UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 17

KANE COUNTY SOILS

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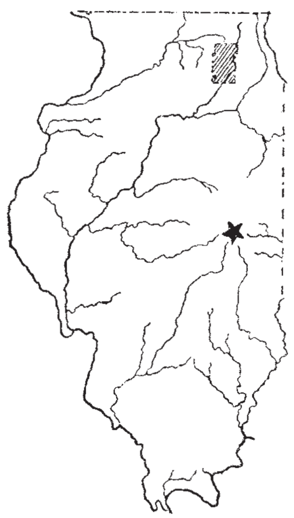

URBANA, ILLINOIS, AUGUST, 1917

INTRODUCTORY NOTE

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, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to anyone 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, in order to help the farmer and landowner 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.

SOIL CONDITIONS IN NORTHEASTERN ILLINOIS

(Statement Supplementing the Soil Reports for the Counties Listed Below)

The soil maps of the counties in northeastern Illinois which were made from 23 to 45 years ago do not show the character of the glacial till underlying the soils in this region. This fact makes it necessary to interpret these maps in the light of more recent knowledge, since the agricultural value of the soils in this part of the state often is determined by the character of the underlying material.

The counties having soil maps which are defective in this respect are Champaign, Cook (unpublished), DuPage, Grundy, Kane, Kankakee, Lake, LaSalle, McHenry, McLean, Piatt, Will, and Woodford.

In addition to the counties listed, the following counties now have soil maps showing the areas where unfavorable underlying glacial till is present: Ford, Iroquois, Kendall, Livingston, Marshall, Putnam, and Vermilion.

The glacial tills in the northeastern part of Illinois vary from highly plastic, very slowly permeable material to loose, sandy, gravelly material which is porous and drouthy. The following tabulation shows the tills ranging in permeability to water from very slowly permeable to optimum or moderate permeability, but does not show the sandy, gravelly tills which occur less extensively than the slowly permeable tills. Only the dark-colored or prairie soils are listed, as they are more extensive than the light-colored or timber soils in all counties in this region except Lake and McHenry.

Silty clay till - Swygert-Bryce soils - slowly permeable
Silty clay loam till - Elliott-Ashkum soils - moderately slowly permeable
Loam till - Saybrook-Lisbon soils - optimum permeability

On all soil maps published prior to 1930 the above-listed soils were for the most part shown as Brown Silt Loam and Black Clay Loam. The agricultural significance of the separations now being made is indicated by the following yields of hybrid corn on farms under good management for the period 1937 to 1944.

Clarence-Rowe	-	average of	3	farms	- 51 bushels an acre
Swygert-Bryce	-	" "	12	"	- 60 bushels an acre
Elliott-Ashkum	-	" "	20	"	- 64 bushels an acre
Saybrook-Lisbon	-	" "	20	"	- 76 bushels an acre

Further information about soil conditions in northeastern Illinois and in other parts of the state may be secured from the county farm advisers and from the Soil Survey, Department of Agronomy, Urbana.

Department of Agronomy
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KANE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER, E. VAN ALSTINE, AND F. W. GARRETT

Kane county is situated in the northeastern part of the state about twenty-five miles south of the Wisconsin line and thirty miles west of Lake Michigan. It lies in three glaciations and comprizes an area of 513 square miles. About one-fourth of the township occupying the northwest corner is in the Iowan glaciation, but the material deposited by that glaciation has been covered almost entirely by a late Wisconsin gravel outwash. The six townships to the east and northeast, with fractions of four others, are included in the late Wisconsin glaciation, while the western and southern parts of the county are in the early Wisconsin glaciation. (See state soil map in Bulletin 193.)

The Illinoisan glaciation preceded all of the glaciations named and covered the county with a layer of drift 20 to 60 feet deep. It must be remembered that long intervals of almost normal temperature conditions occurred between these glaciations. During these intervals, soils were formed of the surface material deposited by the glaciers, and vegetation flourished. The surface of the Illinoisan drift was changed into soil (the Sangamon), and then was later covered by several feet of Iowan loess, a wind deposit formed during the melting of the Iowan ice sheet. Another soil (the Peorian) formed from this, which is characterized usually by having logs or fragments of arbor vitae imbedded in it, was later buried by the drift of the early Wisconsin glaciation. These old soils are encountered in putting down wells. The Sangamon is found at a depth of 150 to 200 feet, while the Peorian is much shallower, occuring at a depth of 40 to 75 feet.

Physiography and Drainage

The topography of Kane county is due almost entirely to the irregular deposition of glacial material. The northeastern part, including practically all of the late Wisconsin glaciation, is a moraine of the Lake Michigan glacier, and expresses in rather extreme form the peculiar topographic irregularities of the moraine. An extension of the moraine follows down the eastern county line into Kendall and Will counties, and another arm extends southward in the center of the county to within five miles of the south boundary line. The valley of the Fox river lies between these arms. These morainic areas comprize most of the rolling land.

In Township 41 North, Range 6 East, a fragment of a Wisconsin moraine is found, where it was apparently overridden by the Lake Michigan glacier. Another fragment lies just south of the gravel outwash plain, but it is very indistinct. The topography of the county is peculiar to that of nearly all late glaciated areas: the inter-morainal tracts are undulating to slightly rolling, while the morainic areas are made up of series of irregular ridges containing many kettle-holes that at one time were filled with water and constituted small lakes or ponds. Many of these have since been drained or filled with partially decayed vegetation, forming peat. Only four ponds were found large enough to map.

The depth of the drift varies from a few feet to more than 300 feet, as indicated by wells in different parts of the county. In the southeastern part along the Fox river, in the early Wisconsin glaciation, the drift is only of slight depth, and in many places there are outcrops of limestone rock. Probably the deepest drift is found in Township 40 North, Range 7 East. In Section 19 the glacial deposit is 336 feet deep. The average thickness approximates 150 feet.

Two distinct drainage systems occur in the county: that of the Fox river, comprizing the eastern and southern parts of the county; and that of the Kishwaukee river, which drains most of the three townships on the north and west. The natural drainage frequently is imperfect, and altho no large lakes exist, yet many swamps occur that need artificial drainage.

The altitudes of some places in the county are as follows: Aurora, 652 feet; Batavia, 719; Big Rock, 710; Brier Hill, 974; Burlington, 924; Carpentersville, 731; Dundee, 727; Elburn, 848; Elgin, 717; Freeman, 909; Geneva, 720; Gilberts, 898; Hampshire, 900; LaFox, 803; Lily Lake, 922; Maple Park, 863; Montgomery, 646; Pingree Grove, 918; Plato Center, 914; St. Charles, 809; Sugar Grove, 729; Wasco, 826; Youngsdale, 799.

SOIL MATERIAL AND SOIL TYPES

The glaciers that covered the county left a deposit called till, glacial drift, or boulder clay (a mixture of boulders, gravel, sand, silt, and clay), but this deposit does not form the soil material except in small areas. The rock flour produced by the grinding action of the glaciers was reworked by the wind and deposited over practically all of the county to a depth of 12 to 40 inches. This loessial, or wind-blown material, has been transformed into soil by weathering and by the accumulation of organic matter, and now covers the level and less rolling areas. There is little doubt but that this wind-blown material was quite uniformly deposited over the exposed surface, but it has subsequently been removed in places by erosion, so that the boulder clay is exposed on some of the more rolling areas. The deposit is thicker on the early Wisconsin glaciation than on the late Wisconsin, because of a deeper original deposit (3 to 6 feet) and because, owing to the less rolling character of the area, there has not been so much erosion.

During the melting of the glacier the streams draining this area were frequently flooded, and the water carried large amounts of rather coarse material, such as gravel and sand. This was deposited in the valley, partly filling it. Later the streams cut down thru the fill, leaving gravel terraces. This gravel was later covered with the fine material that now constitutes the soil. In the northwest township this flood water spread out over a large area, with the result that a gravel plain was formed that extends into DeKalb and McHenry counties. Subsequent deposits of fine material on the surface of the gravel have aided in forming an excellent soil.

The soils of Kane county are divided into the following classes:

(a) Upland prairie soils, usually rich in organic matter. These were originally covered with prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat, poorly drained areas contain the greatest amounts of organic matter, owing to the more luxuriant growth of grasses there and to the excessive moisture in the soil, which provided better conditions for their preservation.

(b) Upland timber soils, including nearly all upland areas that were formerly covered with forests. These soils contain much less organic matter than the soils of the prairies because in the forests the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees are burned by forest fires, or suffer almost complete decay, instead of being incorporated with the soil.

TABLE 1.—SOIL TYPES OF KANE COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (900, 1000, 1100, 1200), page 27			
—26	Brown silt loam	228.29	146 106	44.49
—26.5	Brown silt loam on rock	.37	237	.07
—60	Brown sandy loam	2.97	1 901	.58
—28	Brown-gray silt loam on tight clay	.25	160	.05
—90	Gravelly loam	6.00	3 840	1.18
	(b) Upland Timber Soils (900, 1000, 1100, 1200), page 30			
—34	Yellow-gray silt loam	130.72	83 661	25.47
—34.5	Yellow-gray silt loam on rock	.26	166	.05
—35	Yellow silt loam	6.15	3 936	1.20
—64	Yellow-gray sandy loam	13.96	8 934	2.72
1065	Yellow sandy loam	.23	147	.04
	(c) Terrace Soils (1500), page 38			
—27	Brown silt loam over gravel	14.76	9 446	2.88
—26.4	Brown silt loam on gravel	.85	544	.17
—66	Brown sandy loam over gravel	1.76	1 126	.34
—60.4	Brown sandy loam on gravel	1.40	896	.27
—64.4	Yellow-gray sandy loam on gravel	.56	358	.11
—36	Yellow-gray silt loam over gravel	4.61	2 950	.90
—90	Gravelly loam	.34	229	.06
	(d) Late Swamp and Bottom-Land Soils (1400), page 41			
—01	Deep Peat	14.53	9 299	2.83
—02	Medium peat on clay	.70	448	.14
—03.6	Shallow peat on marl	.04	26	.01
—10	Peaty loam	.09	58	.02
—50	Black mixed loam	68.12	43 597	13.27
—54	Mixed loam	5.91	3 782	1.15
—25	Black silt loam	7.08	4 531	1.38
	Miscellaneous			
	Water	2.52	1 613	.49
	Gravel pits	.62	397	.12
	Quarry	.05	32	.01
	Total	513.14	328 410	100.00

NOTE.—"On" signifies that the underlying material is less than 30 inches below the surface; "over," that it is more than 30 inches.

(c) Terrace soils, which include bench lands, or second bottom lands, that were formed at the time of the melting of the glacier, when the valleys were flooded and the streams overloaded with coarse sediment. Deposits of gravel were formed which later have been cut thru in part by the streams during their ordinary stages. These benches form soil types that are usually underlain by gravel or sand.

(d) Swamp and bottom-land soils, which include the over-flow lands, or flood plains, along the streams, the swamps, and the poorly drained lowlands.

Table 1 shows the area of each type of soil in Kane county in square miles and in acres and its percentage of the total area. It will be noted that the brown silt loam, or rolling prairie land, occupies the larger part of the county. The accompanying map shows the location and boundary of each type of soil, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN KANE 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.[1] (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.)

The chemical analysis of a 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 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 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

[1]For types of very limited extent, or of quite variable character ("mixed"), only one set of samples, or samples representing only the most common phase, may be collected for analysis, and such analyses have, of course, less application.

(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.)

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 in Kane county—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize it.

The soil to the depth indicated includes at least as much 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, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common upland soil of Kane county, the brown silt loam prairie, does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for eleven rotations (44 years), and the other extensive upland soils in the county are markedly poorer.

With respect to phosphorus, the condition differs only in degree, this most important upland soil of the county containing no more of that element than would be required for seventeen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals 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 in this common soil type is sufficient for 26 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 2,200 and 500 years for magnesium, and about 10,500 and 250 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 magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the most prevalent type in the county 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 types of soil in Kane county with respect to their content of important plant-food elements is also very marked. The deep peat contains in the plowed soil of an acre twenty times as much nitrogen as the yellow silt loam, and about five times as much nitrogen but only one-sixth as

TABLE 2.—FERTILITY IN THE SOILS OF KANE COUNTY, ILLINOIS

Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils (900, 1000, 1100, 1200)								
—26	Brown silt loam...	64 870	5 560	1 350	33 530	8 820	10 590		70
—26.5	Brown silt loam on rock	70 460	6 000	1 620	32 420	10 720	15 320		20
—60	Brown sandy loam.	37 700	3 220	1 280	30 840	5 480	6 880		260
—28	Brown-gray silt loam on tight clay	79 780	7 660	1 840	28 840	18 780	34 360	49 260	
—90	Gravelly loam.....	33 220	3 140	1 360	27 540	10 720	15 800	14 000	
	Upland Timber Soils (900, 1000, 1100, 1200)								
—34	Yellow-gray silt loam	31 360	2 530	1 020	34 900	6 720	9 880		50
—34.5	Yellow-gray silt loam on rock.....	40 920	3 780	1 220	33 940	6 560	10 820	54 800	
—35	Yellow silt loam...	16 280	1 360	660	37 420	5 580	9 480		60
—64	Yellow-gray sandy loam	20 640	1 880	680	32 900	3 740	6 640		20
1065	Yellow sandy loam	25 280	2 100	880	32 420	10 740	18 360	42 420	
	Terrace Soils (1500)								
—27	Brown silt loam over gravel	46 640	4 240	1 220	34 120	8 080	9 220		60
—26.4	Brown silt loam on gravel	45 780	4 000	1 200	32 000	7 520	8 000		60
—66	Brown sandy loam over gravel	40 680	3 040	1 440	28 560	3 640	7 760		60
—60.4	Brown sandy loam on gravel	33 580	3 050	1 320	29 400	7 720	10 650	Often	Often
—64.4	Yellow-gray sandy loam on gravel...	24 120	2 120	960	31 200	5 000	7 940		20
—36	Yellow-gray silt loam over gravel.	24 540	2 680	1 060	36 720	8 180	16 040		20
	Late Swamp and Bottom-Land Soils (1400)								
—01	Deep peat[1]	349 640	29 350	1 740	5 730	5 350	25 470		Often
—02	Medium peat on clay[1]	148 220	13 600	1 090	10 550	5 010	13 760		10
—03.6	Shallow peat on marl[1]	262 890	21 180	1 220	4 120	10 050	90 620	158 050	
—10	Peaty loam	288 000	27 200	3 160	21 320	8 760	35 440		60
—25	Black silt loam...	150 240	13 300	2 260	26 900	15 880	29 780	10 840	
—50	Black mixed loam.	110 900	11 340	2 580	32 060	15 640	24 270	Often	Often
—54	Mixed loam	73 420	6 820	1 660	29 480	30 020	61 060	172 480	

[1]Amounts reported are for 1 million pounds of deep peat, medium peat, and shallow peat.

much potassium as the brown silt loam. The total supply of phosphorus in the surface soil varies from 660 pounds per acre in the yellow silt loam to 3,160 pounds in the peaty loam. The magnesium and calcium vary from about 3,000 and 6,000 pounds in the lighter soils to more than 30,000 pounds in some other types. Some types contain an abundance of limestone, while others are slightly acid in the surface, more strongly acid in the subsurface, and sometimes devoid of limestone even in the subsoil. More than 80 percent of the soils of the county contain no limestone in the surface or subsurface to a depth of 20 inches.

With an inexhaustible supply of nitrogen in the air, and with 34,000 pounds of potassium in the most common prairie soil, the economic loss in farming such land with some acidity and with only 1,300 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by the proper use of limestone and phosphorus in rational farm systems, 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 on the University experiment fields in other counties, as at Urbana in Champaign county, at Sibley in Ford county, at Bloomington in McLean county, and for a short period at Joliet in Will county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of central and northern Illinois.

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 (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901. From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed. The average yields are recorded in Table 3.

A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields of clover in 1903 were taken by carefully weighing the yields from small representative areas; but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 3 in computing yields and values.) The average yields of hay shown in the table represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Lc), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots.

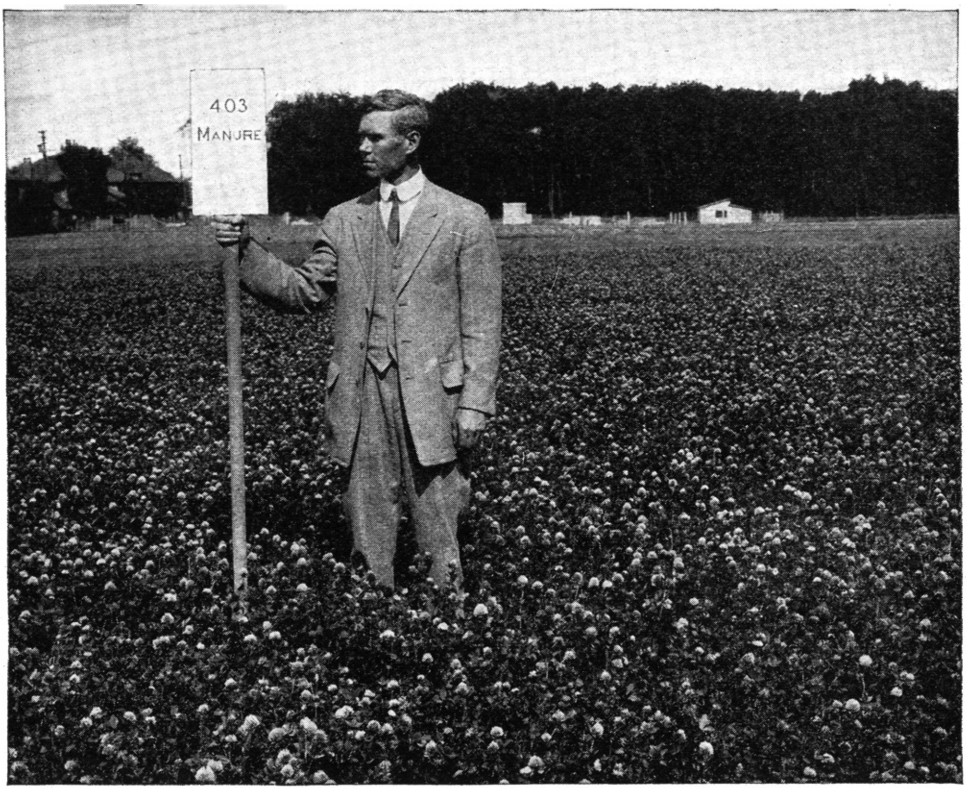

PLATE 1.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently as many tons of manure are applied as there have been tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone were applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained on the following page.

Phosphorus (P) has been applied on Plots 6 to 9 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one-half of each phosphorus plot has received 600 pounds of rock phosphate in place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

PLATE 2.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this "extra heavy" treatment was not begun until 1906, only the usual lime, phosphorus, and potassium having been applied in previous years. These heavy applications are made in an attempt to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the various plots were treated the same as the corresponding plots in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation; wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 4.)

From 1911 to 1915 soybeans were substituted four years because of clover failure; accordingly four-fifths of the soybeans and one-fifth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912 the field was plowed and reseeded. The average yield reported for alfalfa in Table 4 is one-fifth of the combined crops of 1912, 1913, 1914, and 1915.

TABLE 3.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905-1907						Third rotation, 1908-1910					
	Soil treatment	Corn, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons (bu.)	Value of 3 crops	
					Lower prices	Higher prices					Lower prices	Higher prices					Lower prices	Higher prices
1	0........	75.4	48.8	.49	$43.48	$62.12	0......	71.5	46.6	2.07	$52.56	$75.09	0......	49.4	40.8	2.30	$44.81	$64.02
2	Le.......	77.4	45.1	.44	42.80	61.14	Le.....	68.5	52.0	1.83	51.34	73.35	R......	51.5	43.4	(1.93)	43.69	62.41
3	0........	75.3	50.4	.41	43.33	61.91	M......	80.5	54.8	2.19	58.84	84.07	M......	69.3	46.2	2.53	54.90	78.43
4	LeL.....	78.4	47.3	.42	43.62	62.32	LeL....	72.3	58.6	1.98	55.57	79.39	RL.....	58.1	45.7	(2.02)	47.27	67.53
5	L.......	80.8	58.2	.44	47.66	68.08	ML....	84.8	59.8	2.46	63.64	90.92	ML....	74.9	47.5	2.94	60.09	85.85
6	LeLP....	88.0	52.5	.50	49.00	70.00	LeLP..	90.4	70.7	2.69	70.26	100.38	RLP...	83.8	54.5	(2.64)	63.07	90.10
7	LP......	88.8	56.6	.98	53.79	76.84	MLP...	93.2	71.6	3.47	76.96	109.94	MLP...	86.6	55.4	4.17	75.01	107.16
8	LeLPK..	90.1	48.3	.64	49.53	70.77	LeLPK.	93.8	71.7	3.06	74.32	106.18	RLPK..	86.7	53.5	(1.99)	59.26	84.65
9	LPK....	90.5	54.3	1.34	56.26	80.37	MLPK.	95.6	66.9	3.73	78.30	111.86	MLPK.	90.9	53.6	3.90	74.12	105.89
10	LPK....	86.5	53.2	1.23	53.78	76.83	MxLPx.	90.1	62.9	2.86	69.17	98.81	MxLPx.	81.3	54.3	3.79	70.19	100.27

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications of manure and phosphorus; R=crop residues (corn stalks, straw of wheat and oats, and all legumes except seed).

TABLE 4.—YIELDS PER ACRE, FIVE-YEAR AVERAGES, 1911-15: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans-4, tons (bu.)	Clover-1, tons[1] (bu.)	Alfalfa, tons	Value of 5 crops	
								Lower prices	Higher prices
1	0.......	22.2	53.9	46.3	1.60	2.50	2.27	$75.72	$108.17
2	R.......	23.5	56.4	47.8	(21.3)	(.74)	1.85	75.48	107.84
3	M.......	24.8	63.6	54.6	1.68	2.20	1.68	79.16	113.08
4	RL......	25.0	59.2	49.7	(20.7)	(1.03)	1.72	77.21	110.30
5	ML.....	28.1	63.4	57.3	1.72	2.81	2.25	87.22	124.60
6	RLP....	39.1	66.0	64.3	(22.6)	(2.48)	3.28	107.56	153.66
7	MLP....	38.3	67.6	64.9	1.92	4.04	3.25	107.80	154.00
8	RLPK...	38.2	63.7	64.5	(24.2)	(1.41)	3.22	105.17	150.23
9	MLPK..	37.4	64.6	69.3	2.09	3.91	3.31	108.54	155.06
10	MxLPx..	42.9	61.0	72.5	2.19	4.24	3.45	114.03	162.90

[1]The second cutting of clover hay was not included in reporting this crop in Soil Reports 9, 10, and 12.

The "higher prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "lower prices" are 70 percent of these values, or 70 cents for wheat and soybeans, 35 cents for corn, 28 cents for oats, $7 for clover seed, and $7 a ton for hay. The two sets of values are used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing, and marketing. Measured by Illinois prices for the past ten years these lower values are high enough for crops standing in the field ready for harvest.

The cost of limestone delivered at a farmer's railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $25 to $30 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains, ton for ton, but in less readily available form, usually costs the farmer from $6.50 to $7.50 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, commonly costs from $15 to $17 per ton delivered in carload lots in central Illinois.) Under normal conditions potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

To these cash investments must be added the expense of hauling and spreading the materials. This will vary with the distance from the farm to the railroad station, with the character of the roads, and with the farm force and the immediate requirements of other lines of farm work. It is the part of wisdom to order such materials in advance to be shipped when specified, so that they may be received and applied when other farm work is not too pressing and, if possible, when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the

PLATE 3.—CLOVER ON URBANA FIELD, SOUTH FARM
CROP RESIDUES PLOWED UNDER

land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

At the lower prices for produce; manure (6 tons per acre) was worth $1.05 a ton as an average for the first three years during which it was applied (1905 to 1907). For the next rotation the average application of 10.21 tons per acre on Plot 3 was worth $10.09, or 99 cents a ton. During the next four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11.35 tons per acre, worth $6.42 or 57 cents a ton, as measured by its effect on the wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth 84 cents a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last rotation period moisture has been the limiting factor to such an extent as probably to lessen the effect of the manure.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plots 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5 respectively.

PLATE 4.—CLOVER ON URBANA FIELD, SOUTH FARM
FINE-GROUND ROCK PHOSPHATE PLOWED UNDER WITH CROP RESIDUES

As a general average, the plots receiving limestone have produced $1.17 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, these increases varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.06 on five acres (Plot 5) as an average of the last five years. The need of limestone for the best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in bone meal produced increases valued at $1.92 per acre per annum for the first three years and at $4.67 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $5.12 for the third rotation and $5.09 for the last five years, 1911 to 1915. The annual expense per acre for phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for rock phosphate at $7 a ton.

Potassium, applied at an estimated cost of $2.50 an acre a year, seemed to produce slight increases, as an average, during the first and second rotations; but subsequently those increases have been almost entirely lost in reduced average yields, the net result to date being an average loss of $2.43 per acre per annum, or a loss of 97 cents for every dollar invested in potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as an average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,100 pounds of phosphorus and 35,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last five years is about $75. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value is $107. Thus 200 acres of the properly treated land would produce almost as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk, with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. Wheat, however, has as an average yielded best on this plot. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

The field investigations above described have been conducted on fifty experimental plots, laid out by Eugene Davenport a few months after he entered the service of Illinois in 1895.

But it so happens that the oldest soil experiment field in the United States is located at the University of Illinois. It was once on the farm, but is now on the campus of the institution, owing to the development and expansion of the University. This oldest field was started by George E. Morrow, for many years Professor of Agriculture. Here, on part of the field, corn has grown on the same land every year since 1879; on another part, corn and oats have grown

TABLE 5.—YIELDS PER ACRE ON MORROW (M) AND DAVENPORT (D) PLOTS, URBANA

Serial plot No.	Soil treatment	10-year average, 1906-1915			Wheat, bu. 5-yr. av.	Alfalfa, tons 4-yr. av.	Average acre-value[5]
		Corn, bu.	Oats, bu.	Clover, T (bu.)[1]			
M 3	None	28.8	...	...	...	...	$14.40
M 4	None	37.5[2]	38.0[2]	...	...	...	16.98
M 5	None	57.6[3]	33.4[3]	1.69[4]	...	...	19.69
D 1	None	55.5	44.4	1.93	22.2	...	21.75
D 1	None	55.5	44.4	1.93	22.2	3.23	23.86
D 2	Residues	56.9	47.5	(1.81)	23.5	2.93	23.67
D 3	Manure	68.4	52.0	2.08	24.8	2.80	25.72
D 4	Residues, lime	61.5	49.7	(1.93)	25.0	3.11	25.21
D 5	Manure, lime	71.7	53.9	2.34	28.1	3.79	29.36
D 6	Residues, lime, phosphorus	77.0	62.3	(2.44)	39.1	5.03	35.44
D 7	Manure, lime, phosphorus	79.5	63.2	3.04	38.3	4.98	36.71
D 8	Residues, lime, phosphorus, potassium	77.6	62.3	(2.19)	38.2	4.93	34.62
D 9	Manure, lime, phosphorus, potassium	79.5	63.3	3.08	37.3	5.02	36.67

[1]Or equivalent in cowpeas or soybeans.

[2]Five-year average. [3]Three-year average. [4]Four-year average.

[5]Prices: 50 cents a bushel for corn, 40 cents for oats, $1 for wheat and soybeans, $10 for clover seed, $10 a ton for hay.

in alternation; and on a third part, corn, oats, and clover have grown in rotation. These are known as the Morrow Plots.

On these plots, with no restoration of fertility, the acre-value of the produce, as an average of the ten-year period 1906 to 1915, was $14.40 where corn is grown every year, $16.98 where corn and oats are alternated, and $19.69 where corn, oats, and clover are rotated.

On the Davenport Plots, if we include the alfalfa yields for four years, and the wheat yields for five years, with the ten-year averages for the corn, oats, and clover, the acre-value becomes $23.86 with no soil treatment, $35.44 with residues, limestone, and phosphorus, and $36.71 with manure, limestone, and phosphorus.

More complete details regarding these averages are given in Table 5.

As an average of the results secured during the twelve years 1903 to 1914, on the University South Farm where fine-ground raw rock phosphate is applied at the rate of 500 pounds per acre per annum on the typical brown silt loam prairie soil, the return for each ton of phosphate[1] used has been $13.57 on Series 100 and $12.07 on Series 200, with the lower prices allowed for produce, the rotation being wheat, corn, oats, and clover (or soybeans). This gives an average return of $12.82 for each ton of phosphate applied. Averages for each rotation period show the following values for the increase per ton of phosphate used:

	Lower prices	Higher prices
First rotation, 1903 to 1906	$ 8.26	$11.80
Second rotation, 1907 to 1910	11.33	16.19
Third rotation, 1911 to 1914	18.89	26.98

Thus the rock phosphate paid back more than its cost during the first rotation, more than 1½ times its cost during the second rotation, and more than 2½ times its cost during the third rotation period.

One ton of fine-ground rock phosphate costs about the same as 500 pounds of steamed bone meal. Altho in less readily available form, the rock phosphate contains as much phosphorus, ton for ton, as the bone meal; and, when equal money values are applied in connection with liberal amounts of decaying organic matter, the natural rock may soon give as good results as the bone—and, by supplying about four times as much phosphorus, the rock provides for greater durability.

The results just given represent averages covering the residue system and the live-stock system, both of which are represented in this crop rotation on the South Farm.

Ground limestone at the rate of 8 tons per acre was applied to the east half of these series of plots (excepting the check plots, which receive only residues or manure), beginning in 1910 on Series 200 and in 1911 on Series 100. Subsequent applications are made of 2 tons per acre each four years, beginning in 1914 on Series 200 and in 1915 on Series 100. As an average of the results

[1]During the first four years Series 100 received only 1,500 pounds per acre of phosphate, and both series received also ½ ton per acre of limestone, the effect of which probably would be slight, as may be judged from the data secured later and reported herein.

TABLE 6.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 100
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1903	Corn 1904	Oats 1905	Wheat 1906	Clover 1907	Corn 1908	Oats 1909	Clover 1910	Wheat[2] 1911	Corn 1912	Oats 1913	Soybeans 1914	Value 1st four years		Value 2d four years		Value 3d four years		Wheat 1915
		Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices	Bushels per acre
163	RP......	45.1	54.1	57.5	39.8	(.83)	72.0	45.4	(.60)	46.9	74.9	26.8	(16.6)	$78.68	$112.40	$47.92	$ 68.46	$78.17	$111.67	46.9
166	RP......	43.8	49.3	60.9	36.5	(1.00)	74.9	40.8	(1.30)	53.4	79.5	24.6	(17.5)	75.19	107.41	53.74	76.77	84.34	120.49	44.4
169	R.......	42.7	39.5	49.3	28.4	(.90)	65.0	39.9	(1.70)	36.7	67.9	19.1	(15.3)	62.45	89.22	52.12	74.46	65.51	93.59	26.6
170	M.......	41.8	38.7	52.2	26.2	2.56	69.6	40.1	2.87	35.9	76.7	22.5	1.09	61.13	87.33	73.60	105.14	65.90	94.15	31.8
173	MP.....	35.4	53.3	54.6	32.8	3.65	78.4	39.8	4.23	52.7	83.7	29.6	1.45	69.29	98.99	93.74	133.92	84.62	120.89	50.5
176	MP.....	39.3	58.1	61.9	38.8	3.74	79.5	40.0	4.23	51.0	85.6	32.1	1.52	78.58	112.26	94.81	135.45	85.29	121.84	48.9
163	RLP....	....								49.9	87.0	28.2	(18.1)	....				85.94	122.78	50.9
166	RLP....	....								53.6	81.4	26.8	(18.0)	....				86.11	123.02	49.6
169	R.......	....								33.8	62.7	17.0	(15.2)	....				61.00	87.15	25.9
170	M.......	....								32.4	74.4	22.0	1.09	....				62.51	89.30	31.2
173	MLP....	....								51.3	85.7	28.0	1.37	....				83.33	119.05	52.4
176	MLP....	....								51.0	85.6	30.9	1.47	....				84.60	120.86	53.0

TABLE 7.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 200
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Oats 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat[2] 1910	Corn 1911	Oats 1912	Soybeans 1913	Wheat 1914	Value 1st four years		Value 2d four years		Value 3d four years		Corn 1915
		Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices	Bushels per acre
263	RP......	24.7	25.7	32.1	.82	65.3	31.3	42.5	43.7	52.3	72.9	(13.7)	30.6	$42.32	$60.46	$91.96	$131.37	$69.73	$ 99.61	57.9
266	RP......	23.1	24.5	29.3	.80	59.7	26.7	40.7	32.3	50.2	75.7	(12.3)	33.9	39.43	56.34	79.47	113.53	71.11	101.58	56.4
269	R.......	26.8	22.5	26.8	.86	57.9	31.5	39.4	25.3	35.5	61.9	(10.7)	16.1	38.58	55.12	74.38	106.25	48.51	69.31	45.9
270	M.......	22.0	21.5	24.0	.82	55.3	30.0	37.1	28.7	43.1	67.8	.84	17.4	34.72	49.60	73.81	105.45	52.12	74.47	57.0
273	MP.....	23.9	25.0	27.8	.77	62.5	29.5	43.4	43.7	38.6	69.4	1.17	37.2	38.54	55.06	91.10	130.15	67.17	95.96	61.5
276	MP.....	16.1	25.3	30.7	.68	58.0	27.9	44.1	38.2	48.0	68.6	1.34	42.0	37.84	54.06	85.72	122.46	74.79	106.84	57.6
263	RLP....	....							49.0	50.3	78.9	(13.2)	40.4	....				77.22	110.31	50.0
266	RLP....	....							45.2	47.1	78.7	(10.3)	36.0	....				70.93	101.33	55.8
269	R.......	....							35.3	45.3	68.4	(10.5)	20.7	....				56.85	81.21	53.3
270	M.......	....							33.3	45.2	73.2	1.12	20.1	....				58.23	83.18	55.5
273	MLP....	....							46.2	53.7	69.0	1.27	46.2	....				79.34	113.35	49.6
279	MLP....	....							39.5	50.6	69.5	1.24	49.0	....				80.15	114.50	53.5

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.

[2]From 1911 in Series 100, and from 1910 in Series 200, the acre-yields are based on half-plots, limestone having been applied to one half of each of the plots indicated.

from both series, the crop values were increased during the third rotation, 1911-1914, as follows:

	Residue System		Live-Stock System	
	Lower prices	Higher prices	Lower prices	Higher prices
Gain for phosphate...........	$18.82	$26.89	$18.95	$27.07
Gain for limestone	2.30	3.29	2.54	3.63

Detailed records of these investigations are given in Tables 6 and 7, the data being reported by half-plots after 1910-1911. (Series 300 and 400, which are also used in this rotation, are located in part upon black clay loam and a heavy phase of brown silt loam.)

Results of Experiments on Sibley Field

Table 8 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the 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 the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen *and* phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 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 apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield 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 the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be 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 1913 wheat averaged 6.6 bushels without nitrogen or phosphorus (Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

In the lower part of Table 8 is shown the total value of the twelve crops from each of the ten different plots, the amounts varying at the lower prices (35 cents a bushel for corn, 28 cents for oats, and 70 cents for wheat), from $167.32 to $257.91 per acre. Phosphorus without nitrogen has produced $31.27

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
		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	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos.	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas.	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro., phos.	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, nitro., potas.	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas.	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas.	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0
		Increase: Bushels per Acre											
	For nitrogen	.0	.3	2.8	1.1	2.5	9.2	11.6	-9.8	-5.0	.2	-60.3	11.5
	For phosphorus	1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
	For potassium	-4.0	-4.1	-.3	-1.5	-1.7	-4.0	-2.5	-5.6	.2	-.6	-2.5	.7
	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	14.0
	For phos., nitro. over nitro.	-2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
	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	-.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops: Lower prices	Higher prices
101	None	$172.89	$246.98
102	Lime	186.51	266.45
103	Lime, nitrogen	177.44	253.49
104	Lime, phosphorus	217.78	311.11
105	Lime, potassium	167.32	239.03
106	Lime, nitrogen, phosphorus	246.91	352.73
107	Lime, nitrogen, potassium	198.16	283.08
108	Lime, phosphorus, potassium	204.90	292.71
109	Lime, nitrogen, phosphorus, potassium	257.91	368.45
110	Nitrogen, phosphorus, potassium	242.47	346.38

Value of Increase per Acre in Twelve Years

	Lower prices	Higher prices
For nitrogen	-$ 9.07	-$12.96
For phosphorus	31.27	44.66
For *nitrogen* and phosphorus over phosphorus	29.13	41.62
For *phosphorus* and nitrogen over nitrogen	69.47	99.24
For *potassium,* nitrogen and phosphorus over nitrogen and phosphorus	11.00	15.72

in addition to the increase by lime, but with nitrogen it has produced $69.47 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $14.53, or $1.21 an acre a year. The increase on these plots is practically the same as on the field at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize the fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 9 and 10, giving all 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 first twelve years' work tell much the same story as those from the Sibley field. The rotations differed after 1905 by the use of clover and the discontinuing of the use of commercial nitrogen,—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, produced an even larger increase ($98.62) than was produced by phosphorus and nitrogen over nitrogen on the Sibley field ($69.47).

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 opposite 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 9 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

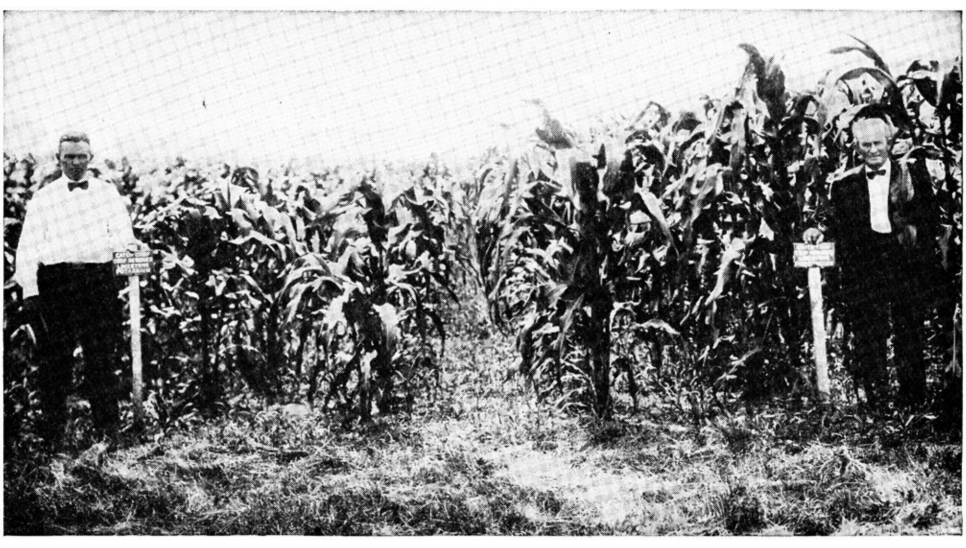

PLATE 5.—CORN IN 1912 ON BLOOMINGTON FIELD
ON LEFT, RESIDUES, LIME, AND POTASSIUM: YIELD, 58.9 BUSHELS
ON RIGHT, RESIDUES, LIME, AND PHOSPHORUS: YIELD, 86.1 BUSHELS

TABLE 9.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914	Soybeans[4] 1915	Wheat 1916
		Bushels or tons per acre[2]														
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2	32.4	29.8		20.5
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9	30.0	40.6		15.8
103	Lime, crop residues	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5	37.5	30.8		21.1
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	44.1	45.0		38.8
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8	32.1	35.8		16.7
106	Lime, residues, phosphorus	43.9	77.6	85.3	50.9	(3)	78.9	45.8	72.5	(1.67)	60.2	86.1	50.4	62.3		40.2
107	Lime, residues, potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9	34.5	34.5		18.7
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	49.4	63.1		39.9
109	Lime, residues, phosphorus, potas.	52.7	80.9	90.5	51.9	(3)	88.4	58.1	64.2	(.42)	60.4	83.4	49.0	54.4		43.8
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	(3)	78.0	51.4	55.3	(.60)	61.0	78.3	33.8	44.8		39.2
	Increase: Bushels or Tons per Acre															
	For residues	-1.9	-.8	9.0	1.7	-.12	1.2	1.6	-4.2		3.1	14.6	7.5	-9.8		5.3
	For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2	3.12	35.1	26.6	14.1	4.4		23.0
	For potassium	.7	-3.9	1.7	4.4	-.07	1.0	.9	-8.3	.15	-.8	9.9	2.1	-4.8		.9
	For residues, phosphorus over phosphorus	2.2	4.6	12.6	11.7	-1.65	-3.2	-1.7	8.7		2.6	11.6	6.3	17.3		1.4
	For phosphorus, residues over residues	8.8	18.1	15.5	20.4	-.46	14.6	8.9	23.1	(.84)	34.6	23.6	12.9	31.5		19.1
	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	-1.4	-7.9		3.6

[1]Commercial nitrogen was used from 1902 to 1905, after which crop residues were substituted.
[2]For clover the figures indicate tons per acre, except where in parentheses, in which case they indicate bushels of seed.
[3]Clover smothered by previous wheat crop.
[4]The soybeans in 1915 were entirely destroyed by hail. Nothing was harvested and the residue was plowed under on all plots.

TABLE 10.—VALUE OF CROPS PER ACRE IN FIFTEEN YEARS, BLOOMINGTON FIELD

Plot	Soil treatment applied	Total value of fourteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$201.18	$287.40
102	Lime	197.82	282.60
103	Lime, residues	208.60	298.00
104	Lime, phosphorus	313.78	448.25
105	Lime, potassium	202.22	288.89
106	Lime, residues, phosphorus	313.17	447.39
107	Lime, residues, potassium	204.19	291.70
108	Lime, phosphorus, potassium	322.85	461.21
109	Lime, residues, phosphorus, potassium	315.13	450.19
110	Residues, phosphorus, potassium	286.54	409.35
	Value of Increase per Acre in Fourteen Crops		
	For residues	10.78	15.40
	For phosphorus	115.96	165.65
	For *residues* and phosphorus over phosphorus	–.61	–.86
	For *phosphorus* and residues over residues	104.57	149.39
	For *potassium*, residues, and phosphorus over residues and phosphorus	1.96	2.80

[1]Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

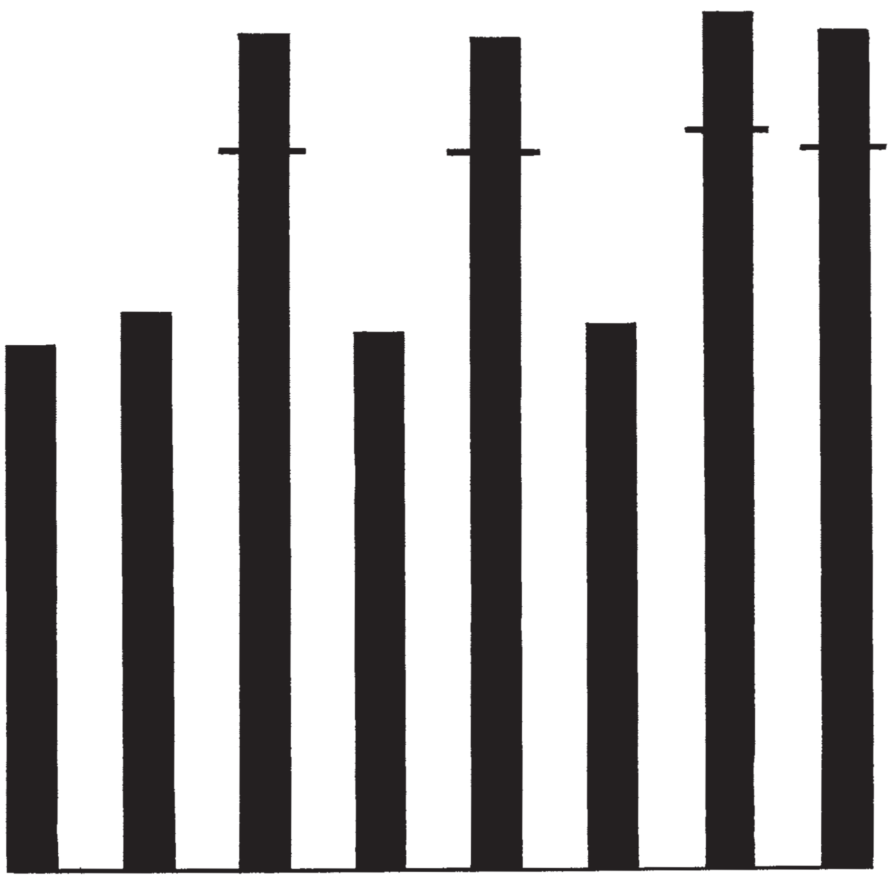

PLATE 6.—CROP VALUES FOR FIFTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD
(R=residues; P=phosphorus; K=potassium, or kalium)

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $6.97 an acre, at the lower prices, as a fifteen-year average. This is $4.17 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the 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 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 on the Bloomington field, 193 pounds per acre of phosphorus, as an average, has been removed in the fourteen crops. This is equal to 16 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 ninety years, they would require as much phosphorus as now constitutes 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 has been applied, the crops have removed only 126 pounds of phosphorus during the same period, which is equivalent to only 10½ percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1916, as an average of all plots where it has been used, has amounted to 375 pounds per acre and has cost $42.[1] This has paid back $113.02, or 269 per cent on the investment; whereas potassium, used in the same number of tests and at about the same cost, has paid back only $2.76 per acre in the fifteen years, or about 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops? (See Table 2; also Table A in the Appendix.)

Nitrogen was applied to the residue plots of this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover 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 the five residue plots. Straw and corn stalks have also been returned to these plots beginning with 1908. The effect of returning these residues to the soil has been appreciable since 1908 (an average increase on Plots 106 and 109 of 3.6 bushels of wheat, 5.4 bushels of corn, and 5.5 bushels of oats) 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 fifteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, 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

[1]This is based on $28 a ton for steamed bone meal; in earlier years the price was about $25.

will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 6 shows graphically the relative values of the fourteen crops for the years 1902 to 1916, 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 cross-bars. 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. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in fifteen years only 61 cents below that from Plot 104 (LP). (See also table on last page of cover.)

Results of Experiments on Joliet Field

In 1914 experimental work was begun on the Joliet experiment field located about three miles northwest of Joliet on the line of the Aurora and Joliet interurban railway. This field occupies thirty-two acres of brown silt loam prairie of the late Wisconsin glaciation.

Ground limestone, at the rate of 4 tons per acre, was the only material applied for the 1914 crops. For 1915 crop residues (corn stalks and straw or chaff from wheat, oats, soybeans, and clover) were turned under, raw rock phosphate and kainit were applied to some plots, as indicated in Table 11, and farm manure was added to Plots 502, 503, and 504 in proportion to the total crop yields of 1914 on the corresponding plots of all series. The amounts of phosphate and kainit applied in pounds per acre were as follows:

Series	Phosphate	Kainit
300...........	500	200
400...........	1,000	400
500...........	1,500	600
100...........	2,000	800
200...........	2,500	1,000
600...........	3,000	1,200

Subsequent applications are made at the rate of 500 pounds of phosphate and 200 of kainit per acre per annum, but they are put on in larger amounts once during the rotation, on a different series each year, beginning with series 300 for 1916. Manure is likewise applied in regular order to the proper plots, beginning with Series 500 for 1915, Series 100 for 1916, etc.

In Tables 11, 12, and 13 are recorded in detail the crop yields secured in 1914, 1915, and 1916, with summaries of crop values at the two prices. Of course no conclusions should be drawn from the results of the first year or two of such experiments, but the data may be of some value if studied in connection with those from longer investigations.

If we count 1,000 pounds of ground limestone per acre as the average annual allowance for "maintenance," then the average increase for limestone for the three seasons shows a return of $3.07 per ton at the lower prices or of $4.38 per ton at the higher prices.

While 200 pounds per acre of phosphate each year would be ample to maintain the natural supply in the soil, the plan is to provide for positive soil en-

TABLE 11.—YIELDS PER ACRE IN SOIL EXPERIMENTS, JOLIET FIELD, 1914
BROWN SILT LOAM PRAIRIE; LATE WISCONSIN GLACIATION

Series		100	200	300	400	500	Value of 5 crops	
Plot	Treatment	Wheat, bu.	Clover, tons (bu.)	Oats, bu.	Corn, bu.	Soybeans tons (bu.)	Lower prices	Higher prices
1	0	16.5	2.00	60.9	44.7	1.24	$66.93	$ 95.61
2	0	19.3	2.05	60.2	46.9	1.40	70.93	101.33
3	L	20.9	1.97	59.8	52.4	1.51	74.07	105.82
4	L	21.5	2.02	59.5	50.2	1.28	72.38	103.40
5	0	18.2	1.91	50.2	42.3	1.15	63.02	90.03
6	0	19.9	(.42)	53.3	50.6	(11.9)	57.83	82.62
7	L	20.8	(1.00)	60.8	53.2	(13.3)	66.51	95.02
8	L	20.2	(.92)	59.1	51.0	(11.9)	63.31	90.44
9	L	22.0	(1.83)	68.8	53.1	(14.8)	76.42	109.17
10	0	17.4	(1.25)	52.5	45.1	(11.1)	59.19	84.55
Average with limestone[1]							$71.10	$101.57
Average without limestone[1]							62.70	89.57
Increase for limestone							$ 8.40	$ 12.00

[1] These computed results include weighted averages for the legume hay and seed.

TABLE 12.—YIELDS PER ACRE IN SOIL EXPERIMENTS, JOLIET FIELD, 1915

Series		100	200	300	400	500	600	Value of 6 crops	
Plot	Treatment	Soybeans, bu.	Wheat, bu.	Soybeans, bu.	Oats, bu.	Corn, bu.	Alfalfa, tons	Lower prices	Higher prices
1	0	14.4	9.8	10.6	72.5	28.6	1.79	$ 67.20	$ 96.00
2	M[1]	15.2	7.9	12.5	73.0	36.3	2.13	72.98	104.25
3	ML[1]	15.2	14.3	13.3	70.5	38.3	2.83	82.91	118.45
4	MLP[1]	16.8	20.3	14.8	75.0	47.7	3.73	100.13	143.05
5	0	15.2	10.6	13.9	67.7	28.5	2.18	71.98	102.83
6	R	14.0	15.6	13.0	62.8	32.4	2.57	76.73	109.62
7	RL	15.8	20.0	13.7	63.6	28.7	2.90	82.80	118.29
8	RLP	15.2	24.9	15.1	65.0	31.2	3.39	91.49	130.70
9	RLPK	16.3	30.4	15.0	72.0	43.4	3.56	103.46	147.80
10	0	15.1	25.2	12.8	63.1	27.1	1.90	77.62	110.89
Average increase for limestone								$ 8.00	$ 11.43
Average increase for phosphate								12.95	18.50
Increase for kainit								11.97	17.10

[1] Manure applied for corn only (Series 500).

TABLE 13.—YIELDS PER ACRE IN SOIL EXPERIMENTS, JOLIET FIELD, 1916

Series		100	200	300	400	500	600	Value of 6 crops	
Plot	Treatment	Corn, bu.	Soybeans, tons (bu.)	Wheat, bu.	Clover, tons (bu.)	Oats, bu.	Alfalfa, tons	Lower prices	Higher prices
1	0	18.1	.55	4.1	1.17	70.9	1.46	$51.31	$ 73.31
2	M[1]	29.4	.59	5.2	1.24	75.9	1.78	60.45	86.36
3	ML[1]	34.0	.66	8.3	1.16	77.2	2.96	72.79	103.98
4	MLP[1]	33.4	.63	7.9	1.65	77.7	4.35	85.39	121.98
5	0	18.5	(8.2)	6.0	(.33)	73.3	2.16	54.37	77.67
6	R	18.9	(7.9)	9.9	(.42)	71.1	2.23	57.53	82.19
7	RL	21.6	(8.9)	13.2	(.50)	63.9	2.88	64.58	92.26
8	RLP	25.0	(11.5)	18.7	(.50)	59.8	4.10	78.83	112.62
9	RLPK	25.1	(15.0)	15.2	(.42)	81.4	4.38	86.32	123.31
10	0	18.6	1.06	7.1	1.15	74.1	1.72	59.74	85.34
Increase for manure (Series 100 and 500)								5.36	7.65
Increase for residues								3.16	4.52
Average increase for limestone								9.70	13.84
Average increase for phosphate								13.42	19.18
Increase for kainit								7.49	10.69

[1] Manure applied on Series 100 and 500 only.

NOTE.—Lower prices are based on 70 cents a bushel for wheat, 35 cents for corn, 28 cents for oats, $7 a ton for hay: higher prices, $1 a bushel for wheat, 50 cents for corn, 40 cents for oats, $10 a ton for hay.

richment by applying 500 pounds a year for several rotations. Even at this rate, the average increase produced in 1915 and 1916, per ton of phosphate, amounts to $8.79 at the lower prices for the crops, or to $12.56 at the higher prices. These values compare well with $8.26 and $11.80, the values of the increase per ton of phosphate during the first rotation on the University South Farm at Urbana. The corresponding returns in the third rotation at Urbana were $18.89 and $26.98.

Kainit is used, not for soil enrichment, but as a stimulant. Its temporary use may be profitable. If used at all, it should be with intelligence and with the

TABLE 14.—FERTILITY IN THE SOILS OF KANE COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils (900, 1000, 1100, 1200)								
–26	Brown silt loam..	63 250	5 480	2 050	69 800	22 260	19 520		120
–26.5	Brown silt loam on rock	99 560	8 320	2 760	68 920	23 120	24 120		40
–60	Brown sandy loam	41 200	3 680	1 840	64 080	12 720	12 120		40
–28	Brown-gray silt loam on tight clay	65 920	5 840	3 080	60 040	51 200	93 840	235 920	
	Upland Timber Soils (900, 1000, 1100, 1200)								
–34	Yellow-gray silt loam	20 650	2 300	1 690	72 070	24 660	21 480		260
–34.5	Yellow-gray silt loam on rock...	26 680	3 000	2 040	66 760	20 000	19 600	21 160	
–35	Yellow silt loam..	18 680	1 600	1 320	83 120	14 360	16 760		1 400
–64	Yellow-gray sandy loam	15 400	1 480	1 320	69 640	11 640	19 160		120
1065	Yellow sandy loam	28 960	2 360	1 760	67 760	33 440	46 240	115 360	
	Terrace Soils (1500)								
–27	Brown silt loam over gravel	47 240	4 280	1 840	70 400	20 960	17 040		160
–26.4	Brown silt loam on gravel	43 280	4 400	1 920	66 800	18 720	12 800		160
–66	Brown sandy loam over gravel	33 120	2 600	1 680	62 760	25 040	19 120		520
–60.4	Brown sandy loam on gravel	41 060	3 480	2 220	60 280	22 940	26 620	Often	Often
–64.4	Yellow-gray sandy loam on gravel..	20 000	2 080	1 640	62 920	18 760	14 000		600
–36	Yellow-gray silt loam over gravel	22 120	2 520	1 760	72 360	24 240	14 960		40
	Late Swamp and Bottom-Land Soils (1400)								
–01	Deep peat[1].	811 860	63 930	2 840	6 400	11 060	56 270		Often
–02	Medium peat on clay[1].	118 360	11 280	1 160	26 140	9 600	18 340		20
–03.6	Shallow peat on marl	222 000	13 600	1 360	5 000	49 760	1 184 880	2 924 800	
–10	Peaty loam	215 400	21 480	2 600	58 080	19 920	47 240		40
–25	Black silt loam...	191 000	11 000	2 600	61 080	33 080	46 840	12 040	
–50	Black mixed loam	60 720	5 880	3 080	70 420	32 500	33 840	Often	Often
–54	Mixed loam	141 320	13 640	3 800	55 760	51 920	112 920	325 000	

[1]Amounts reported are for 2 million pounds of deep peat and medium peat.

thought of increasing the production of legume crops, crop residues, or farm manure, which when turned under not only liberate potassium from the soil and phosphorus from rock phosphate, but also provide the necessary nitrogen for soil enrichment and finally make the further use of kainit or other potash salt ineffective and unprofitable. The 200 pounds of kainit per acre for each year supplies only 20 pounds of potassium, while the plowed soil of an acre contains 37,780 pounds of the same element, and a hundred-bushel crop of corn (grain and stalks) requires 73 pounds. In contrast, it may be noted that 4 tons of phosphate (the amount to be applied per acre in 16 years) will about double the phosphorus content of the plowed soil.

TABLE 15.—FERTILITY IN THE SOILS OF KANE 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	Soil acidity present
	Upland Prairie Soils (900, 1000, 1100, 1200)								
-26	Brown silt loam..	33 260	3 350	2 690	113 290	55 310	53 150	Often	
-26.5	Brown silt loam on rock	60 960	5 400	3 480	102 060	51 240	42 480	36 900	
-60	Brown sandy loam	30 840	2 700	2 400	95 880	28 140	21 420		1 080
-28	Brown-gray silt loam on tight clay	39 480	3 780	3 780	95 100	88 800	181 440	490 920	
	Upland Timber Soils (900, 1000, 1100, 1200)								
-34	Yellow-gray silt loam	16 120	2 280	3 100	112 980	87 760	121 570	Often	
-34.5	Yellow-gray silt loam on rock...	35 040	4 080	3 660	106 380	53 340	65 520	179 700	
-35	Yellow silt loam..	21 900	2 700	2 820	136 800	51 360	45 180	88 740	
-64	Yellow-gray sandy loam	11 580	1 620	2 460	117 180	39 480	36 720	67 200	
1065	Yellow sandy loam	18 360	2 400	2 880	96 240	144 960	239 220	990 960	
	Terrace Soils (1500)								
-27	Brown silt loam over gravel	30 660	3 360	2 700	103 860	40 680	27 240		840
-26.4	Brown silt loam on gravel	35 580	3 900	2 760	100 140	42 360	36 420	42 420	
-66	Brown sandy loam over gravel	22 860	2 280	2 220	97 080	43 440	31 620		2 340
-60.4	Brown sandy loam on gravel	44 160	3 960	2 700	89 040	36 120	37 860	48 000	
-36	Yellow-gray silt loam over gravel	18 240	2 640	3 240	105 000	43 920	28 920		900
	Late Swamp and Bottom Land Soils (1400)								
-01	Deep peat[1].......	1 168 020	87 090	3 740	12 780	16 700	79 400		390
-02	Medium peat on clay	60 000	6 240	2 640	89 040	72 900	88 620	269 160	
-03.6	Shallow peat on marl.........	186 420	12 780	300	420	73 560	2 114 520	5 172 240	
-10	Peaty loam......	170 700	14 580	3 360	92 460	117 960	218 640	794 700	
-25	Black silt loam...	179 340	8 100	3 480	105 180	59 160	75 960	85 380	
-50	Black mixed loam	30 900	3 090	4 080	115 560	56 550	55 920	58 110	
-54	Mixed loam......	150 540	12 180	3 540	64 860	167 580	279 780	1 167 240	

[1]Amounts reported are for 3 million pounds of deep peat.

A six-crop rotation is practiced on the Galesburg experiment field on the brown silt loam prairie of the upper Illinois glaciation. During the first three years the average returns were $2.65 for phosphate and $4.05 for potash salt used in addition to phosphate, but during the next six years the corresponding average annual returns from three acres were $7.31 for phosphate and $1 for potash. This was in a rational system of farming which, of course, includes the use of home-grown organic matter.

THE SUBSURFACE AND SUBSOIL

In Tables 14 and 15 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Kane county, 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 these tables is that the most common upland soils are acid in the surface and subsurface and sometimes contain no limestone in the subsoil. These tables also show great stores of potassium and only limited amounts of phosphorus, in agreement with the data for the surface stratum (Table 2).

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of Kane county cover 237.88 square miles, or 46.37 percent of the area of the county. They are usually quite dark in color owing to their high organic-matter content. They usually occupy the less rolling and comparatively level land, altho exceptions are to be found.

Brown Silt Loam (926, 1026, 1126, 1226)

Brown silt loam is the most extensive type in Kane county, covering an area of 228.29 square miles (146,106 acres), or 44.49 percent of the area of the county. This type is found on the more level land, a considerable portion of which needs artificial drainage. Small basin-like depressions, or kettle-holes, are rather common in the brown silt loam of the late Wisconsin glaciation. These sometimes contain water and are frequently very difficult to drain. While this type is primarily prairie, yet in some sections timber has extended over it to a slight extent. The trees found on the timbered areas are usually bur oak, wild cherry, and elm, but their occupation of the soil has not been sufficiently long to change its character to any great extent. The type, however, may include some small areas of yellow-gray silt loam (-34) too small to be shown on the map.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly drained tracts. In physical composition it varies to some extent, but it normally contains from 50 to 70 percent of the different grades of silt. In the low areas the proportion of clay is usually higher than on the more rolling parts, where a perceptible amount of sand may occur. On account of the varied topography of the type, the organic-matter content in the surface soil is quite variable, but it averages 6.2 percent, or 62 tons per acre. In the more rolling phase, small patches are found which have been eroded to such an extent that the yellow subsoil appears. These areas are usually not large enough to be shown on the map as a separate type. The brown silt loam of the late Wisconsin glaciation contains a slightly higher percentage of organic matter than the early Wisconsin, the difference being approximately one percent.

The subsurface is represented by a stratum varying from 5 to 16 inches in thickness. This variation is due to erosion, the stratum being thinner on the more rolling areas. In physical composition the subsurface varies about the same as the surface soil, but on the less rolling areas it normally contains a larger percentage of clay, while on the more rolling areas the sand content becomes greater. The organic-matter content is about the same in both glaciations, but varies with topography, being greater on the more level land, where it averages 2.9 percent, or 58 tons per acre in a stratum 13⅓ inches thick. In color the subsurface varies from a dark brown or almost black to a light yellowish brown, which becomes lighter with depth.

The natural subsoil begins 11 to 22 inches beneath the surface and extends to an indefinite depth but is sampled to 40 inches. It varies from a yellow to a drabbish yellow, clayey material, sometimes composed wholly or in part of boulder clay or drift. In some of the flat areas that are subject to erosion, but where material has washed in from the higher surrounding land, the subsoil to a depth of 40 inches does not reach the boulder clay.

In the management of this type, it is essential that manure or crop residues, including legumes, should be returned to the soil in the most practical and advantageous way. No form of organic matter should be burned. In live-stock farming the manure should be applied to the soil as soon as possible after it is produced, in order to avoid loss. Both limestone and phosphorus should be regularly applied on the normal brown silt loam, but such soil enrichment is not so necessary on some of the small abnormal areas. For results secured in field experiments on brown silt loam, see the preceding pages.

Brown Silt Loam on Rock (1026.5, 1126.5, 1226.5)

Brown silt loam on rock occupies .37 square miles (237 acres). It occurs principally along the Fox river in the vicinity of Batavia.

The surface soil, 0 to 6⅔ inches, consists of a dark brown to black silt loam containing about 6.2 percent of organic matter.

The subsurface soil is a brown silt loam containing about 4.3 percent of organic matter.

The presence of rock so near the surface renders this type of little value except for pasture. Where there is danger of erosion, it should not be plowed. Top-dressings of manure may improve the pasture; and with the development of acidity applications of ground limestone will encourage the growth of clover in the herbage.

Brown Sandy Loam (960, 1060, 1160, 1260)

Brown sandy loam occurs in small isolated areas, principally in the northern part of the county in the late Wisconsin glaciation. The total area is 2.97 square miles (1,900 acres), or .58 percent of the area of the county. The sand of this type is derived quite largely from glacial material.

The surface soil, 0 to 6⅔ inches, consists of a brown sandy loam varying in color from a light or yellowish brown to a dark brown or even to black. The sand content varies, being much more abundant in small patches that have been produced largely by the action of the wind. The organic-matter content is about 3.3 percent, or 33 tons per acre.

The subsurface, 6⅔ to 18 or 20 inches, consists of a brown to a yellowish brown sandy loam, varying with the variation in the surface soil. The organic-matter content is about 1.8 percent.

The subsoil is quite variable, in some places being made up of boulder clay while in others it is a yellowish sand, or a clayey sand or sandy clay.

Brown sandy loam is generally well drained, but some areas in Township 42 North, Range 6 East, need artificial drainage. This type requires for its improvement the large use of organic matter. Being loose and better aerated than brown silt loam, it suffers greater loss of that constituent by oxidation; hence greater difficulty is found in maintaining the necessary supply. Crop residues, legume crops, and manure must constitute the chief materials by which the organic matter is maintained. Ground limestone should be used regularly at the rate of about 2 tons per acre every four years, after a heavier initial application. Because of the deep feeding range afforded plant roots the application of phosphorus is not likely to prove profitable until the present supply is reduced.

Brown-Gray Silt Loam on Tight Clay (928, 1028, 1128)

Brown-gray silt loam on tight clay occupies the low and poorly drained areas in Kane county. It covers only .25 square mile (160 acres).

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing about 6.9 percent of organic matter.

The subsurface consists of a grayish silt that passes into a tight clay layer at a depth of about 18 inches. This stratum contains approximately 2.8 percent of organic matter.

The subsoil varies from a yellowish or mottled grayish yellow clay to a clayey silt, the upper part of which is tough and almost impervious.

This type is generally poorly drained because of the tight subsoil. It should receive the same treatment for maintaining organic matter as brown silt loam. Deep-rooting crops, especially, should be grown for the purpose of loosening the tight clay stratum. Where sampled, this type was generally found to be well supplied with limestone and phosphorus, but acidity may occur in local areas, and these should be limed.

Gravelly Loam (990, 1090, 1190, 1290)

Gravelly loam covers an area of 6 square miles (3,840 acres), or 1.18 percent of the area of Kane county. It occurs principally in the late Wisconsin glaciation in somewhat isolated, irregular areas. These are found chiefly on glacial ridges, where the fine material has been removed by erosion and the gravelly till exposed. The amount of gravel in this type varies quite largely, many small patches containing so much that they could be shown on the map as gravel if the areas were of sufficient size. The organic-matter content averages about 2.9

percent. It was impossible, with a soil auger, to collect a sample from the subsurface.

When cultivated, the greatest need of this type is for organic matter and nitrogen.

(b) UPLAND TIMBER SOILS

The upland forest soils are deficient in organic matter, owing to the fact that in forests the vegetable material from trees accumulates upon the surface and is either burned or suffers almost complete decay. Grasses, which furnish large quantities of humus-forming roots, do not grow to any extent. At the same time, the organic matter that had accumulated before timber began growing is being removed thru various decomposition processes, with the result that in these soils the content has become too low for the best forest growth.

The total area of timber soils in the county is 151.32 square miles, or 29.48 percent of the area of the county. In some cases where severe erosion has occurred on prairie soils, small areas of these are mapped with the timber soils.

Yellow-Gray Silt Loam (934, 1034, 1134, 1234)

Yellow-gray silt loam is a very extensive type in Kane county, covering an area of 130.72 square miles (83,661 acres), or 25.47 percent of the entire area of the county. It is very irregularly distributed, but usually occupies the more rolling areas. In topography it varies from the characteristic billowy and kettle-hole features of the moraines to almost level intermorainal tracts. Much the larger part of this type occurs in the northern part of the county in the late Wisconsin glaciation.

The surface soil, 0 to 6⅔ inches, is a gray or yellowish gray silt loam, incoherent and mealy, but not granular. It varies greatly in physical composition owing to the fact that in some places the thin covering of loess has been removed by erosion, and the variable drift thus exposed. There are many local areas of sandy or gravelly loam, but they are too small to be shown on the map. Likewise many small areas of dark soil, such as brown silt loam or black mixed loam, too small to be indicated on the map, are found in the kettle-hole depressions. The amount of organic matter in the surface soil varies from 1.6 to 3.2 percent. This wide variation is due to the relation of the type to other types, the content of organic matter increasing where yellow-gray silt loam grades into brown silt loam (1126 and 1226) and decreasing where it passes into yellow silt loam (1135 and 1235). In some places erosion has reduced the content of organic matter much below the normal, so that many small areas are yellow in color. Coarse gravel and even small boulders are found on some of the steeper slopes.

The subsurface varies from 3 to 10 inches in thickness, being thinner on the more rolling areas. In color it is gray, grayish yellow, or yellow. It is somewhat pulverulent but becomes more coherent and plastic with depth. The amount of organic matter is low, averaging only about .8 percent, or 16 tons per acre in a stratum 13⅓ inches thick.

The subsoil is usually a yellow to a grayish yellow boulder clay. On the more level areas, however, the boulder clay may not be reached within 40 inches of the surface. The deeper subsoil frequently contains large amounts of limestone, and shows brisk effervescence with hydrochloric acid.

In the management of yellow-gray silt loam, one of the essential points is the maintenance or increase of organic matter. This is much more necessary with this type than with brown silt loam, because this soil is naturally much more deficient in the constituent. The organic matter tends to prevent "running together," and on some of the more rolling areas lessens the washing; it gives better tilth to the soil under all conditions. As it decays, it supplies nitrogen and tends to liberate other plant food, as explained in the Appendix. Other essentials are the application of ground limestone and phosphorus, and the large use of clover, alfalfa, or other legumes, which should be returned to the soil either directly with other crop residues or in manure, thus providing an adequate supply of new nitrogen.

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. There, as an average of duplicate trials each year for the four years 1911 to 1914, the crop values from four acres were $23.49 from untreated land, $26.03 where organic manures were applied in proportion to the amount of crops produced, and $47.97 where 6 tons per acre of limestone and the organic manures were applied—the wheat, corn, oats, and clover (or cowpeas or soybeans) grown in the rotation being valued at the higher prices heretofore mentioned. In 1915 the wheat crop was completely destroyed by hail, but the corresponding values for the other three crops were $21.85 with no soil enrichment, $28.67 with organic matter, and $47.01 with limestone and organic matter.

Owing to the low supply of organic matter, phosphorus produced almost no benefit, as an average, during the first two years; but with increasing applications of organic matter, the effect of phosphorus is becoming more apparent in subsequent crops (see Circular 181 for details). Of course the full benefit of a four-year rotation cannot be realized during the first four years. The farm manure was applied to one field each year, and the fourth field received no manure until the fourth year. Likewise, crop residues plowed under during the first rotation may not be fully recovered in subsequent increased yields until the second or third rotation period.

More recently the people of White county have furnished the University with a tract of yellow-gray silt loam near Enfield, on which experiments have been started. The crop values from four acres, as an average of the first three years (1913-1915), were $25.30 from unfertilized land, $28.18 with organic manures, $33.86 with manures and limestone, and $39.42 with manures, limestone, and rock phosphate; and the corresponding values for 1915 were $30.95 with no treatment, $40.96 with organic manures, $50.53 with manures and limestone, and $60.36 with manures, limestone, and phosphate. (In all of these cases, the results given are the averages of data from two systems of farming, which include the use of farm manure in one and green manures and crop residues in the other, and are on the basis of the higher values mentioned above.)

While limestone is the material first needed for the economic improvement of the more acid soils of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the northern part of the state are first in need of phosphorus, altho limestone and organic matter must also be provided for permanent and best results.

TABLE 16.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD
YELLOW-GRAY SILT LOAM, UNDULATING TIMBERLAND; LATE WISCONSIN GLACIATION

Plot	Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913	Wheat 1914	Corn 1915[4]	Oats 1916
		Bushels or tons per acre[2]														
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3	.50	30.8		30.6
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5	.60	30.0		25.3
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	([3])	40.8		35.3
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	1.32	54.2		45.9
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	.72	34.0		28.8
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9	([3])	41.3		61.6
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9	([3])	43.2		31.9
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9	1.60	46.0		40.6
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9	([3])	41.0		54.1
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1	([3])	37.8		47.8
	Increase: Bushels or Tons per Acre															
	For nitrogen	1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6	-14.2	6.9		10.8		10.0
	For phosphorus	5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8	12.8	31.6	.72	24.2		20.6
	For potassium	3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6	-4.2	1.3	.12	4.0		3.5
	For nitrogen, phosphorus over phosphorus	6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8	-.4	2.2		-12.9		15.7
	For phosphorus, nitrogen over nitrogen	10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6	26.6	22.5		.5		26.3
	For potassium, nitrogen, phosphorus over nitrogen, phosphorus	4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0	7.2	-15.0		-.3		-7.5

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the other, tons of hay.
[3]No seed produced: clover plowed under on these plots.
[4]Corn failed in 1915 owing to storms and cold weather.

TABLE 17.—VALUE OF CROPS PER ACRE IN FIFTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of fourteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$143.69	$205.27
102	Lime	126.83	181.18
103	Lime, nitrogen	134.59	192.27
104	Lime, phosphorus	215.05	307.21
105	Lime, potassium	146.94	209.92
106	Lime, nitrogen, phosphorus	196.66	280.95
107	Lime, nitrogen, potassium	142.47	203.53
108	Lime, phosphorus, potassium	212.72	303.89
109	Lime, nitrogen, phosphorus, potassium	206.37	294.82
110	Nitrogen, phosphorus, potassium	210.00	300.00

Value of Increase per Acre in Fourteen Crops

For nitrogen	7.76	11.09
For phosphorus	88.22	126.03
For *nitrogen* and phosphorus over phosphorus	-18.39	-26.26
For *phosphorus* and nitrogen over nitrogen	62.08	88.68
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	9.71	13.87

[1]Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

Table 16 shows in detail fifteen years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field, page 7, for further explanations.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of forty tests (four each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of fifteen years each dollar invested in phosphorus paid back $2.10 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) produced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with four almost complete crop failures (1904, 1907, 1910, and 1915), 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 in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

From a comparison of the results from the Urbana, Sibley, and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course where nitrogen is needed for soil improvement in general farming the atmosphere is the most economical source from which to obtain it. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow-Gray Silt Loam on Rock (1034.5, 1134.5, 1234.5)

Yellow-gray silt loam on rock occurs along the Fox river in the southeastern part of Kane county and covers .26 square mile, or 166 acres.

The surface soil, 0 to 6⅔ inches, is a brownish yellow silt loam containing 3.5 percent of organic matter, or 35 tons per acre.

The subsurface contains 1.2 percent of organic matter. Rock usually occurs 25 to 30 inches beneath the surface, but in small areas it may appear at a slightly lesser or greater depth.

Yellow Silt Loam (935, 1035, 1135, 1235)

Yellow silt loam occurs principally along the Fox river. It has been produced by the eroding action of the Fox river and the small streams that empty into it. In Township 40 North, Range 7 East, where there is a rolling morainal topography, a considerable area of this type occurs. The type covers a total of 6.15 square miles (3,936 acres), or 1.2 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish gray silt loam usually containing some sand or gravel. This stratum is frequently formed from glacial drift, the loess having been removed by erosion. Owing to its derivation, it varies a great deal in physical composition. The organic-matter content averages about 1.4 percent, or 14 tons per acre.

The subsurface varies from 3 to 10 inches in thickness. It is composed of a yellow or grayish yellow silt loam, but may vary from this to boulder clay or even to a very gravelly form of boulder clay. It contains .8 percent of organic matter.

The subsoil is composed almost entirely of yellow boulder clay.

One of the best uses to which this type can be put is permanent pasture. As a rule it cannot be satisfactorily cropped in ordinary rotations but it may be used very successfully for long rotations with pasture or meadow much of the time. Where both the surface and the subsurface are acid, ground limestone may well be used for legumes in the rotation or even as a top dressing to encourage their growth in pastures. Where this type has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such land the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 18 and 19, and shown photographically in Plates 7 and 8.

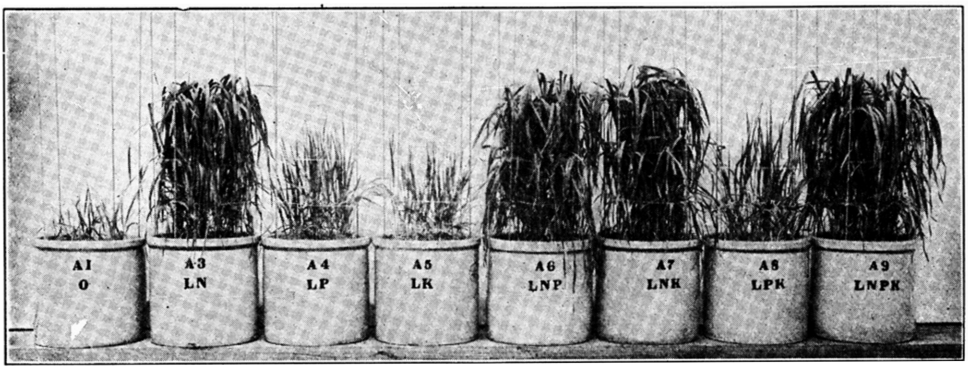

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 18)

TABLE 18.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

In one experiment, a large quantity of typical worn hill soil was collected from two different places. Each lot of soil was thoroly mixed and put in ten four-gallon jars. Wheat was planted in one series and oats in the other.[1] Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 18.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under usual conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

[1]Soil for wheat pots, from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

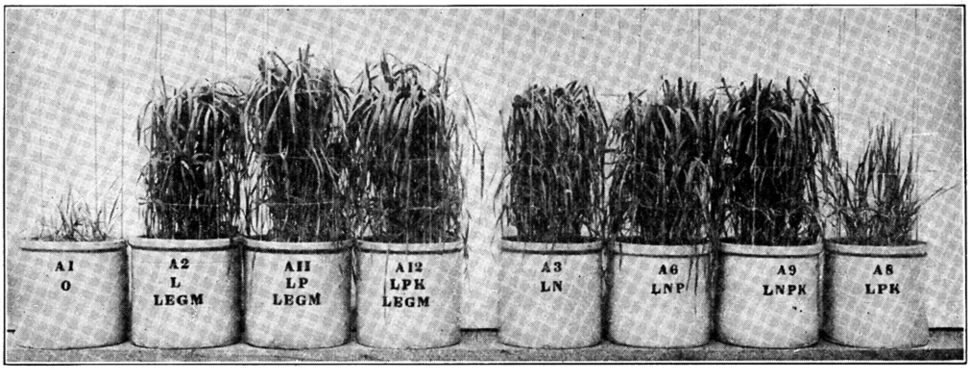

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 19)

TABLE 19.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS
(Grams per pot)

No. Pot	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains the essential minerals and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same kind of worn hill soil as that used for wheat in the former experiment. The results are reported in Table 19.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 18 in showing the very great need of nitrogen for the improvement of this type of soil,—and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care. As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with erosion, which is sure to occur to some extent, the phosphorus supply will be renewed from the subsoil.

Probably the best legumes for this type of soil are sweet clover and alfalfa. On soil deficient in organic matter sweet clover grows better than almost any other legume, and the fact that it is a very deep-rooting plant makes it of value in increasing the organic matter and preventing washing. Worthless slopes that have been ruined by washing may be made profitable as pasture by growing sweet clover. The blue grass of pastures may well be supplemented by sweet clover and alfalfa, and a larger growth obtained, because the legumes provide the necessary nitrogen for the blue grass.

To get alfalfa well started requires the liberal use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Yellow-Gray Sandy Loam (964, 1064, 1164, 1264)

Yellow-gray sandy loam occurs principally in the morainal area of Township 42 North, Ranges 6 and 7 East. Other areas are found along the Fox river. In topography it is usually rolling, and interspersed with small areas of yellow sandy loam. The type covers an area of 13.96 square miles (8,934 acres), or 2.72 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow sandy loam usually containing some gravel; in a few instances small patches of gravelly loam occur. The soil is made largely from sandy till. The organic-matter content is about 1.8 percent, or 18 tons per acre.

The subsurface stratum varies from 3 to 10 inches in thickness. It is of a lighter color than the surface soil owing to the smaller amount of organic matter present (about .6 percent). This stratum is usually formed from gravelly sandy till, but often contains a considerable proportion of clay.

The subsoil varies from gravelly till to gravelly sand.

For the improvement of this type, the addition of organic matter and nitrogen is essential. Limestone should also be applied liberally for the best results with legumes; and, where the subsurface and subsoil are quite compact owing to the presence of silt and clay, the addition of phosphorus will be required for best results.

Yellow Sandy Loam (1065)

Yellow sandy loam occurs in small isolated areas in Township 42 North, Ranges 6 and 7 East. The sand is derived from glacial drift.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow sandy loam containing 2.2 percent of organic matter, or 22 tons per acre. In physical composition it is a slightly gravelly, sandy loam. The amount of gravel, however, varies in different parts; some small patches of gravelly loam occur, that are not sufficiently large to map. This stratum is normally made up of 60 to 75 percent of sand.

The subsurface is a yellow sandy loam containing 1.2 percent of organic matter. In physical composition it is similar to the surface soil, but it possibly varies thru a greater range.

The subsoil consists of yellow, gravelly, sandy till which in many places is somewhat clayey.

For the improvement of this type, applications of organic matter and nitrogen are essential. Also, every precaution should be taken to prevent erosion. Where acidity develops in local areas, limestone should be applied, but phosphorus is not likely to prove profitable.

(c) TERRACE SOILS

Terrace soils occur along streams. They were formed at a time when the streams were much larger than they are at present, owing to melting glacier ice, and carried large amounts of coarse material such as sand and gravel. Upon any decrease in their velocity, these over-loaded streams would deposit debris along their courses; and this resulted in the partial filling of the valley and the forming of what are now the terraces, bench lands, or second bottom lands. Finer material later deposited over this sand and gravel forms the present soil.

When the streams again reached their normal size, after the glacier had melted, they began cutting down thru the deposit, and they are now so low that the terraces, or benches, do not overflow. A gravel outwash plain occurs in the northwestern part of Township 42 North, Range 6 East, that was formed by the shallow water of the melting ice spreading over a large level area and depositing sand and gravel which was later covered with a fine material well adapted to forming a good soil.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel occurs principally along the Fox river, with smaller areas along some of the smaller streams. An area is also found in the northwestern corner of the county in the old gravel outwash plain. The occurrence of this type along the Fox is very irregular owing in part to the varying width of the original valley. The largest areas occur at Aurora and north of Elgin. That even small streams were important agents in terrace formation is evident northwest of Elgin. The type covers 14.76 square miles (9,446 acres), or 2.88 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies from a brown to a very dark brown silt loam, frequently containing sufficient sand to form a loam but not enough to form a sandy loam. The topography is usually flat but slight undulations may occur that were probably produced by the channels of the flooded streams. The surface soil contains 4 percent of organic matter, or 40 tons per acre.

The subsurface stratum varies from 7 to 16 inches in thickness. It contains 2 percent of organic matter, or 40 tons in a layer 13⅓ inches thick. In physical composition it is about the same as the surface soil.

The subsoil is a yellow to a mottled yellow silt loam, with some gravel appearing in the deeper subsoil.

All strata are pervious to water, so that drainage is practically perfect. The gravel is so far from the surface that crops do well even in years of some drouth. This is one of the best of the terrace types.

In the improvement of this type limestone, phosphorus, and organic matter should be provided in about the same amounts as recommended for the brown silt loam prairie soil (-26). However, because of the greater porosity of this type applications of phosphorus are likely to occupy third place in immediate effect.

Brown Silt Loam on Gravel (1526.4)

Brown silt loam on gravel occurs along the Fox river, the principal areas being just south of Elgin. In this type the amount of fine material covering the gravel is not so thick as in brown silt loam over gravel (1527). The type covers .85 square mile (544 acres).

The surface soil, 0 to 6⅔ inches, contains about 3.9 percent of organic matter, or 39 tons per acre. In physical composition it is a slightly sandy silt loam, but the sand content is not sufficient to give distinctive characteristics.

The subsurface stratum, varying from 8 to 12 inches in thickness, is a brown to light yellowish brown silt loam containing a perceptible amount of gravel, which aggregates in some cases as much as 5 percent. The organic-matter content is 1.9 percent, or 38 tons in a stratum 13⅓ inches thick.

The subsoil consists of medium and fine gravel with sand and a slight amount of finer soil constituents.

This soil type is well drained, and, because of the nearness of gravel to the surface, will not resist drouth well. In the management of the type, care must be taken to maintain the supply of organic matter, since this constituent is so important in the conservation of moisture. Phosphorus additions are not likely to prove profitable, because of the porosity of all strata, but limestone may well be tried where clovers do not thrive as well as formerly, or where alfalfa is to be started. When well started, the deep-rooting alfalfa may secure plenty of limestone from the subsoil.

Brown Sandy Loam over Gravel (1566)

Brown sandy loam over gravel occurs along the Fox river, principally in the two northern townships. Several areas are also found in the gravel outwash plain in Township 42 North, Range 6 East. In the formation of the type, sand, silt, and some clay were deposited on the surface of the gravel to a depth of 36 to 54 inches. The type covers an area of 1.76 square miles (1,126 acres), or .34 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam varying from a light or yellowish brown to almost black. The content of sand is not far from 60 percent, but this varies to some extent, some small areas being quite sandy and others more loamy. The organic-matter content is approximately 3.5 percent, or 35 tons per acre.

The subsurface, consisting of a stratum 6 to 12 inches in thickness, is a brownish yellow to brown sandy loam that passes into a yellow silty sand. Some gravel occurs, but not in significant amounts. The organic-matter content is 1.4 percent.

The subsoil is a yellow silty sand that passes into gravel at a depth of 36 to 48 inches.

All the strata are pervious to water, and this condition generally permits good drainage. In the management of the type the factors of importance are the liberal use of ground limestone and organic matter (including the growing of legumes in crop rotation) and the return to the soil of such crops with other crop residues and farm manure.

Brown Sandy Loam on Gravel (1560.4)

Brown sandy loam on gravel occurs along the Fox river in the two upper townships and also in the gravel outwash plain in Township 42 North, Range 6 East. It covers a total area of 1.4 square miles (896 acres), or .27 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a light brown sandy loam varying in content of sand and containing from 2 to 3 percent of gravel. The organic-matter content varies somewhat but averages about 2.8 percent, or 28 tons per acre.

The subsurface stratum contains 1.6 percent of organic matter and a considerable amount of gravel. It usually extends to the gravel layer, which appears at a depth varying from 16 to 22 inches.

The subsoil varies from a medium gravel to a fine sand, with slight intermixtures of finer soil constituents.

The proximity of gravel to the surface reduces the moisture-holding capacity of this type, with the result that crops may suffer from drouth. The use of ground limestone and the maintenance of organic matter are the important factors in the management of the type.

Yellow-Gray Sandy Loam on Gravel (1564.4)

Yellow-gray sandy loam on gravel also occurs along the Fox river and is distributed more or less along its entire length in Kane county. It is of very little importance agriculturally. It covers an area of .56 square mile (358 acres).

The surface soil, 0 to 6⅔ inches, consists of a light brownish gray or yellowish gray sandy loam on gravel containing approximately 2.1 percent of organic matter, or 21 tons per acre. Practically all of this type has been covered with forests, a fact which accounts for its low organic-matter content.

The subsurface, extending from a depth of 6⅔ inches to gravel, which occurs at a depth of 16 to 22 inches, consists of a yellow sandy loam with some gravel.

The subsoil consists of an open gravel, which provides excellent drainage. The thinness of the stratum of fine material renders the soil poor in resisting drouth.

The use of ground limestone and the increase of organic matter are the most important factors in the management of this type. Such treatment will increase the water-holding capacity, improve the tilth of the soil, and supply nitrogen.

Yellow-Gray Silt Loam over Gravel (1536)

Yellow-gray silt loam over gravel occurs principally along the Fox river, but several small areas are to be found along the smaller streams. It covers 4.61 square miles (2,950 acres), or .9 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a grayish or yellowish gray silt loam containing 2.1 percent of organic matter, or 21 tons per acre.

The subsurface soil, comprizing a layer from 6 to 10 inches thick, is a yellow to grayish yellow silt loam and contains about 1 percent of organic matter.

The subsoil is a clayey silt of a yellow or slightly grayish yellow color. Gravel occurs at a depth of 32 to 48 inches.

As this type is low in organic matter and phosphorus, devoid of limestone, and distinctly acid in the subsoil, these materials should of course be supplied for soil improvement.

Gravelly Loam (1590)

Gravelly loam is found in a few isolated areas along the Fox river in Township 42 North, Range 8 East. The type aggregates 229 acres, but is of little importance. It occurs in narrow areas along the edges of terraces, usually on the slope between a terrace and the first bottom land.

The surface soil, 0 to 6⅔ inches, consists of a brownish, gravelly loam containing a small amount of organic matter. The soil is not uniform, some small patches being practically all gravel while others may contain large amounts of coarse sand. Coarse gravel, from 1 to 2 inches in diameter, largely constitutes the subsurface and the subsoil.

This type is of very little agricultural importance and makes only poor pasture. No sample was collected for analysis.

(d) LATE SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat occurs in practically every part of the county, in areas varying from 10 acres or less to a square mile or more in extent. It occupies low, swampy areas that have an almost constant supply of water. It covers 14.53 square miles (9,299 acres), or 2.83 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies from a brown to a black peat containing about 60 percent of organic matter, or 300 tons per acre.

The subsurface and subsoil strata each contain about 70 percent of organic matter. In some cases sandy or silty material is found mixed with the subsoil.

Drainage is of first importance with this type. This in many cases is rather difficult to secure because tiles cannot be laid to good advantage in peat on account of irregular settling and the consequent displacement of the line. This difficulty may be partly overcome by placing the tiles upon boards laid in the bottom of the ditch, altho such a system cannot be regarded as permanent.

Where thoro drainage can be provided, either by the above method, by open ditches, or by laying tiles deep enough to secure a solid bed for them, very marked improvement can be made in the productive power of deep peat by the liberal use of potassium, which is by far the most deficient element.

In Table 20 are given all results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which however were cropped the same as the plots.

TABLE 20.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL (Bushels per acre)

Plot No.	Soil treatment for 1902	Corn 1902	Corn 1903	Soil treatment for 1904	Corn 1904	Corn 1905	Four crops
1	None	10.9	8.1	None	17.0	12.0	48.0
2	None	10.4	10.4	Limestone, 4000 lbs.	12.0	10.1	42.9
3	Kainit, 600 lbs.	30.4	32.4	Limestone, 4000 lbs. / Kainit, 1200 lbs.	49.6	47.3	159.7
4	Kainit, 600 lbs. / Acidulat'd bone, 350 lbs.	30.3	33.3	Kainit, 1200 lbs. / Steamed bone, 395 lbs.	53.5	47.6	164.7
5	Potassium chlorid, 200 lbs.	31.2	33.9	Potassium chlorid, 400 lbs.	48.5	52.7	166.3
6	Sodium chlorid, 700 lbs.	11.1	13.1	None	24.0	22.1	70.3
7	Sodium chlorid, 700 lbs.	13.3	14.5	Kainit, 1200 lbs.	44.5	47.3	
8	Kainit, 600 lbs.	36.8	37.7	Kainit, 600 lbs.	44.0	46.0	164.5
9	Kainit, 300 lbs.	26.4	25.1	Kainit, 300 lbs.	41.5	32.9	125.9
10	None	14.9[1]	14.9	None	26.0	13.6	69.4

[1]Estimated from 1903; no yield was taken in 1902 because of a misunderstanding.

The results of the four years' tests, as given in Table 20, are in complete harmony with the information furnished by the chemical composition of peat soil. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one-third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

The use of 700 pounds of sodium chlorid (common salt) produced no appreciable increase over the best untreated plots, indicating that where potassium is itself actually deficient, salts of other elements cannot take its place.

Applications of 2 tons per acre of ground limestone produced no increase in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

Reducing the application of kainit from 600 to 300 pounds for each two-year period, reduced the yield of corn from 164.5 to 125.9 bushels. The two applications of 300 pounds of kainit (Plot 9) furnished 60 pounds of potassium for the four years, an amount sufficient for 84 bushels of corn (grain and stalks). Attention is called to the fact that this is practically the difference between the yield of Plot 9 (125.9 bushels) and the yield obtained from Plot 2 (42.9 bushels), the poorest untreated plot.

Farm manures and crop residues also contain sufficient potassium to make their use very effective on deep peat soil; and with prohibitive prices for commercial potash salts, farm manure, corn stalks, straw, etc., must be utilized for the improvement of such soils.

[1]In 1904 the yields were taken from quarter-acre plots because of severe insect injury on the other parts of the field.

Medium Peat on Clay (1402)

Medium peat on clay occurs in low, swampy places similar to those occupied by deep peat, but the conditions for the formation of this type have not been so favorable as for deep peat, and as a consequence the peaty material is less than 30 inches thick. The type covers only 448 acres in Kane county.

The surface soil, 0 to 6⅔ inches, varies in its organic-matter content from about 25 percent to more than 75 percent.

The subsurface contains less organic matter than the surface soil. It extends from a depth of 6⅔ inches to 12 to 30 inches, at which depth this peaty layer rests upon the clay subsoil.

If this type is not productive when well drained, it may be improved by extra deep plowing, by which process the more clayey material can be reached; otherwise the use of manure or commercial potassium is advised. (See treatment recommended for *Deep Peat* and *Black Mixed Loam.*)

Shallow Peat on Marl (1403.6)

Shallow peat on marl occurs in a low, swampy area 26 acres in extent. It is very unusual, and is the only area of the kind yet found in the state. It probably has no agricultural value as a soil.

The surface soil, 0 to 6⅔ inches, contains about 45 percent of organic matter and about 16 percent of calcium carbonate, the subsurface about 73 percent of calcium carbonate and 10 percent of organic matter, and the subsoil about 86 percent of calcium carbonate and 5 percent of organic matter.

This marl is white in color and crumbles to a powder upon drying. It could be used with marked benefit upon the acid soils of the upland in the vicinity.

Peaty Loam (1410)

Peaty loam occupies only 58 acres in Kane county. The surface soil, 0 to 6⅔ inches, contains about 25 percent of organic matter, the subsurface about 9 percent, and the subsoil about 5 percent.

Drainage is the first requirement of this type, and when drained it ought to produce good crops.

Black Mixed Loam (1450)

Black mixed loam is distributed over the entire county with the exception of the southern and southwestern parts, where the black silt loam of the early Wisconsin glaciation takes its place. The type occurs in the low, swampy areas, and practically all of it needs artificial drainage. It occupies a total area in the county of 68.12 square miles (43,597 acres), or 13.27 percent of the area of the county. It is exceeded in area only by brown silt loam and yellow-gray silt loam.

The surface soil, 0 to 6⅔ inches, is a black mixed loam varying from a clay loam to a sandy loam and even to a peaty loam or a peat, but the variation is so irregular that it is impossible to indicate the separate areas on the map. The average organic-matter content is approximately 10 percent, but variations from this amount are very great.

The subsurface most commonly consists of a black mixed loam that passes into a drab or mottled yellowish drab loam containing some gravel. The organic-matter content varies with the surface soil, but is much lower.

The subsoil consists of a drab or yellowish drab mixture of sand, silt, and clay, with some gravel.

This type underdrains well, all strata being pervious to water. It is rapidly being tile-drained and generally constitutes a very fertile soil, the exception being where peaty alkali exists. This in some places becomes quite serious, but with the aid of potassium salts, coarse stable manure, and the turning under of straw, cobs, etc., the effect of the alkali may be overcome to a large extent. Sweet clover usually grows well on alkali soils, and a crop of it turned under may aid in the growing of a good crop of corn. The use of these means should also be considered where the land is well drained, if it does not produce satisfactory crops.

In Tables 21 and 22 are recorded the results from Series 200 and Series 300 of the Momence experiment field, for the years 1904 to 1914, on peaty loam soil. A rotation consisting of two crops of corn, one of oats, and one of clover has been practiced. Nitrogen has been provided in legume crops, cover crops, and crop residues in the system of grain farming, and in farm manures in the live-stock system. The legume cover crops and crop residues have been made use of since the beginning, but no manure was applied till 1908, after the first clover crop of 1907. The manure has been applied in proportion to the crop yields. Where larger crops were produced, proportionately more manure was subsequently applied; and, consequently, more manure has been applied to Series 300 than to Series 200. Phosphorus has been applied in the form of steamed bone meal carrying 12½ percent phosphorus, at the rate of 200 pounds per acre per annum. No potassium has been applied to Series 200, but potassium has been applied to the whole of Series 300 at the rate of 150 pounds of potassium sulfate per acre per annum. Common salt (sodium chlorid) was applied to the north half of all the plots of Series 200 at the rate of 600 pounds per acre in the spring of 1908. So far as it is possible to observe, no effect has been produced by the salt.

The untreated land of Series 200 will produce under favorable conditions 10 to 15 bushels of corn per acre. The south half of Plot 202 occupies the area of an old stack bottom. For this reason the yields from that plot are larger than normal, at least for the first three or four years. The yields from Plots 201 and 203 were also thus influenced but not to the same extent.

As an average of the returns from Plots 301, 305, and 310 (compare with 201, 205, and 210) potassium increased the crop values by $25.64 per acre during the four years 1904 to 1907, or by $6.41 a year, at a cost of $3.78, but during the next eight years the average yearly increase for potassium alone was only $4.07, which is not much above its cost. When used in addition to manure, the potassium did not pay its cost.

Plots 3 and 4 of Series 200 received an average of 3.7 tons of manure per acre in the spring of 1908 and 5.6 tons in 1912. The return in the eight crops was $15.35 for the 9.3 tons, or $1.65 per ton. On Series 300 the corresponding return was $5.22 for 16 tons of manure, or 33 cents per ton, when used in addition to potassium, the manurial value of the cover crop on Plot 4 being included in both cases. Phosphorus did not produce sufficient increase, at the lower prices for produce, to pay its cost.

Table 21.—Crop Yields in Soil Experiments, Momence Field, 1904 to 1915: Series 200

Plot	Soil treatment applied	Corn 1904	Corn 1905	Oats 1906	Clover 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Corn 1912	Corn 1913	Oats 1914	Soybeans 1915	Value of last 8 crops: Lower prices[1]	Value of last 8 crops: Higher prices[2]
		Bushels or tons (clover) per acre													
201	None	14.2	11.4	29.4	0	9.2	19.0	36.9	.21	18.6	12.6	27.2	9.5	$46.86	$66.94
202	Residues	20.1	16.1	32.2	0	8.2	25.2	37.5	Turned	32.2	24.4	27.5	11.3	57.61	82.30
203	Manure	13.4	10.1	24.4	0	11.8	27.8	38.8	.23	35.8	24.6	23.8	11.2	61.98	88.54
204	Manure, cover crop	6.3	6.6	25.3	0	14.2	25.8	46.9	.44	36.6	17.0	34.1	10.3	65.73	93.90
205	None	4.4	5.6	21.2	0	8.2	17.0	48.1	.29	16.2	9.4	33.4	9.8	49.49	70.70
206	Phosphorus	8.7	8.6	23.4	0	14.0	16.0	51.3	.45	18.2	15.2	37.2	9.8	56.98	81.40
207	Residues, phosphorus	10.9	10.1	30.6	0	6.0	17.6	42.8	Turned	27.4	18.0	30.3	12.3	53.23	76.04
208	Manure, phosphorus	1.5	8.9	30.9	0	17.4	17.6	52.2	.80	41.8	12.6	35.6	11.7	69.66	99.52
209	Manure, cover crop, phosphorus	9.4	10.8	38.1	0	25.2	24.4	62.5	.58	51.6	23.6	41.9	12.3	85.58	122.26
210	None	6.5	10.0	29.4	0	8.6	14.4	45.0	.29	17.8	11.2	27.2	9.8	47.31	67.58

Table 22.—Crop Yields in Soil Experiments, Momence Field, 1904 to 1915: Series 300

Plot	Soil treatment applied	Corn 1904	Corn 1905	Oats 1906	Clover 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Corn 1912	Corn 1913	Oats 1914	Soybeans 1915	Value of last 8 crops: Lower prices[1]	Value of last 8 crops: Higher prices[2]
		Bushels or tons (clover) per acre													
301	Potassium	34.9	41.5	36.6	.10	20.2	44.4	35.6	.26	39.4	41.6	20.9	11.5	$76.65	$109.50
302	Potassium, residues	35.5	35.6	38.1	.28	12.4	54.0	38.8	Turned	38.8	43.6	26.2	12.5	79.03	112.90
303	Potassium, manure	41.1	44.1	40.3	.30	20.0	58.4	39.1	.67	49.8	47.4	26.9	12.0	93.03	132.90
304	Potassium, manure, cover crop	38.5	40.5	33.1	.10	22.6	47.2	40.0	.59	49.8	43.4	30.6	11.7	89.14	127.34
305	Potassium	42.9	45.2	41.2	.48	25.6	48.2	43.8	.71	44.2	45.0	31.6	11.8	91.39	130.56
306	Potassium, phosphorus	45.9	47.7	41.6	1.03	22.0	47.4	41.3	.98	52.0	42.2	30.0	12.3	92.69	132.40
307	Potassium, phosphorus, residues	44.4	50.5	45.3	.40	15.8	53.6	40.0	Turned	45.2	41.6	29.1	13.0	83.12	118.74
308	Potassium, phosphorus, manure	54.4	54.9	44.7	.33	29.6	59.4	53.1	1.13	65.2	49.4	34.4	13.0	112.77	161.10
309	Potassium, phosphorus, cover crop, manure	52.2	55.5	45.9	.05	23.8	54.2	51.6	.98	57.8	45.4	39.1	11.5	103.73	148.18
310	Potassium	30.3	37.5	35.3	.08	16.2	45.0	35.9	.20	33.6	36.0	27.5	11.8	73.19	104.56

[1]Corn at 35 cents a bushel, oats at 28 cents, soybeans at 70 cents, clover at $7 a ton.
[2]Corn at 50 cents a bushel, oats at 40 cents, soybeans at $1, clover at $10 a ton.

The plain conclusion to be drawn from these investigations is that either potassium or manure should be used to begin the improvement of this type. When good crop yields are secured, more and more manure should be returned, and the application of commercial potassium may then be greatly reduced, or possibly ultimately discontinued. Of course, if some other soil on the farm needs the manure even more because of deficiency in both potassium and nitrogen, one may use less manure and more potassium on the peaty swamp land.

Mixed Loam (1454)

Mixed loam occurs in irregular areas along the streams, as first bottom, or overflow land. The total area is 5.91 square miles (3,782 acres), or 1.15 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black to brown mixed loam, which differs but little from much of the preceding type, black mixed loam, except that it receives deposit during overflow. The organic-matter content is about 6 percent, or 60 tons per acre.

The subsurface is a brown mixed loam, usually containing some gravel. In organic-matter content it is about the same as the surface soil.

The subsoil is a drab to yellowish drab mixture of different soil constituents, silt predominating. It contains about 4 percent of organic matter.

Drainage is the one important requirement of this type. All strata are pervious, so that no difficulty is experienced in obtaining good underdrainage, provided the outlet is sufficient.

Black Silt Loam (1425)

Black silt loam occurs in low, swampy places somewhat similar to those occupied by black mixed loam. The total area is 7.08 square miles (4,531 acres), or 1.38 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black silt loam varying to a black clayey silt loam. It contains about 12 percent of organic matter, and when well drained is very granular and comparatively easy to work.

The subsurface stratum varies from 9 to 12 inches in thickness, and is a black to brown silt loam, that passes into a drab or yellowish drab, clayey silt. It contains about 8 percent of organic matter.

The subsoil is a drab or yellowish drab, pervious, clayey silt, containing some gravel.

This type is one of the best in the county when well drained. Some few alkali spots are found, but they are not so common as in black mixed loam (1450). Good farming is the most essential point in the management of the type at the present time. This should include crop rotation and some effort to provide decaying organic matter in order to maintain soil organisms and soil activities.

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 soil-survey map of the entire state.

Other publications of general interest are:

Bulletins

76 Alfalfa on Illinois Soils
94 Nitrogen Bacteria and Legumes
115 Soil Improvement for the Worn Hill Lands of Illinois
125 Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois
181 Soil Moisture and Tillage for Corn
182 Potassium from the Soil
190 Soil Bacteria and Phosphates

Circulars

82 Physical Improvement of Soils
110 Ground Limestone for Acid Soils
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?
129 The Use of Commercial Fertilizers
149 Results of Scientific Soil Treatment: Methods and Results of Ten Years' Soil Investigation in Illinois
165 Shall We Use "Complete" Commercial Fertilizers in the Corn Belt?
167 The Illinois System of Permanent Fertility
181 How Not to Treat Illinois Soils
186 The Illinois System of Permanent Fertility from the Standpoint of the Practical Farmer: Phosphates and Honesty

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 ascertaining, and 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 truthworthy. 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 the 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 corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with a plane table for determining directions of angling 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, ditches, 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 for this purpose being carried in the field.

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 carried 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, such 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) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprizing undecomposed and partially decayed vegetable or organic material
	Mineral matter	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

[1]25 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—Soils with 15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—Soils with 15 to 35 percent of partly decomposed organic matter mixed with much clay and 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 a little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

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

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

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

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 it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous 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, cowpeas, straw, and corn stalks. 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 furnish or 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 nitrous 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 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 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 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 composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure. 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

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farmyard dung."

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. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (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, alfalfa, 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 wheat, corn, oats, and clover 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 never known to limit the yield of general farm crops grown under normal conditions.)

To be sure, these are large yields, but shall we try to make possible the production of yields only a 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 land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the ten

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

Produce		Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Kind	Amount					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
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

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

years 1906 to 1915, a yield of 77 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 79 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. 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 which 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. Thus, in the conversion of sufficient organic nitrogen into nitrate nitrogen for a 100-bushel crop of corn, the nitrous acid formed is alone sufficient to convert seven times as much insoluble tricalcium phosphate into soluble monocalcium phosphate as would be required to supply the phosphorus for the same crop.

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 it 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 ($CaCO_3MgCO_3$), 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 on land being prepared 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 or returned after threshing (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. 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.

For the best production of seed in grain farming, alsike, sweet clover, or mammoth clover may well be grown. 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 (such as cowpea wilt) these may 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. In 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 following.)

(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 from one-half ton to one 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 12 to 14 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 to 12 cents a pound in steamed bone meal and 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 a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 to 800 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 may 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 supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought, as a rule.)

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 renews 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 the 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 reseeding 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. The mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting 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 with other crop residues 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 twenty-four 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 sixty years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. 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 wheat crop removed annually an average of 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 sixty years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were 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. Where only 70 pounds of sodium was applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of sixty 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 on the wheat crop is becoming much more marked than that of sodium or magnesium; 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 the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is 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 in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; 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 6⅔ 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) will 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 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 in Wayne county, 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, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit 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 included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure was 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 by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; 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, but its decomposition yields organic acids.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food they consume, 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, farmers following this practice 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; and with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] 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

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

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. Practically the same amount of calcium was found, by analyses, in 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 was applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 780 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 four or five 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.

Physical Improvement of Soils

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth and prevents the soil from running together badly; and as it decays it furnishes nitrogen for the crop and aids in the liberation of mineral plant food. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth. This decomposition is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal or the destruction of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter content by plowing under manure or crop residues, such as corn stalks, straw, and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

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. 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. The nitrogen in a ton of corn stalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result. Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. To obtain the greatest value from the manure, it should be applied to the soil as soon as it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes 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 produce 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 result, and if put in oats, the soil is so compact as to be unfavorable for their growth. Sometimes the soil is worked 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 organic matter below the amount necessary to maintain good tilth.

FIFTEEN 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	3.33
1905	Wheat, bu.	28.8	39.2	10.4	7.28
1906	Clover, tons	.58	1.65	1.07	7.49
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	2.86
1910	Clover, tons	1.09	4.21	3.12	21.85
1911	Wheat, bu.	22.5	57.6	35.1	24.58
1912	Corn, bu.	47.9	74.5	26.6	9.30
1913	Corn, bu.	30.0	44.1	14.1	4.93
1914	Oats, bu.	40.6	45.0	4.4	1.23
1915	Soybeans, bu.	0	0	0	0
1916	Wheat, bu.	15.8	38.8	23.0	16.10

Total value of increase in fifteen years . . . $115.95
Total cost of phosphorus in fifteen years . . . 42.00

Net profit in fifteen years . . . $ 73.95

After the first year the phosphorus began to more than pay its annual cost; and during the second five-year period the increase produced by the phosphorus was worth almost as much as the total crops produced on the land not receiving phosphorus. In later years the need of organic manures with phosphorus has become apparent. (See pages 19 to 23 for more complete details.)

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

BULLETINS

No.

76 Alfalfa on Illinois Soil. 1902 (5th edition, 1913)
*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 (See No. 157)
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 (2d 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 (2d edition, 1912)
157 Peaty Swamp Lands; Sand and ''Alkali'' Soils. 1912
177 Radium as a Fertilizer. 1915
181 Soil Moisture and Tillage for Corn. 1915
182 Potassium from the Soil. 1915
190 Soil Bacteria and Phosphates. 1916
193 Summary of Illinois Soil Investigations. 1916
194 A New Limestone Tester. 1917

CIRCULARS

*64 Investigations of Illinois Soils, 1903
*68 Methods of Maintaining the Productive Capacity of Illinois Soils. 1903 (2d edition, 1905)
*70 Infected Alfalfa Soil, 1903
*72 Present Status of Soil Investigation, 1903 (2d edition, 1904)
*82 The Physical Improvement of Soils, 1904 (3d edition, 1912)
86 Science and Sense in the Inoculation of Legumes, 1905 (2d edition, 1913)
*87 Factors in Crop Production; Special Reference to Permanent Agriculture in Illinois. 1905
*96 Soil Improvement for the Illinois Corn Belt. 1905 (2d 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 (2d 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 (3d edition, 1912)
*116 Phosphorus and Humus in Relation to Illinois Soils. 1908
*119 Washing of Soils and Methods of Prevention. 1908 (2d 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 (3d 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 (2d 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 (2d edition, 1912)
155 Plant Food in Relation to Soil Fertility. 1912
*157 Soil Fertility: Illinois Conditions, Needs, and Future Prospects. 1912
165 Shall We Use ''Complete'' Commercial Fertilizers in the Corn Belt? 1912 (4th ed., 1913)
167 The Illinois System of Permanent Fertility. 1913
168 Bread from Stones. 1913
181 How Not to Treat Illinois Soils. 1915
185 A Limestone Tester. 1916
186 I. The Illinois System of Soil Fertility from the Standpoint of the Practical Farmer. II. Phosphates and Honesty. 1916
193 Why Illinois Produces only Half a Crop. 1917

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
6 Knox County Soils. 1913
7 McDonough County Soils. 1913
8 Bond County Soils. 1913
9 Lake County Soils. 1915
10 McLean County Soils. 1915
11 Pike County Soils. 1915
12 Winnebago County Soils. 1916
13 Kankakee County Soils. 1916
14 Tazewell County Soils. 1916
15 Edgar County Soils. 1917
16 Du Page County Soils. 1917
17 Kane County Soils. 1917

*Out of print.

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