plots 106 and 109 are only \$3.09 behind Plots 104 and 108 in the value of the eleven crops harvested, and this would have been covered by about $\frac{1}{2}$ bushel more clover seed in 1906 or 1910, or it may be covered by 10 bushels more corn in 1913. The values from Plots 103 and 107 average \$4.28 more than the values from Plots 102 and 105. (See also last page of cover.)

THE SUBSURFACE AND SUBSOIL.

In Tables 6 and 7 are recorded the amounts of plant food in the subsurface and the subsoil, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in Tables 6 and 7 is that the most common upland timber soil is usually more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of lime-

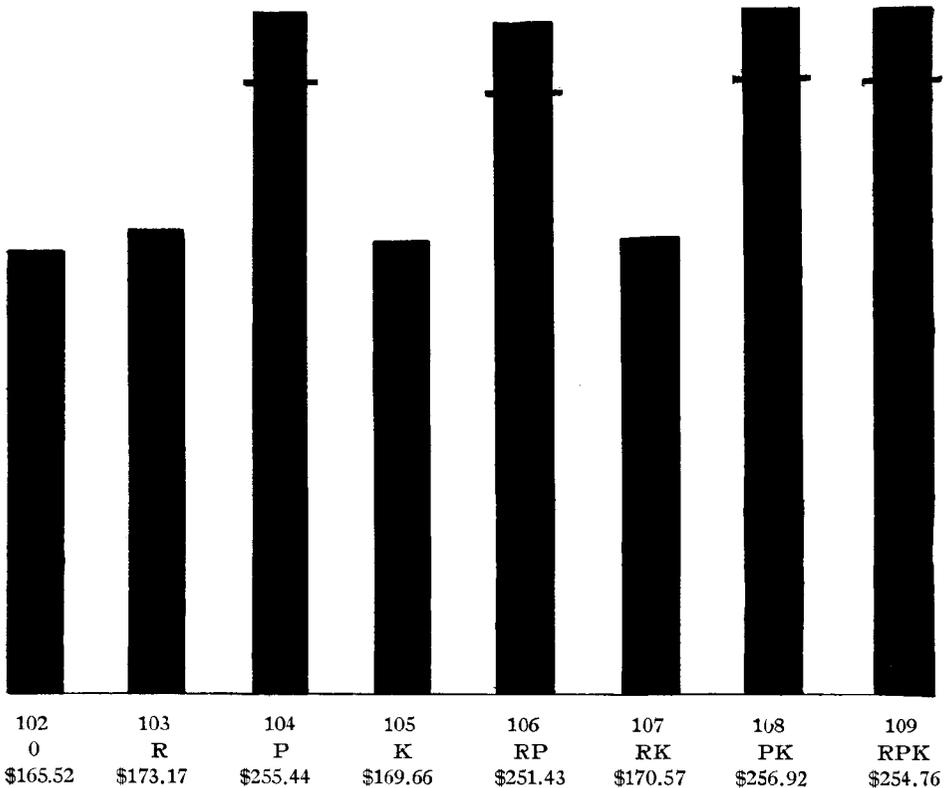


PLATE 5. CROP VALUES FOR ELEVEN YEARS,
BLOOMINGTON EXPERIMENT FIELD

stone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during periods of partial drouth, which are critical periods in the life of such plants as clover. While the common brown silt loam prairie soil is usually slightly acid, the upland soils that are

TABLE 6.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface (about 6 $\frac{2}{3}$ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
Upland Prairie Soils									
1126	Brown silt loam	69139	6163	2184	69646	22877	22973	rarely	often
1126.3	Brown silt loam on till.....	38520	4160	1480	88560	33520	14040		80
1120	Black clay loam	82360	7560	2840	72320	26160	37960	2040	
1125	Black silt loam	52720	5280	2920	74040	27360	36260	16620	
1160	Brown sandy loam.....	34360	3080	1720	60440	16000	16000		1480
Upland Timber Soils									
1134	Yellow-gray silt loam.....	23947	2280	1907	81853	20840	15187		1427
1135	Yellow silt loam	17947	2280	1387	90000	27813	10580		8000
Terrace Soils									
1526	Brown silt loam	76907	7507	3067	119680	44133	30573	55987	
1526.4	Brown silt loam on gravel...	56200	5240	1960	67480	21960	18120		120
1526.5	Brown silt loam on rock.....	198920	16480	10560	94920	30360	49800	15160	
1527	Brown silt loam over gravel...	45760	4600	1760	71080	19200	12920		120
1534.4	Yellow-gray silt loam on gravel	19720	2480	2000	70840	20160	17120		80
1536	Yellow-gray silt loam over gravel.....	15880	2120	1840	79640	20280	16160		440
1560	Brown sandy loam.....	31680	2900	2040	38380	6860	9740		80
1560.4	Brown sandy loam on gravel	28400	2760	2440	56240	11880	9480		80
1560.5	Brown sandy loam on rock.	67720	5880	2480	25160	9920	15440	3920	
1564	Yellow-gray sandy loam over gravel...	12440	1600	1680	64480	12760	13280		80
1581	Dune sand.....	12750	1200	1350	44200	8400	10800		150
1590	Gravelly loam..	103760	10000	3680	51800	41280	80360	153720	
Swamp and Bottom-Land Soils									
1426	Deep brown silt loam.....	98560	9160	4120	83480	63400	128560	428120	
1454	Mixed loam (small streams)	36560	4560	2040	56520	81600	127880	542960	
1401	Deep peat....	546860	46740	2360	14640	15680	157680	265880	
1402	Medium peat on clay.....	195720	19140	1620	28640	12780	26400	2580	
Residual Soils									
060.5	Brown sandy loam on rock.	13440	1480	1600	57800	11320	1720		1040
083	Residual sand..	12000	1200	1250	10450	3600	1800		500

or were timbered are already distinctly in need of limestone, as a rule; and, as already explained, they are even more deficient in phosphorus and nitrogen than the common prairie soil.

TABLE 7.—FERTILITY IN THE SOILS OF LA SALLE COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone required
Upland Prairie Soils									
1126	Brown silt loam	21886	2683	3048	109387	57857	61769	often	rarely
1126.3	Brown silt loam on till.	21300	3660	2400	178200	205620	250320	1167840	
1120	Black clay loam	45240	4500	3360	109320	40320	43200	2580	
1125	Black silt loam.	14610	2370	3840	112020	66090	87480	205830	
1160	Brown sandy loam.....	21120	2700	2520	100380	38220	32820		240
Upland Timber Soils									
1134	Yellow-gray silt loam.....	23500	2460	3280	133040	68360	76760		3510
1135	Yellow silt loam	22840	3100	2540	170560	101860	62240	371520	
Terrace Soils									
1526	Brown silt loam	50340	5840	3440	178820	90440	92420	347900	
1526.4	Brown silt loam on gravel....	49560	5100	3360	93300	48060	31440		300
1527	Brown silt loam over gravel...	30540	3420	2940	107700	34920	21720		600
1534.4	Yellow-gray silt loam on gravel								
1536	Yellow-gray silt loam over gravel ...	19260	3180	3600	117360	38520	28020		1440
1560	Brown sandy loam.....	19350	1470	1830	59640	10830	12420		90
1564	Yellow - gray sandy loam over gravel...	11760	1620	2760	83460	22320	17940		420
1581	Dune sand.....	19130	1800	2030	66300	12600	16200		230
Swamp and Bottom-Land Soils									
1426	Deep brown silt loam.....	136200	13740	5820	125340	126000	205140	728040	
1454	Mixed loam (small streams)	20880	2100	2160	68400	137220	261360	1045980	
1401	Deep peat	820290	70110	3540	21960	23520	236520	398820	
1402	Medium peat on clay... ..	49500	4140	3660	102660	135240	395280	1124100	
Residual Soils									
083	Residual sand..	18000	1800	1880	15680	5400	2700		750

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE

Brown Silt Loam (1126; also 926 on Moraines)

This type occupies 922.16 square miles, or 590,182 acres, and constitutes 79.7 percent of the entire area of the county. In topography it varies from flat to rolling, the average being what would be called gently rolling with irregular undulations due to the action of the glacier in thus depositing material. In many places the surface is not sufficiently rolling for good drainage, and it has been necessary to use tile drainage to a large extent.

The soil to a depth of 3 to 5 feet is formed from wind-blown loessial material similar in origin to the deep loess deposits found near the great stream valleys, but finer in physical composition. This type, altho typically a prairie soil, may include in its area a small amount of land that has been forested in comparatively recent time.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown silt loam, varying on the one hand to black as it grades into black clay loam (1120) or black silt loam (1125), and on the other, to grayish brown or yellowish brown as it grades into the timber types. It contains a sufficient amount of the coarser constituents (coarse silt and sand) to make it work easily and yet enough of fine silt and clay to give it stability. The organic-matter content varies from 4.2 to 8.7 percent, with an average of 5.9 percent; in other words, from 42 to 87 tons per acre, with an average of 59 tons. It is less in the more rolling areas, while in the low and poorly drained parts it is greater, the larger moisture content having permitted a ranker growth of grasses and roots with more favorable conditions for their preservation.

The subsurface stratum varies in thickness from 9 to 16 inches and in color from a dark brown to a yellowish brown silt loam. Both color and depth vary with the topography, being lighter and shallower on the more rolling areas and the areas where this type grades into the timber types.

The beginning of the subsoil is indicated by a change in color and texture. It is a yellow clayey silt or silty clay, somewhat plastic when wet. Where the drainage has been good, it is of a bright or a pale yellow color, but where poorly drained, it approaches an olive.

A phase of this type has been recognized in this county where, by the removal of part of the fine loessial material, the glacial drift or till is found less than 30 inches from the surface. In some places this may give a somewhat inferior soil owing to the compact and less pervious character of the subsoil. But this does not occur very often; most of the till in this type is pervious, and some of it in Townships 33 and 34, Range 5 East, is quite gravelly. Limited areas of sandy and gravelly loam, too small to be shown on the map, are quite common in the morainal regions.

In the management of this type, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep it in good physical condition, or good tilth. It is a common practice in the corn belt to pasture the corn stalks during the winter and, too often, rather late in the spring after the ground has thawed out. This tramping puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing and wetting and drying, with the aid of ordinary tillage, fail to pro-

duce good tilth before the crop is planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes farmers work their soil when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the amount of organic matter below the amount that is necessary to maintain good tilth.

Every practicable means should be used to maintain the supply of organic matter. Clover should be grown every three or four years and the bulk of the crop turned under either directly or as manure. All straw should be returned to the land and plowed under if not used for bedding or feed. One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks, and to burn them is a very serious waste.

The stalks should be cut up with a disk or stalk cutter and turned under. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus. A ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as four tons of average farm manure, but, when burned, both the humus-making material and the nitrogen are forever destroyed and lost.

The normal and the lighter phases of brown silt loam already require liberal additions of nitrogenous organic matter and phosphorus for the increase and maintenance of their crop-producing power. As a rule, limestone can also be added with profit, and the importance of using limestone becomes greater year after year. The heavier phase of this soil type, usually found in narrow areas along old sloughs or draws, is still rich in humus and nitrogen, moderately rich in phosphorus, and well supplied with lime carbonate. Often the soil type in these narrow strips is black silt loam (1125), but it is in too small areas to map separately from the brown silt loam. It should be kept in mind that phosphorus is a constituent of humus and is usually associated with limestone; and phosphorus is not likely to be greatly needed where the soil is still rich in humus and shows the presence of limestone by foaming when moistened with strong hydrochloric acid. (See Circular 150 for detailed directions for testing the soil for limestone or acidity.)

Black Clay Loam (1120)

This type comprises 6.4 square miles, or 4,096 acres, and constitutes about $\frac{1}{2}$ percent of the total area of the county. It occupies the lower and flatter areas where the accumulation of organic matter and finer soil constituents has been going on. It has poor natural drainage, and was originally in swamps or sloughs, but by means of artificial drainage, it has been completely reclaimed. Altho the soil is fine-grained, it drains well, having a large number of checks, or joints, which make it quite permeable to water. The openings produced by worms and crayfish and deep-rooting plants have further increased this permeability.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a black clay loam, plastic and granular, varying locally to a black clayey silt loam where much silt has been

washed in covering the more clayey layer. It is very well supplied with organic matter, containing about 7 percent. A considerable percentage of sand, chiefly of the finer grades, may be found in this stratum.

The subsurface soil, 6 $\frac{2}{3}$ to 18 or 20 inches, varies from a black to a brown clay loam, usually somewhat heavier than the surface stratum.

The subsoil, extending to a depth of 40 inches, is a dark drab, mottled or yellow clay loam, varying locally to a yellowish clayey silt. It frequently contains concretions of lime.

In the management of this type, the most important thing is to keep it in good tilth. To do this, thoro drainage is the first essential. Then it is necessary to use every means to maintain the supply of organic matter, for, it must be remembered, heavy clay soils become difficult to work in proportion as the organic matter is removed. Continued burning of corn stalks on this type of soil will finally result in great injury to its tilth and working condition.

Clover is especially beneficial to this black clay loam, as it loosens it up to a considerable depth and gives greater permeability to moisture and roots. However, it is not immediately necessary that so much clover or manure be plowed under on this type as on the brown silt loam.

As yet no field experiments have been conducted on black clay loam, but, where the soil contains sufficient limestone to respond to the test with strong acid, there is no need to add more, unless for physical improvement. No marked profit can be expected from adding phosphate, altho it will doubtless pay to keep the phosphorus content up to at least its present percentage.

Black Silt Loam (1125)

This type occupies low, flat areas of prairie land somewhat similar to those of the black clay loam (1120), but it has had more of the coarser material washed in, and as a result is somewhat friable. It covers a total area of 17.39 square miles, or 11,129 acres, comprising about 1.5 percent of the entire area of the county. In topography this type is flat and poorly drained naturally.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a black silt loam varying on the one hand to brown silt loam, and on the other to black clay loam. It is very granular and pervious to water. The organic-matter content is about 6.4 percent, or 64 tons per acre.

The subsurface, 6 $\frac{2}{3}$ to 20 inches or more, is a black to dark brown clayey silt loam quite pervious to water. It contains 2.27 percent of organic matter, or 45 tons per acre.

The subsoil is a yellow or drabbish yellow slightly clayey silt that allows free movement of water.

In the management of this black silt loam, the same precautions should be observed as in that of black clay loam (1120). The black silt loam contains less clay and more silt and limestone than the black clay loam, but otherwise the two types are very much alike in composition and requirements.

Brown Sandy Loam (1160)

A small area of about 13 acres of rather coarse brown sandy loam occurs in Section 27, Township 36 North, Range 2 East, that does not differ greatly in fertility from the brown silt loam around it. This is the only area of this type in the county.

Since this type is somewhat sour in all strata to a depth of 40 inches, the use of 2 to 5 tons per acre of ground limestone should prove profitable, especially for the production of alfalfa or of clover in crop rotation. For a sandy loam, it is well supplied with phosphorus, considering the deep-feeding range afforded to plant roots; but legume crops should have a prominent place in the crop rotation and the nitrogen should be maintained by organic manures.

(b) UPLAND TIMBER SOILS

The upland timber soils differ from the prairie soils principally in the fact that they contain less organic matter. This low organic-matter content produces another striking difference, that of color, the prairie soils being black or brown, while the timber soils are yellow or gray.

Yellow-Gray Silt Loam (1134, or 934 when found on morainal ridges)

This type covers 94.56 square miles (60,518 acres) or 8.17 percent of the entire area of the county. It is located almost without exception on the upland along the larger streams, and comprises the less rolling areas that have been forested. The natural drainage systems have been better developed in this type than in any other except the yellow silt loam (1135).

The surface $6\frac{2}{3}$ inches is a gray, yellowish gray, or brownish gray silt loam, the color varying with the topography; the nearly level areas usually are either lighter or darker in color, while the more rolling parts have more of a yellow or brownish yellow color. The organic-matter content also varies with the topography and with the length of time in forest as indicated by the character of the trees, but it averages 2.8 percent, or 28 tons per acre $6\frac{2}{3}$ inches deep.

The subsurface soil, $6\frac{2}{3}$ to 12 or 18 inches, is usually a gray to grayish yellow silt loam. The thickness of this stratum varies with the topography, being thinner on the more rolling areas. The amount of organic matter present is about 21 tons for 4 million pounds of soil.

The subsoil, extending to a depth of 40 inches, is a somewhat plastic yellow or grayish yellow clayey silt, the lower part sometimes reaching the glacial drift. This is due to the removal by erosion of a large part of the loessial material. This glacial drift may be locally a very gravelly deposit, but usually it is a gravelly clay that may be lacking in permeability. Otherwise each stratum of this type is quite pervious to water, with the exception of the level gray areas, where a tight, more or less compact clayey layer has formed. This occurs only in areas too small to be shown on the map.

This type is low in organic matter, and one of the first considerations for physical improvement is the problem of how to increase this constituent. It is scarcely possible under the present system of cropping even to maintain the supply of organic matter, much less to increase it. Crop residues must be turned back either directly or in manure, the corn stalks must be cut up and turned under instead of being burned, straw should be returned, clover grown and turned under, and pasture may be used to good advantage. Erosion should be prevented as much as possible, not only on this type, but on all others as well. Soils rich in organic matter are much less likely to erode because of the effect of the organic matter on permeability and granulation.

Aside from its low content of organic matter, this soil has a very good physical composition. It has a good topography, and affords excellent conditions for drainage. After the brown silt loam, it is by far the most im-

portant type of soil in the county. It occupies 60,000 acres of land, or five times as much as any less extensive all-tillable type.

On the whole, the yellow-gray silt loam offers one of the best opportunities for profitable soil improvement, and its improvement is more a matter of procedure than of experiment. The soil is normal in general character, and its chemical composition plainly reveals what is required for improvement; namely, limestone, nitrogenous organic matter, and phosphorus.

This type is acid in the surface, more acid in the subsurface, and still more acid in the subsoil.¹ An application of about 2 tons of limestone and half a ton of fine-ground rock phosphate every four years, with plenty of clover and crop residues or farm manure, will gradually work improvement; and, if one is prepared to make the investment, the initial applications may well be 5 tons of limestone and even 3 or 4 tons of phosphate. With 38,580 pounds in the surface soil of an acre, the potassium problem is merely one of liberation, and with even slight erosion, which is certain to occur where the surface drainage is good, the gradual renewal from the still greater abundance in the subsurface and subsoil insures a permanent supply of potassium for rational systems of either grain farming or live-stock farming. In comparison, analysis reveals only 1,033 pounds of total phosphorus in the surface soil of an acre and a still lower proportionate amount in the subsurface.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. Here, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels in 1910, 23.6 bushels in 1911, and 22 bushels in 1912; while the corresponding averages from land treated with heavy applications of limestone and a limited amount of organic manures were 41.4 bushels in 1910, 41.3 bushels in 1911, and 50.1 bushels in 1912, the corn being grown on a different series of plots every year in a four-year rotation of wheat, corn, oats, and clover. About the same proportionate increases were produced in wheat and hay, and the effect on oats was also marked.

Owing to the low supply of organic matter and limestone, phosphorus produced no benefit, as an average, during the first two years, but with increasing supplies of organic matter the effect of phosphorus is seen in the 1912 crops. Of course, a single four-year rotation cannot be practiced in three years, and the full benefit of the system of rotation and soil treatment is not to be expected before the third or fourth four-year period.

While limestone is the material first needed for the economic improvement of the more acid soil of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the central and northern parts of the state are frequently most deficient, relatively, in phosphorus and organic matter.

Table 8 shows in detail eleven years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity, this type in La Salle county is intermediate between the similar soils in Saline and Lake counties, but no experiment field has been conducted on this important soil type in the early Wisconsin glaciation.

¹In one set of soil samples, limestone was found in the lower stratum, but this is unusual (as when till is found within 40 inches) and it was not included in the average.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation												
		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912
Plot	Soil treatment applied	Bushels per acre										
101	None ¹	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5
103	Lime, nitrogen ...	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1
105	Lime, potassium .	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8
106	Lime, nitro., phos.	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9
107	Lime, nitro., potas.	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9
108	Lime, phos., potas.	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9
109	Lime, nitro., phos. potas.	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9
110	Nitro., phos., potas.	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1

Average Increase: Bushels per Acre

For nitrogen	3.0	4.7	1.6	-8.4	4.8	3.9	-10.1	5.9	-1.4	-6.5	-.3
For phosphorus ..	9.2	16.7	11.1	9.0	24.6	11.0	-1.4	13.7	2.1	24.6	21.6
For potassium.....	6.0	11.0	6.9	.3	3.2	5.9	-3.9	2.3	-1.2	1.1	-8.6
For nitro., phos. over phos.	6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8	-.4	2.2
For phos., nitro. over nitro.	10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6	26.6	22.5
For potas., nitro., phos. over nitro., phos.	4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0	7.2	-15.0

Value of Crops per Acre in Eleven Years

Plot	Soil treatment applied	Total value of eleven crops	Value of increase
101	None.....	\$112.16	
102	Lime.....	96.38	\$-15.78
103	Lime, nitrogen	97.89	-14.27
104	Lime, phosphorus	157.67	45.51
105	Lime, potassium.....	111.86	-.30
106	Lime, nitrogen, phosphorus	152.75	40.59
107	Lime, nitrogen, potassium	104.89	-7.27
108	Lime, phosphorus, potassium	160.25	48.09
109	Lime, nitrogen, phosphorus, potassium.....	164.83	52.67
110	Nitrogen, phosphorus, potassium	172.78	60.62

Average Value of Increase per Acre in Eleven Years

		Cost of increase
For nitrogen	\$-1.45	\$165.00
For phosphorus ..	56.12	27.50
For potassium.....	9.28	27.50
For nitrogen and phosphorus over phosphorus.....	-4.92	165.00
For phosphorus and nitrogen over nitrogen.....	54.86	27.50
For potassium, nitrogen, and phosphorus over nitrogen and phosphorus.....	12.08	27.50

¹Plot 101, the check plot, is the lowest ground but it is well drained and is appreciably better land than the rest of the field. Plot 102 is a more trustworthy check plot.

The Antioch field was started in order to learn as quickly as possible just what effect would be produced by the addition of nitrogen, phosphorus, and potassium, singly and in combination. These elements have all been added in commercial form. Only a small amount of lime was applied at the beginning, and with the abnormality of Plot 1 and with an abundance of limestone in the subsoil (a common condition in the late Wisconsin glaciation), no conclusions can be drawn regarding the effect of lime.

As an average of 44 tests (4 each year for 11 years), liberal applications of commercial nitrogen produced a slight decrease in crop values, phosphorus paid back 200 percent of its cost, while each dollar invested in potassium brought back only 34 cents (a net loss of 66 percent). Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but whenever a corn yield of 40 bushels or more was secured where phosphorus was applied either alone or with potassium, then the addition of nitrogen produced an increase. From a comparison of the results from the Sibley and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen thru the growing of legume crops in the rotation rather than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequently weakness of straw; and of course the most economic source of nitrogen, where that element is needed for soil improvement in general farming, is the atmosphere. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (1135 or 935)

This type, like the preceding, is found principally along the large streams, but it also includes other hilly and broken land unsuited for ordinary agriculture. It comprises 41.12 square miles, or 26,317 acres, and constitutes 3.55 percent of the total area of the county. The development of natural drainage channels has been carried to excess, and altho perfectly surface-drained this land has been spoiled by nature for many agricultural purposes.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a yellow silt loam varying to a grayish yellow. The freshly plowed soil appears yellow or brownish yellow, but when it becomes dry after a rain it is of a grayish color. The organic-matter content is quite low, averaging only 2.05 percent, or 20 $\frac{1}{2}$ tons in the plowed soil of an acre.

The subsurface varies from a yellow silt loam to a yellow clayey silt loam, and contains only about 15 tons of organic matter per acre of 4 million pounds, the amount diminishing with depth. The thickness of this stratum varies from 2 to 12 inches, depending on the amount of recent erosion.

The subsoil consists of a yellow clayey silt.

Owing to erosion, this type varies greatly. Glacial drift is frequently exposed on the surface. In some cases it forms both subsurface and subsoil, while in others it constitutes all or part of the subsoil, or it may even be found only below 40 inches.

The first and most important thing in the management of this soil is to prevent erosion, which may occur either by sheet washing or by gullyng.

On uniform slopes sheet washing does the greater damage, but on the irregular slopes found in this county both forms do great damage. Many of the slopes are too steep to permit of cultivation, and they ought not to be cleared of the protecting forest. Most of this type is in forest or pasture, and should never be cultivated, for, if broken up, erosion would shortly ruin the land for all purposes. (For methods of preventing erosion of soils see Circular 119.)

The only general soil treatment recommended for this type is the use of ground limestone either when preparing the land for seeding to legume crops or as a top-dressing on pastures to encourage the growth of clovers in the pasture herbage. Where the slope is not too steep, alfalfa may sometimes be grown to advantage. In getting this crop started, 500 pounds per acre of steamed bone meal or acid phosphate may well be plowed under with farm manure, and then 5 tons per acre of ground limestone should be applied before preparing the seed bed, which of course, ought to be well inoculated with soil from an old alfalfa field or sweet-clover patch. (See Circular 86, "Science and Sense in the Inoculation of Legumes.")

Rock Outcrop (1199)

This type consists of rock ledges and some uncovered rock surfaces, principally in the Illinois-river valley from Utica east. The rock is nearly all St. Peters sandstone, with some magnesian limestone in the vicinity of La Salle and Utica that is used for cement. A shaley sandstone is exposed in the Illinois-river valley near Seneca that gives rise to a residual type of soil in that region.

(c) TERRACE SOILS

These consist of soils formed on terraces, or benches, in valleys. The terraces owe their formation generally to the deposition of material from an overloaded stream during the melting of the glaciers. In this way valleys were partly filled. Later these streams cut down thru these fills and developed new bottom lands or flood plains at a lower level, leaving part of the old fill as a terrace. The lowest and most recently formed bottom land is called *first bottom*. The material filling the valleys may be coarse or fine. That forming the terraces in the Vermilion valley, Indian creek, and in part in the Illinois-river valley, is mostly silt, while in the Fox-river valley it is sand and gravel. Part of the terrace of the Illinois-river valley seems to be the stony floor of the valley covered from a few inches to several feet with fine material that now forms the soil. In many cases this material is partly of residual origin. (The series number for the terrace soils is 1500.)

Brown Silt Loam (1526)

This type occurs only in the Illinois-river valley. Owing to its method of formation, it is somewhat variable. The material is derived both from sediment deposited by the Illinois river at a former period and by small streams from the upland. The older material is characterized by a much darker color and heavier texture, while the newer deposit brought down by small streams is usually lighter in color as well as coarser in texture. This type is not generally well drained, and in many areas thoro drainage is the first essential. As a rule, it lies sufficiently above the Illinois river to allow of good drainage.

The total area of this type is 10.26 square miles, or 6,566 acres, and comprises .88 percent of the entire area of the county.

The surface soil, 0 to $6\frac{2}{3}$ inches, varies from a light brown silt loam to a dark brown clayey silt loam, the heavier phase predominating. Locally, even some black clay loam is found, also small areas of muck or shallow peat, with their characteristic surface soils, while in places the surface soil contains a considerable percentage of gravel. These local variations are in too small areas to be shown on the map.

The subsurface soil varies from a brown to a black silt loam or clay loam extending to a depth of from 16 to 25 inches.

The subsoil varies from a yellow plastic clayey silt to a drab clay, the latter usually occurring in the areas originally poorly drained.

The different strata of this type are sufficiently pervious to permit good drainage, and drainage is a matter of first importance. The organic matter should be maintained, and even increased in the lighter phases. The type is exceedingly rich in potassium and limestone (especially in the subsurface and subsoil), but the addition of phosphorus will be necessary if its productive power is to be maintained at a high point.

Brown Silt Loam on Gravel (1526.4)

The total area of this type in the county is 83.2 acres. As an average, the gravel is about 22 inches below the surface. This provides excellent drainage,—in fact, too good for seasons when the crop is likely to suffer from lack of moisture.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown silt loam containing a perceptible amount of sand.

The subsurface, $6\frac{2}{3}$ to 16 or 18 inches, is a light brown silt loam becoming lighter with depth.

The subsoil is composed chiefly of gravel, but it may have some silty material overlying the gravel. The comparatively thin stratum of fine material does not furnish a sufficient reservoir for the moisture necessary for crop use unless rains are frequent.

While this type is not markedly acid, it is devoid of limestone even to a depth of 40 inches. Organic manures, phosphorus, and limestone are all required for the improvement and maintenance of its fertility.

Brown Silt Loam on Rock (1526.5)

This type occupies only 38.4 acres and lies in one area in the Illinois-river valley east of Ottawa. It is rather poorly drained. The surface soil is a brown to black slightly clayey silt loam, while the subsurface is somewhat heavier. On the whole, this is one of the richest soils found in Illinois. It is about twice as rich in nitrogen and four times as rich in phosphorus as the common corn-belt prairie land. The rocks, which are not always covered by the soil, consist of boulders and not bed rock, and consequently the subsoil may absorb and retain moisture fairly well. It is suggested that this area may once have been the roosting place for wild water fowls or other birds, and that the exceptional richness of the soil may be due to the accumulated droppings and decomposed feathers and skeletons of the birds. Much of the area can be used only for pasture because of the numerous boulders, many of which lie near the surface while some rise above it.

Brown Silt Loam over Gravel (1527)

This type aggregates 5.12 square miles, or 3,277 acres. It occurs in large areas along the Fox river and lies on part of the old gravel fill of that valley. As a rule, the type is well drained, owing to the pervious character of the subsoil. The topography is undulating, due to erosion and the action of wind in piling up silt and sand.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown silt loam, the color varying with the topography and drainage.

The subsurface soil, $6\frac{2}{3}$ to 18 inches, is a light brown silt loam underlain by a yellow silt subsoil. Locally this type has a perceptible amount of sand.

This type is rich only in potassium, and requires for its improvement limestone, organic manures, and phosphorus.

Yellow-Gray Silt Loam on Gravel (1534.4)

A small area of this type, 12.8 acres, occurs in Sections 35 and 36, Township 35 North, Range 4 East. The surface soil is a light grayish yellow silt loam containing 2.5 percent of organic matter, while the subsurface soil contains .8 percent. Gravel occurs commonly at a depth of 18 to 24 inches.

The analysis shows the need of organic manures, phosphorus, and limestone.

Yellow-Gray Silt Loam over Gravel (1536)

This type is found to some extent along the larger streams, but especially along the Fox river. It covers a total area of 6.68 square miles, or 4,275 acres, a trifle over $\frac{1}{2}$ percent of the total area of the county. The topography varies somewhat, erosion and wind action having produced a gently rolling or undulating surface.

The surface soil varies from a grayish yellow to a yellow silt loam. Sand in perceptible amounts is almost invariably present. The organic-matter content amounts to 2.5 percent, or 25 tons per acre.

The subsurface soil, $6\frac{2}{3}$ to 16 inches, is a yellow to grayish yellow silt loam containing about .7 percent of organic matter.

The subsoil is a yellow pulverulent silt.

For a silt loam, this type is poor in organic matter and phosphorus, and it is acid even to a depth of 40 inches, so that, in addition to organic matter and phosphorus, limestone should be supplied.

Brown Sandy Loam (1560)

This type covers only 4.80 square miles, or 3,072 acres, and occurs entirely along the Fox and Illinois rivers. Its height above the river varies somewhat, being so low in some places as to be subject to overflow during extremely high water. It is generally well drained, altho in some small areas the difficulty of securing a proper outlet renders it too wet.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown sandy loam, the color varying with the drainage. The sand is mostly coarse. Much of it in the Illinois-river valley is probably derived from the sandstone in the immediate vicinity.

Owing to its physical composition, this type is easy to work and to keep in good tilth.

The subsurface soil, $6\frac{2}{3}$ to about 20 inches, is a brown sandy loam, the color becoming lighter with depth. This is underlain with a yellow or brown-

ish yellow subsoil that varies from a sandy loam to a sand. In some cases this latter is probably residual sand. At lower depths gravel is sometimes found; indeed at Sheridan large quantities are being taken from this type of terrace soil.

Considering its deep feeding range, this sandy loam is well supplied with phosphorus. Limestone and organic manures are the materials most needed for its improvement, and it is not unlikely that potassium could be used with profit. While the total supply of potassium is large, most of it is locked up in medium or coarse sand grains. To obtain the best and most profitable results on such soils, the use of potassium is usually required, altho very marked improvement can be made with limestone and legume crops; and, if all coarse products are returned to the soil either directly or in manure, without loss by leaching, the necessity for purchasing potassium will be greatly reduced.

Brown Sandy Loam on Gravel (1560.4)

This type occupies an area of 192 acres in the valley of the Illinois river near Seneca. It is rather variable both as to the amount of sand it contains and the depth to the gravel beneath the surface.

The surface stratum, 0 to $6\frac{2}{3}$ inches, is a brown sandy loam, with 2.2 percent organic matter, while the subsurface is lighter in color, containing 1.2 percent of organic matter. The depth to gravel varies from 12 to 30 inches.

This type is well supplied with phosphorus but is poor in organic matter and, altho nearly neutral, contains no limestone. The use of potassium in addition to limestone and organic manures may prove profitable, especially if much potassium is carried away in the products sold from the farm.

Brown Sandy Loam on Rock (1560.5)

This type occurs only in the Illinois-river valley and represents the rock of the old river bed that has become covered with sandy material either thru deposition from water or wind or thru disintegration of the underlying sandstone by weathering agencies. This material has become mixed with more or less organic matter, thus forming a soil. The area covered is 5.73 square miles, or 3,667 acres, a little less than $\frac{1}{2}$ percent of the entire area of the county. The depth to the rock varies from 12 to 30 inches.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown sandy loam, with a variable quantity of sand and 4.55 percent, or 60 tons per acre, of organic matter.

The subsurface varies from a sandy loam to a sand, the latter being derived from the sandstone underlying it.

This type is not of great value agriculturally because of the proximity of the rock to the surface, which renders it a poor soil to resist either drouth or excessive rainfall, altho the crops suffer less from the latter than from the former. Much of it is not under cultivation. Liberal use should be made of legumes and organic manures; and both the physical and the chemical compositions indicate that potassium should be applied for the best results. The soil still contains a fair amount of humus and limestone; and, for a sandy loam, the phosphorus supply is very satisfactory, altho, where the depth of soil is too restricted, additional phosphorus may be needed if the improvement of such shallow soil is attempted. This, however, is scarcely to be ad-

vised, unless for special crops and with provision to supplement the rainfall by irrigation when necessary. The narrow ratio between the nitrogen and the organic carbon indicates that the organic matter consists largely of old plant residues resistant to decay.

Yellow-Gray Sandy Loam (1564)

This type covers less than 10 acres of land. The surface is a yellowish gray sandy loam. The soil is very poor in nitrogen and organic matter, and the supply of limestone is limited, the subsurface and subsoil being acid. Liberal use of these materials should effect enormous improvement; indeed with the deep feeding range afforded plants, and the amount of phosphorus and potassium in the lower strata, it is doubtful if anything more than limestone and organic manures can be used with profit in good systems of farming.

Dune Sand (1581)

This type occupies only 25 acres, a part of which is in the Fox-river valley and the rest in the Illinois-river valley south of the river and west of Ottawa. It has the characteristic dune topography. The surface soil is a slightly loamy sand, with less than 1 percent of organic matter, underlain by a uniformly yellowish sand of medium texture. Only limestone and organic manures are needed to markedly improve this soil, but for the highest and most profitable improvement potassium and phosphorus may also need to be supplied, and probably in the order named.

Gravelly Loam (1590)

This type occurs in the Illinois-river valley west of Ottawa on both sides of the river, the gravel north of the river being the coarser. It occupies an area of 300 acres, and is undulating in topography.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a mixture of gravel, sand, and a small amount of the finer constituents, together with 5.56 percent of organic matter, or 74 tons per acre.

The subsurface resembles the surface but contains less organic matter. The gravel becomes so large and abundant at a depth of 15 to 24 inches that sampling with the soil auger is impracticable.

This is a moderately rich soil and ought to grow alfalfa, grapes, or other crops that are adapted to the soil and topography. With a liberal use of legume crops or organic manure, potassium is the only addition likely to prove profitable, most of this element being locked up in the coarse sand and gravel.

(d) SWAMP AND BOTTOM-LAND SOILS

Deep Brown Silt Loam (1426)

The Illinois river below a point about halfway between Utica and La Salle has developed a wide, level flood-plain extending to the west side of the county, while the flood-plain to the eastward is narrower and less conspicuous and in some places absent entirely. The deposition of sediment on this overflowed land has formed the deep brown silt loam of the bottom land. As a rule, it is low and rather poorly drained, with flat to slightly undulating topography.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a brown, somewhat-clayey silt loam

containing 4.42 percent of organic matter, or 44 tons per acre. It varies somewhat from this composition, in places being sufficiently sandy to modify the texture to a considerable extent.

The subsurface and subsoil vary but little from the surface, containing 4.27 percent and 4 percent, respectively, of organic matter.

This is a rich, deep soil, and its fertility is usually well maintained by the sediments deposited from overflow, including some sewage received from the city of Chicago. It is exceedingly fertile, and crops grow upon it with remarkable rapidity.

A thoroly adequate system of underdrainage which will quickly remove the surplus soil water would be of great assistance in getting the land into condition for planting as soon as possible after the usual spring overflow. It is by no means certain, however, that permanent protection from overflow with its usual enriching deposit, would result in a larger aggregate of crops produced during a long series of years, provided the normal level of the water is not too near the surface of the land.

Deep Peat (1401)

This type is found exclusively in the Illinois-river valley, with the exception of a small area in Section 27, east of Tonica, and occupies a total area of 364 acres. The peat in the Illinois valley is found generally in the lower and more poorly drained areas near the bluff and where the land receives water either from springs or from surface drainage from higher land. This has brought about conditions favorable for the growth and preservation of peat-forming grasses, sedges, and mosses, whose partly-decayed products have accumulated until a deposit of peat 30 inches or more in depth has formed. Much of this is still a swamp and is utilized, if at all, only for hay.

Owing to the origin of this type, there is generally not much difference between the strata.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown peat varying somewhat in the different areas on account of the amount of decomposition from overflow. The one composite sample collected from this stratum contained 30.6 percent of organic matter, but in some areas the amount is doubtless still higher.

The subsurface soil is a brown, undecomposed peat, showing 47.12 percent of organic matter in the sample collected. The subsoil changes but little to a depth of 40 inches.

Drainage is the first requirement of this type. A trial application of potassium is recommended; and, with continued cropping, applications of phosphorus may also become profitable. (See Illinois Bulletin 157, "Peaty Swamp Lands.")

Medium Peat on Clay (1402)

This type is represented by an area of about 83 acres east of Tonica in Section 27. It occupies a depression in the center of which is an area of deep peat with the medium peat surrounding it. This area has been drained and is under cultivation.

The surface stratum, 0 to $6\frac{2}{3}$ inches, is a dark brown peat containing 36.1 percent of organic matter so thoroly decomposed as to have lost all traces of vegetable tissue.

The subsurface is a black, decomposed peat lying upon a drab clay 16 to 20 inches below the surface.

If this soil does not produce good crops when well drained, the remedy is likely to be found in deep plowing. If necessary, one plow should follow another in the same furrow in order to reach the clay (which is rich in potassium) and mix it with the more peaty top soil, as more fully explained in Bulletin 157.

(e) RESIDUAL SOILS

This class of soils is formed by the accumulation of the loose material resulting from the weathering of rocks in place. Very little of this class exists in Illinois, owing to the action of the glaciers in removing and covering up the residual material by glacial drift, or boulder clay. La Salle county probably has the largest area of residual soil found in the state.

Brown Sandy Loam on Rock (060.5)

This type covers 2.38 square miles, or 1523 acres. It is formed from the disintegration of a shaly sandstone, and is found only in the valley of the Illinois river where the drift has been removed by the stream. The process of disintegration has produced from 12 to 30 inches of loose material which forms the soil.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a light brown sandy loam varying to a yellowish brown. It contains many small pieces of the shaly sandstone, usually not over an inch or two in diameter and $\frac{1}{2}$ inch thick. It contains 2.27 percent of organic matter, or 30 tons per acre.

The subsurface soil is a yellow to brownish yellow sandy loam. Rock is found 12 to 30 inches below the surface. The proximity of the rock to the surface makes the crops growing on this type very subject to drouth or to excessive moisture. Drainage is at once very essential and extremely difficult.

This type is poor in organic matter and contains no limestone; both these materials should be provided for its improvement. Considering its shallow character and coarse texture, we may expect that both phosphorus and potassium will be required for its most marked improvement, and irrigation may also be needed; but so much expense as this would entail is justified only for intensive cropping.

Residual Sand (083)

This type is formed from the disintegration of the St. Peters sandstone and has no particular agricultural value. None of it is under cultivation, but it carries a rather stunted growth of timber. The type covers 70 acres and, in addition, some small areas along the bluffs of the Illinois river not large enough to map. The surface for about 2 inches is a slightly loamy sand and then passes into a yellow sand which continues to within a few inches of the sand rock, where a white sand is encountered. The topography is very rolling.

In plant-food content this residual sand is the poorest soil thus far found in Illinois. While the top soil was found to contain about 2 tons of limestone per acre, this was evidently due to some surface addition, for the subsurface and subsoil contain no lime.

To produce satisfactory crops upon this soil, liberal use should be made of organic manures, phosphorus, potassium, and dolomitic limestone, the latter supplying calcium and magnesium. Provision should also be made for irrigation as a means of protection during even short periods of drouth, especially where the bed rock is only 2 or 3 feet below the surface. Such complete treatment would not be practical except possibly in gardening.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"

Bulletin No. 94, "Nitrogen Bacteria and Legumes"

Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"

Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"

Circular No. 110, "Ground Limestone for Acid Soils"

Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"

Circular No. 129, "The Use of Commercial Fertilizers"

Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"

Circular No. 165, "Shall we use 'Complete' Commercial Fertilizers in the Corn Belt?"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of indicating on a map the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of their work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and cor-

rected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, additional streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is taken by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

		CONSTITUENTS OF SOILS										
Soil Constituents	Organic Matter	{ Comprising undecomposed and partially decayed vegetable material										
	Inorganic Matter	<table border="0"> <tr> <td>Clay.....</td> <td>001 mm.¹ and less</td> </tr> <tr> <td>Silt.....</td> <td>001 mm. to .03 mm.</td> </tr> <tr> <td>Sand.....</td> <td>.03 mm. to 1. mm.</td> </tr> <tr> <td>Gravel.....</td> <td>1. mm. to 32 mm.</td> </tr> <tr> <td>Stones.....</td> <td>32. mm. and over</td> </tr> </table>		Clay.....	001 mm. ¹ and less	Silt.....	001 mm. to .03 mm.	Sand.....	.03 mm. to 1. mm.	Gravel.....	1. mm. to 32 mm.	Stones.....
Clay.....	001 mm. ¹ and less											
Silt.....	001 mm. to .03 mm.											
Sand.....	.03 mm. to 1. mm.											
Gravel.....	1. mm. to 32 mm.											
Stones.....	32. mm. and over											

¹25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand and silt and a little clay.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 15 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no agricultural value.

More or less organic matter is found in nearly all the above classes.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungus diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cow-peas, straw, and cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than the old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when incorporated with fresh farm manure; so that, when used together, two tons of the mixture may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive

condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of such crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are not known ever to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitro- gen, pounds	Phos- phorus, pounds	Potas- sium, pounds	Magne- sium, pounds	Cal- cium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244 ¹	42	51	16	4
Total in four crops		510 ¹	77	322	68	168

¹These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. Thus on Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials the farmer can utilize most profitably to bring about the liberation of plant food.

The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen.

At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves the soil poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed-bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($\text{CaCO}_3\text{MgCO}_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone (CaCO_3); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.

Second year, corn.

Third year, wheat or oats (with clover or clover and grass).

Fourth year, clover or clover and grass.

Fifth year, wheat and clover or grass and clover.

Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times, and alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same

time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

- 1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
- 1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
- 1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
- 1 ton of timothy requires 24 pounds of nitrogen.
- 1 ton of clover contains 40 pounds of nitrogen.
- 1 ton of cowpeas contains 43 pounds of nitrogen.
- 1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. For grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages below.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit will no doubt be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, since this will necessitate returning to the soil either all produce except the grain (in grain farming) or the manure produced in live-stock farming. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional re-seeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and

the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat has been 12.7 bushels on untreated land, 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied; and, as further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the average wheat crop removed 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) has been 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus have been applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If more than three-fourths of the potassium removed were returned in the straw (see Table A), and if the decomposition products of the straw have power to liberate additional amounts of potassium from the soil, the necessity of purchasing potassium in a good system of farming on such land is very remote.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there

is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface $6\frac{2}{3}$ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) would permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all of these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing \$5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing \$4.00, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit has paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield include an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure had been applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate as determined by chemical analysis; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food consumed, it is easy to determine from Table A

that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming, or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, such farmers ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses¹ of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. And practically the same amount of calcium was found by analyzing the Rothamsted drainage waters.

Common limestone, which is calcium carbonate (CaCO_3), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

¹Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

- | No. | BULLETINS |
|------|--|
| 76 | Alfalfa on Illinois Soil, 1902 (4th edition, 1910). |
| *86 | Climate of Illinois, 1903. |
| *88 | Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois, 1903. |
| *93 | Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils, 1904. |
| 94 | Nitrogen Bacteria and Legumes, 1904 (4th edition, 1912). |
| *99 | Soil Treatment for the Lower Illinois Glaciation, 1905. |
| 115 | Soil Improvement for the Worn Hill Lands of Illinois, 1907. |
| 123 | The Fertility in Illinois Soils, 1908 (2nd edition 1911). |
| *125 | Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois, 1908. |
| 145 | Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils, 1910 (2nd edition, 1912). |
| 157 | Peaty Swamp Lands; Sand and "Alkali" Soils, 1912. |

CIRCULARS

- *64 Investigations of Illinois Soils, 1903.
- *68 Methods of Maintaining the Productive Capacity of Illinois Soils, 1903 (2nd edition, 1905).
- *70 Infected Alfalfa Soil, 1903.
- *72 Present Status of Soil Investigation, 1903.
- 82 The Physical Improvement of Soils, 1904 (3rd edition, 1912).
- 86 Science and Sense in the Inoculation of Legumes, 1905 (2nd edition, 1913).
- *87 Factors in Crop Production, with Special Reference to Permanent Agriculture in Illinois, 1905.
- *96 Soil Improvement for the Illinois Corn Belt 1905 (2nd edition, 1906).
- *97 Soil Treatment for Wheat on the Poorer Lands of the Illinois Wheat Belt, 1905.
- *99 The "Gist" of Four Years' Soil Investigations in the Illinois Wheat Belt, 1905.
- *100 The "Gist" of Four Years' Soil Investigations in the Illinois Corn Belt, 1905.
- 105 The Duty of Chemistry to Agriculture, 1906 (2nd edition, 1913).
- 108 Illinois Soils in Relation to Systems of Permanent Agriculture, 1907.
- 109 Improvement of Upland Timber Soils of Illinois, 1907.
- 110 Ground Limestone for Acid Soils, 1907 (3rd edition, 1912).
- *116 Phosphorus and Humus in Relation to Illinois Soils, 1908.
- 119 Washing of Soils and Methods of Prevention, 1908 (2nd edition, 1912).
- *122 Seven Years' Soil Investigation in Southern Illinois, 1908.
- 123 The Status of Soil Fertility Investigations, 1908.
- 124 Chemical Principles of Soil Fertility, 1908.
- 127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3rd edition, 1912).
- 129 The Use of Commercial Fertilizers, 1909.
- 130 A Phosphate Problem for Illinois Land Owners 1909.
- 141 Crop Rotation for Illinois Soils, 1910 (2nd edition, 1913).
- 142 European Practice and American Theory Concerning Soil Fertility, 1910.
- 145 The Story of a King and Queen, 1910.
- 149 Results of Scientific Soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois, 1911.
- 150 Collecting and Testing Soil Samples, 1911 (2nd edition, 1912).
- 155 Plant Food in Relation to Soil Fertility, 1912.
- 157 Illinois Conditions, Needs, and Future Prospects, 1912.
- 165 Shall we Use "Complete" Commercial Fertilizers in the Corn Belt? 1912 (4th edition, 1913).
- 167 The Illinois System of Permanent Fertility, 1913.

SOIL REPORTS

- 1 Clay County Soils, 1911.
- 2 Moultrie County Soils, 1911.
- 3 Hardin County Soils, 1912.
- 4 Sangamon County Soils, 1912.
- 5 La Salle County Soils, 1913.

*Out of print.

ELEVEN YEARS' RESULTS WITH PHOSPHORUS ON THE UNIVERSITY OF ILLINOIS
SOIL EXPERIMENT FIELD AT BLOOMINGTON, ON THE TYPICAL
PRAIRIE LAND OF THE ILLINOIS CORN BELT

Year	Crop grown	Yield without phosphorus	Yield with phosphorus	Increase for phosphorus	Value of increase per acre
1902	Corn, bu.....	37.0	41.7	4.7	\$ 1.64
1903	Corn, bu.....	60.3	73.0	12.7	4.44
1904	Oats, bu.....	60.8	72.7	11.9	3.57
1905	Wheat, bu.....	28.8	39.2	10.4	7.28
1906	Clover, tons.....	.58	1.65	1.07	6.42
1907	Corn, bu.....	63.1	82.1	19.0	6.65
1908	Corn, bu.....	35.3	47.5	12.2	4.27
1909	Oats, bu.....	53.6	63.8	10.2	3.06
1910	Clover, tons.....	1.09	4.21	3.12	18.72
1911	Wheat, bu.....	22.5	57.6	35.1	24.57
1912	Corn, bu.....	56.8	80.8	24.0	8.40
Total value of increase in eleven years.....					\$ 89.02
Total cost of phosphorus in eleven years.....					27.50
Net profit in eleven years.....					\$ 61.52

After the first year the phosphorus never failed to more than pay its annual cost; and, as an average of the last four years, the increase produced by the phosphorus is worth as much as the total crops produced on the land not receiving phosphorus. (For more complete details see Plots 102 and 104, Table 5, page 16.)

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