

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

SOIL REPORT NO. 16

DU PAGE COUNTY SOILS

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URBANA, ILLINOIS, MAY, 1917

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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.

DU PAGE COUNTY SOILS

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

Du Page county is located in the northeastern part of Illinois, the eastern boundary being from fifteen to twenty miles west of Lake Michigan.

During the Glacial period Du Page county was covered with at least three ice sheets. At that time snow and ice accumulated in the region of Labrador and to the west of Hudson Bay to such an amount that it pushed outward from these centers, especially southward, until a point was reached where the mass melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of material, including clay, silt, sand, gravel, boulders, and even large masses of rock. Many of these materials were carried for hundreds of miles and rubbed against surface rocks or against each other until ground into powder. When, thru the melting of the ice, the limit of advance was reached, the material carried by the glacier accumulated in a broad undulating ridge, or moraine. When the ice melted more rapidly than the glacier advanced, the terminus of the glacier would recede and the material would be deposited somewhat irregularly over the area previously covered. The glacier receded and advanced a number of times, and with each advance another moraine was formed. The intermorainal tracts are now occupied chiefly by level, undulating, or slightly rolling plains.

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were torn from their lodging places by the enormous denuding power of the ice sheet, and ground up together. A pressure of forty pounds per square inch is exerted by a mass of ice one hundred feet thick, and these ice sheets may have been hundreds or even thousands of feet in thickness. The material carried along in the ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Preglacial ridges and hills were rubbed down, valleys were filled with the debris, and the surface features were changed entirely. The mixture of material deposited by the glacier is known as boulder clay, till, glacial drift, or simply drift.

The first ice advance that covered Du Page county was the Illinois glacial lobe, which covered the state with the exception of Jo Daviess county in the northwest corner, Calhoun county and some of Pike county between the Illinois and Mississippi rivers, and the seven southern counties. (See state map in Bulletin 193.) The second advance was the Early Wisconsin glacier, which covered the northeastern third of the state. The third advance was the Late Wisconsin glacier, which extended only about 30 miles west of Lake Michigan but to a greater distance to the south.

Du Page county is located entirely within the late Wisconsin glaciation, the eastern two-thirds being occupied by the Valparaiso morainic system. This moraine divides in the northeastern part of the county, producing a small intermorainal tract extending from north of Itasca to south of Elmhurst. A large intermorainal area separates the Valparaiso system from Minooka Ridge, which extends along the western boundary of the county:

PHYSIOGRAPHY AND DRAINAGE

The county varies in topography from rolling to slightly undulating. The principal variations are due to the irregular deposition of glacial material, which varies from only a few feet in depth to a maximum of more than 160 feet, with an average, as given by Leverett, of 100 feet. The morainic areas are characterized by a peculiar billowy appearance produced by the large numbers of rounded knobs and kettle-holes, or basin-like depressions, that vary in depth from two or three feet to 50 feet or more and in diameter from a few rods to 20 rods. A few lakes are found, the largest of which does not cover a greater area than 20 acres. Many swamps exist that undoubtedly represent former lakes. The only area where rock outcrop occurs is along the Des Plaines river in the southern part of the county. Erosion topography is found in limited areas in the southern part along the Des Plaines river, in the southeastern part of Township 39 North, Range 11 East, and along the east branch of the Du Page river in Township 38 North, Range 10 East.

With the exception of a small area along the western side, the entire county is drained by the branches of the Du Page and Des Plaines rivers. The extreme western part drains into the Fox river. There are about fifteen small lakes in the county and hundreds of swamps, large and small, indicating a very poorly developed system of natural drainage. Practically all of the black mixed loam (1450) was originally swampy. The small kettle-holes are difficult to drain in the usual way by means of tile. The vertical system of drainage may be used satisfactorily in many of these, the better since the glacial drift in this county has many strata of sand and gravel, and by forming a passageway in the bottom of these ponds to the gravel bed, the water will find its way out.

The altitudes of some places in Du Page county are as follows: Bensenville, 681 feet; Clarendon Hills, 730; Cloverdale, 763; Downers Grove, 717; Elmhurst, 681; Frontenac, 709; Granger, 771; Hinsdale, 691; Itasca, 695; Lisle, 684; Lombard, 727; Naperville, 693; Ontarioville, 815; Roselle, 772; Wayne, 760; Wheaton, 753; Winfield, 726; West Chicago, 784.

SOIL MATERIALS AND SOIL TYPES

The Lake Michigan glacier left a deposit of boulder clay (a mixture of boulders, sand, silt, and clay) which has been transformed into soil in some places, but the larger part of the county subsequently received a shallow deposit of 12 to 40 inches of loessial material formed from the fine rock flour produced by the grinding action of the glacier. This has been reworked by the wind and water and now covers the level and less rolling areas to an average depth of 12 to 24 inches. Beneath this stratum is found the regular boulder clay of the drift, the surface of which frequently contains considerable numbers of small gravel,

indicating the washing out of some of the fine material before the deposition of the loess.

~~The soils of Du Page county have a varied character as a result of the large number of swamps that existed before artificial drainage was introduced. The swampy conditions gave rise to the accumulation of large amounts of organic matter, rendering the soil of these areas very different from that of the higher and more rolling land. The rivers usually flow in broad swampy bottom lands, and low gravel terraces frequently occur, more particularly along the east branch of the Du Page river. As a rule, the comparatively level areas contain a much deeper deposit of loessial material than the more rolling upland, and in many places the glacial drift constitutes the material from which the soil was formed, the loess having been removed by erosion.~~

The soils of Du Page county are divided into the following classes:

(a) Upland prairie soils, rich in organic matter. These were originally covered with prairie grasses, the partly decayed roots of which have been the source of the organic matter.

(b) Upland timber soils, including a large part of the upland that was formerly covered with forests.

(c) Terrace soils, which include bench lands or second bottom lands, formed by deposition from overloaded streams during the melting of the glacier and subsequently.

(d) Late swamp and bottom-land soils, which include the overflow lands or flood plains of streams and the very poorly drained lowlands where peats, peaty loams, and mucks have been formed.

(e) Miscellaneous.

Table 1 shows the area of each type of soil in Du Page county in square miles and in acres, and its percentage of the total area. The accompanying map shows the location and boundary lines of the various types, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN DU PAGE 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,

¹For 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.

TABLE 1.—SOIL TYPES OF DU PAGE COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area				
(a) Upland Prairie Soils (page 26)								
1026	Brown silt loam	196.01	125 446	59.95				
1226								
1020					Black clay loam29	186	.09
1220								
1028								
1228	Brown-gray silt loam on tight clay.....	.08	51	.03				
1260								
1090	Brown sandy loam .....	.04	26	.01			
1290								
	Gravelly loam .....	.20	128	.06			
(b) Upland Timber Soils (page 28)								
1034	Yellow-gray silt loam	67.51	43 206	20.65				
1234								
1035	Yellow silt loam	7.57	4 845	2.32				
1235								
(c) Terrace Soils (page 35)								
1527	Brown silt loam over gravel ¹	2.78	1 779	.85				
1526.4	Brown silt loam on gravel ¹.....	.47	301	.14			
1536	Yellow-gray silt loam over gravel ¹.....	.97	621	.30			
1534.2	Yellow-gray silt loam on gravel ¹.....	.07	45	.02			
(d) Late Swamp and Bottom-Land Soils (page 37)								
1401	Deep peat	6.54	4 186	2.00				
1402	Medium peat on clay.....	.50	320	.15				
1450	Black mixed loam	39.26	25 126	12.01				
1450.5	Black mixed loam on rock.....	.05	32	.01				
1454	Mixed loam	3.69	2 362	1.13				
1426.5	Brown silt loam on rock.....	.08	51	.02				
1498	Stony loam .....	.44	282	.13			
(e) Miscellaneous								
99	Rock outcrop .....	.09	58	.03			
	Gravel pits .....	.08	51	.02			
	Quarries .....	.02	13	.01			
	Water .....	.24	154	.07			
	Total	326.98	209 267	100.00				

¹“On” signifies that the gravel is less than 30 inches below the surface; “over,” that it is more than 30 inches.

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

TABLE 2.—FERTILITY IN THE SOILS OF DU PAGE COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil¹ (about 0 to 6 $\frac{2}{3}$ 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									
1026 1226	Brown silt loam.....	60 490	5 180	1 240	39 530	9 690	9 280		80
1020 1220		118 820	11 100	2 360	34 300	16 900	27 720	23 240	
1028 1228	Brown-gray silt loam on tight clay.....	79 600	6 840	1 520	32 020	7 820	9 740		160
1260		Brown sandy loam....	44 040	3 680	1 260	35 840	6 400	7 500	100
1090 1290	Gravelly loam	69 100	3 180	1 540	29 880	59 840	97 260	390 860	
Upland Timber Soils									
1034 1234	Yellow-gray silt loam.	39 440	3 440	1 020	41 440	8 810	8 240		60
1035 1235		Yellow silt loam.....	12 560	1 500	760	53 440	12 380	5 240	420
Terrace Soils									
1527	Brown silt loam over gravel	57 760	4 800	1 280	34 340	8 140	9 520		60
1526.4	Brown silt loam on gravel	58 480	5 020	1 340	33 860	9 760	9 680		60
1536	Yellow-gray silt loam over gravel	39 900	3 580	1 200	36 240	7 500	9 120		20
1534.2	Yellow-gray silt loam on gravel	37 200	3 400	1 420	36 800	7 080	9 040		20
Late Swamp and Bottom-Land Soils									
1401	Deep peat	393 200	27 090	1 030	4 900	3 840	24 320		250
1402	Medium peat on clay.	302 070	24 060	1 260	8 570	7 620	24 400	4 240	
1450	Black mixed loam....	103 050	9 790	2 220	39 840	16 610	24 670	Often	Rarely
1450.5	Black mixed loam on rock	169 080	11 140	1 760	44 580	22 220	21 960		20
1454	Mixed loam	125 100	10 340	2 220	41 060	14 620	18 080		80
1426.5	Brown silt loam on rock	66 700	5 880	1 380	45 640	34 480	54 180	186 280	
1498	Stony loam	52 340	4 500	1 380	36 840	13 940	22 420	42 400	

¹In 1 million pounds of peat (1401 and 1402).

from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

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

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 Du Page county—the plowed soil of an acre about $6\frac{2}{3}$ inches deep. In addition, the table shows the amount of limestone present, if any, or the 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 Du Page 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 ten rotations (40 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 sixteen 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 30 centuries if only the grain is sold, or for 500 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,400 and 600 years for magnesium, and about 9,000 and 200 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 Du Page 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 eighteen times as much nitrogen as yellow silt loam, and about five times as much nitrogen but only one-eighth as much potassium as brown silt loam. The total supply of phosphorus in the surface soil varies from 760 pounds per acre in the yellow silt loam to 2,360

pounds in the black clay loam. The amounts of magnesium and calcium vary from about 4,000 to 5,000 pounds in some types to more than 20,000 pounds in others. Some types contain an abundance of limestone; others are practically neutral or slightly acid; and still others, such as the yellow-gray silt loam and the brown sandy loam, are acid in the surface and more strongly acid in the subsurface but sometimes contain an abundance of limestone in the subsoil. More than 90 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 39,000 pounds of potassium in the plowed soil of the most common prairie, the economic loss in farming such land with some acidity and with only 1,200 pounds of total phosphorus 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 on this most extensive type of soil have already been conducted 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 (Le), 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 I.—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 have been 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 the 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.

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

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						Soil treatment	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			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

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	O.....	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

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

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 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



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

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.

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



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

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.

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 phosphate¹ 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

¹During 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 5.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 100
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn	Corn	Oats	Wheat	Clover	Corn	Oats	Clover	Wheat ²	Corn	Oats	Soybeans	Value 1st four years		Value 2d four years		Value 3d four years		Wheat
		1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1914	Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices	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 6.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 200
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Oats	Oats	Wheat	Clover	Corn	Oats	Wheat	Wheat ²	Corn	Oats	Soybeans	Wheat	Value 1st four years		Value 2d four years		Value 3d four years		Corn
		1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1914	Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
		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

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

²From 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.

Series 200 and in 1915 on Series 100. As an average of the results 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 5 and 6, 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. See discussion under *Black Clay Loam*, page 27.)

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 7 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 7 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 in addition to the increase by lime, but with nitrogen it has produced \$69.47 above the

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn	Corn	Oats	Wheat	Corn	Corn	Oats	Wheat	Corn	Corn	Oats	Wheat
		1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	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

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

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 8 and 9, 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 8 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

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



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

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 percent 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 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

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

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

Plot	Soil treatment applied ¹	Corn	Corn	Oats	Wheat	Clover	Corn	Corn	Oats	Clover	Wheat	Corn	Corn	Oats	Soy-beans ⁴	Wheat
		1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	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	-0.7	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	-4.6	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

¹Commercial nitrogen was used from 1902 to 1905, after which crop residues were substituted.

²For clover the figures indicate tons per acre, except where in parentheses, in which case they indicate bushels of seed.

³Clover smothered by previous wheat crop.

⁴The soybeans in 1915 were entirely destroyed by hail. Nothing was harvested and the residue was plowed under on all plots.

TABLE 9.—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 <i>residues</i> and phosphorus over phosphorus.....	-.61	-.86
For <i>phosphorus</i> and residues over residues.....	104.57	149.39
For <i>potassium</i> , residues, and phosphorus over residues and phosphorus.....	1.96	2.80

¹Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at \$7 a ton.

²Wheat at \$1 a bushel, corn at 50 cents, oats at 40 cents, hay at \$10 a ton.

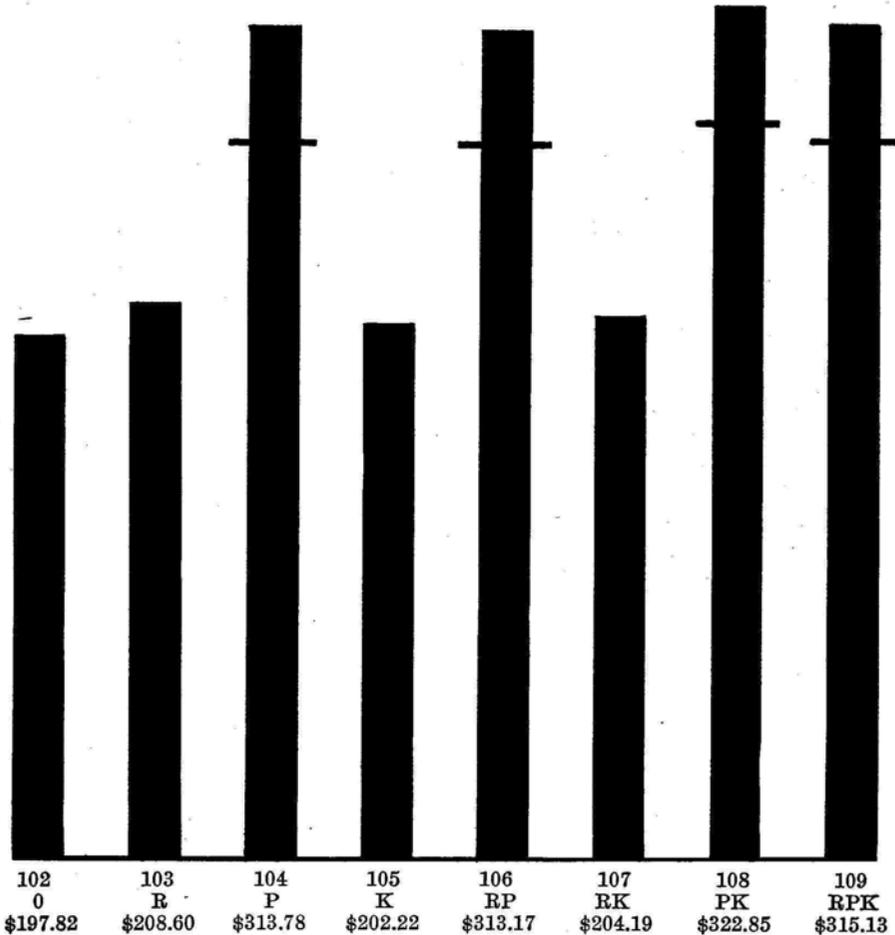


PLATE 6.—CROP VALUES FOR FIFTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD (R=residues; P=phosphorus; K=potassium, or kalium)

phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910 whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. 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 inter-urban 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 10, 11, and 12 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 enrichment by applying 500 pounds a year for several rotations. Even at this rate, the

TABLE 10.—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

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

TABLE 11.—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	

¹Manure applied for corn only (Series 500).

TABLE 12.—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	(.82)	6.0	(.33)	73.3	2.16	54.37	77.67
6	R.....	18.9	(.79)	9.9	(.42)	71.1	2.23	57.53	82.19
7	RL.....	21.6	(.89)	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	

¹Manure 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.

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 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

TABLE 13.—FERTILITY IN THE SOILS OF DU PAGE COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface soil¹ (about 6½ 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									
1026 } 1226 }	Brown silt loam..	61 020	5 740	1 850	83 070	26 040	16 300		200
1020 } 1220 }	Black clay loam	54 160	6 080	2 920	75 080	35 400	40 200	55 440	
1028 } 1228 }	Brown-gray silt loam on tight clay	68 040	3 880	1 840	77 280	17 640	18 400		80
1260	Brown sandy loam	38 120	3 280	1 600	76 040	17 480	14 000		1 200
Upland Timber Soils									
1034 } 1234 }	Yellow-gray silt loam	27 690	3 350	1 390	97 830	31 860	14 310		380
1035 } 1235 }	Yellow silt loam	15 680	2 280	1 640	122 800	48 720	26 720	62 080	
Terrace Soils									
1527	Brown silt loam over gravel ...	64 240	5 720	1 960	73 000	20 680	16 920		80
1526.4	Brown silt loam on gravel	51 080	4 840	1 920	71 440	24 360	16 920		160
1536	Yellow-gray silt loam over gravel	30 880	3 200	1 760	75 760	23 400	15 560		80
1534.2	Yellow-gray silt loam on gravel	36 280	3 520	2 280	77 840	18 520	15 080		40
Late Swamp and Bottom-Land Soils									
1401	Deep peat	748 440	45 760	1 400	11 580	9 520	57 220		400
1402	Medium peat on clay	179 840	15 360	1 400	33 980	17 580	29 000	7 060	
1450	Black mixed loam	91 040	8 890	2 920	85 760	35 550	35 360	Often	Rarely
1450.5	Black mixed loam on rock..	284 720	14 080	3 360	80 520	48 000	52 640		40
1454	Mixed loam	139 760	10 440	3 120	86 280	30 000	34 640		80
1426.5	Brown silt loam on rock	175 400	18 720	3 080	88 800	58 360	79 880	203 720	

¹In 2 million pounds of peat (1401).

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.

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 13 and 14 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Du Page 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

TABLE 14.—FERTILITY IN THE SOILS OF DU PAGE COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil¹ (about 20–40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Lime-stone present	Soil acidity present
Upland Prairie Soils									
1026 } 1226 }	Brown silt loam	34 000	3 850	2 360	141 770	83 080	85 210	Often	Rarely
1020 } 1220 }	Black clay loam	22 500	3 180	3 960	123 300	49 260	49 680	30 720	
1028 } 1228 }	Brown-gray silt loam on tight clay	26 280	4 380	3 420	113 940	49 800	40 440		60
1260	Brown sandy loam	28 500	2 700	1 980	121 260	46 560	42 000	106 680	
Upland Timber Soils									
1034 } 1234 }	Yellow-gray silt loam	29 060	3 680	2 550	160 740	102 930	124 850	429 210	
1035 } 1235 }	Yellow silt loam	22 680	2 640	2 580	166 200	134 940	168 360	677 700	
Terrace Soils									
1527	Brown silt loam over gravel . . .	53 460	5 880	2 880	110 460	54 300	34 020	34 560	
1536	Yellow-gray silt loam over gravel	40 920	4 680	2 880	105 300	117 960	145 200	565 980	
Late Swamp and Bottom-Land Soils									
1401	Deep peat	1093 440	62 580	1 170	24 780	12 420	44 580		540
1402	Medium peat on clay	79 080	5 700	3 420	118 140	157 980	281 520	1 013 940	
1450	Black mixed loam	25 360	3 640	3 820	137 880	84 400	91 680	Often	Rarely
1454	Mixed loam	106 500	7 020	3 720	137 400	50 460	45 720		60

¹In 3 million pounds of deep peat (1401).

most common upland soils are acid in the surface and subsurface and sometimes contain no limestone in the subsoil. These tables also show the presence in the soil of great stores of potassium and only limited amounts of phosphorus—a condition which agrees with the data for the surface stratum shown in Table 2.

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of Du Page county cover 196.62 square miles or 60.14 percent of the entire county. They are usually quite dark in color owing to their large organic-matter content. They occupy the less rolling and comparatively level, but not swampy, land.

Brown Silt Loam (1026 and 1226)

Brown silt loam is the most important as well as the most extensive type in Du Page county, covering an area of 196.01 square miles (125,446 acres), or 59.95 percent of the area of the county. It occupies much of the less rolling land, a considerable portion of which needs artificial drainage. The presence of kettle-holes in some places makes complete drainage rather difficult, and small ponds are frequently found. Many local areas of yellow-gray silt loam, sandy loam, gravelly loam, and peat, too small to be shown on the map, are interspersed.

The surface soil, 0 to 6 $\frac{2}{3}$ 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. The clay content as well as the organic-matter content increases as the type approaches the black mixed loam (1450) of the swampy areas.

This type is divided into two phases, the morainal (1026) and the intermorainal (1226), differing chiefly in topography and in organic-matter content. The morainal phase is generally decidedly more rolling than the intermorainal and contains less organic matter. The average amount of organic matter in the surface soil of the morainal phase is 5 percent, or 50 tons per acre, while the intermorainal phase contains 5.6 percent, or 56 tons per acre.

Where the type passes into yellow-gray silt loam, it is much more variable. The slightly higher points, usually not more than a fraction of an acre in extent, may be decidedly gray or yellow, while the lower adjoining parts may be quite dark, even black, thus giving extreme variations of brown silt loam impossible to indicate on the map.

The subsurface is represented by a stratum varying from 6 inches to 20 inches in thickness. This variation is due to changing topography and to erosion, the stratum becoming thinner on the more rolling areas. Less organic matter has accumulated on the more rolling areas than on the more nearly level tracts, and to a less depth. In physical composition the subsurface varies the same as the surface soil, but it normally contains a slightly larger amount of clay and a considerably smaller amount of organic matter. The organic matter in the intermorainal phase averages 2.9 percent, or 58 tons per acre, and in the morainal phase 2.4 percent, or 48 tons per acre. In color the subsurface varies from a dark brown to a light yellowish brown, becoming lighter with depth.

The natural subsoil begins 12 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 of glacial drift. In some of the flat areas where material has washed in from the higher surrounding parts, the subsoil to a depth of 40 inches does not reach the drift. In some places the stratum of glacial gravel beneath the loessial material interferes with the collecting of samples.

Altho brown silt loam is fairly well supplied with organic matter, yet continuous cropping, with the removal of practically all of the crop residues, will gradually reduce the amount until it becomes seriously deficient. On many farms or many parts of farms this condition has already been brought about.

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; and in livestock farming the manure should be applied to the soil as soon as possible after it is produced, in order to avoid loss. Limestone and phosphorus should also 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.

Black Clay Loam (1020 and 1220)

Black clay loam occupies only a few small areas aggregating 186 acres, or .09 percent of the area of the county.

The surface soil, 0 to $6\frac{2}{3}$ inches, consists of a black clay loam varying toward a dark brown silt loam. It contains an average of 10.2 percent of organic matter, or 102 tons per acre.

The subsurface is represented by a stratum of black clay loam about 16 inches thick, which becomes yellow or drabbish yellow with depth. It contains 4.7 percent of organic matter, which is equivalent to 94 tons per acre.

The subsoil consists of a yellowish or drabbish yellow, pervious, silty clay or clayey silt, that drains readily. ~~In some places limestone gravel is present.~~

Better drainage is needed in places, but the type commonly contains plenty of lime and is well supplied with all the elements of fertility. The addition of moderate amounts of decaying organic matter is necessary in order to provide for the liberation of sufficient plant food for crop needs; and ultimately, of course, phosphorus must be added to maintain high production.

Brown-Gray Silt Loam on Tight Clay (1028 and 1228)

Brown-gray silt loam on tight clay comprizes only a few small areas which total 51 acres.

The surface soil is a brown or dark brown silt loam containing approximately 6.8 percent of organic matter, or 68 tons per acre.

The subsurface soon passes into a gray silty stratum much lower in organic matter; the average content for the subsurface is 2.9 percent.

The subsoil begins at a depth of approximately 16 inches and consists of a tight, tough, waxy clay, yellowish or mottled grayish yellow in color. This tight stratum varies somewhat in thickness but averages from 12 to 15 inches and is underlain by a more pervious stratum.

Drainage is the first requirement of this type, the tight clay making natural drainage somewhat difficult. As a means for breaking up the tight clay, deep-rooting crops are helpful. The soil is acid; and to encourage the growth of clover 3 or 4 tons of ground limestone should be applied. The addition of phosphorus is also essential for the highest improvement and the maintenance of fertility.

Brown Sandy Loam (1260)

Brown sandy loam occupies only 26 acres in Du Page county.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, consists of a brown sandy loam varying from a light or yellowish brown to a dark brown or even black. The organic-matter content is 3.8 percent, or 38 tons per acre. The area is extremely variable and includes a very small portion of dune sand too small to be shown on the map.

The subsurface varies from a brown or a yellowish sandy loam to a sand.

The subsoil is generally yellow sand but grades to a much coarser texture.

This type requires the application of considerable amounts of organic matter for its improvement. Being well aerated, it suffers from loss of that constituent; hence great difficulty is found in maintaining the necessary supply. Crop residues, legume crops, and manure must constitute the 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; but, 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.

Gravelly Loam (1090 and 1290)

Gravelly loam covers 128 acres. It is found in nearly all of the morainal areas to a greater or less extent.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a brown gravelly loam containing about 6 percent of organic matter. Where this type occurs in large areas, it usually contains too much gravel to be cultivated. Occasionally small stones two or three inches in diameter are present.

The subsurface and subsoil are gravel mixed with some sand and a few stones.

This type is used only for pasture, and it is not very good for that purpose except in seasons of abundant rainfall.

(b) UPLAND TIMBER SOILS

The upland timber 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 amounts of humus-forming roots, do not grow to any extent. At the same time, the organic matter that had accumulated before the timber began growing is removed thru various decomposition processes, with the result that in these soils the content has become too low for best growth of farm crops.

Yellow-Gray Silt Loam (1034 and 1234)

Yellow-gray silt loam in Du Page county is next in extent to brown silt loam. It is very irregularly distributed, and occupies mostly the rolling morainal

areas and those bordering the larger streams. The type covers 67.51 square miles (43,206 acres), or 20.65 percent of the area of the county. It varies greatly in topography from the characteristic billowy or knob-and-basin features of the moraines to the almost level intermorainal tracts. Probably 50 percent is still in timber but furnishes fair pasture.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a gray, yellowish gray, or brownish yellow silt loam, incoherent and mealy but not granular. It varies greatly in physical composition owing to the fact that in some places erosion has removed the thin covering of loess, thus exposing the variable drift. 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 (1450), are found in the slight depressions. The organic matter in the surface soil averages 3.4 percent. Of the two phases, the morainal and the intermorainal, the former contains an average of 2.7 percent of organic matter, while the latter contains 4 percent. With the relation of the type to other types, the organic-matter content varies, increasing where the type grades into brown silt loam and decreasing where it grades toward yellow silt loam. In some places erosion has reduced the content of organic matter much below the normal, so that many small areas are yellow in color.

The subsurface stratum varies from 3 to 10 inches in thickness, being thinner on the more rolling areas. In color it is gray, grayish yellow or yellow, somewhat pulverulent, but becoming more coherent and plastic with depth. The amount of organic matter is low, averaging only 1.2 percent, or 24 tons per acre.

The subsoil is a yellow to grayish yellow boulder clay. The deeper subsoil contains considerable amounts of limestone, and frequently 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 yellow-gray silt loam than with brown silt loam, because yellow-gray silt loam is naturally much more deficient in that 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 cor-

TABLE 15.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD
YELLOW-GRAY SILT LOAM, UNDULATING TIMBERLAND; LATE WISCONSIN GLACIATION

Plot	Soil treatment applied ¹	Corn	Corn	Oats	Wheat	Corn	Corn	Oats	Wheat	Corn	Corn	Oats	Clover	Wheat	Corn	Oats
		1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1812	1913	1914	1915 ⁴	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	(*)	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	(*)	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	(*)	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	(*)	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	(*)	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

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

TABLE 16.—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

¹Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at \$7 a ton.

²Wheat at \$1 a bushel, corn at 50 cents, oats at 40 cents, hay at \$10 a ton.

responding 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 15 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 Silt Loam (1035 and 1235)

Yellow silt loam is distributed somewhat irregularly thruout Du Page county, but it occurs most abundantly along the Des Plaines river and the east branch of the Du Page river. It covers 7.57 square miles (4,845 acres), or 2.32 percent of the area of the county. The larger part of this type has been produced by erosion, but a part is also due to the piling up of the material of the moraines into steep hills or ridges. Kettle-holes are very frequently found.

The surface soil is a yellow or yellowish gray silt loam. This stratum may consist of a thin layer of loessial material, altho it is oftener formed from boulder clay. The organic matter content is about 1.1 percent, or 11 tons per acre, which is about the same as the subsurface of yellow-gray silt loam.

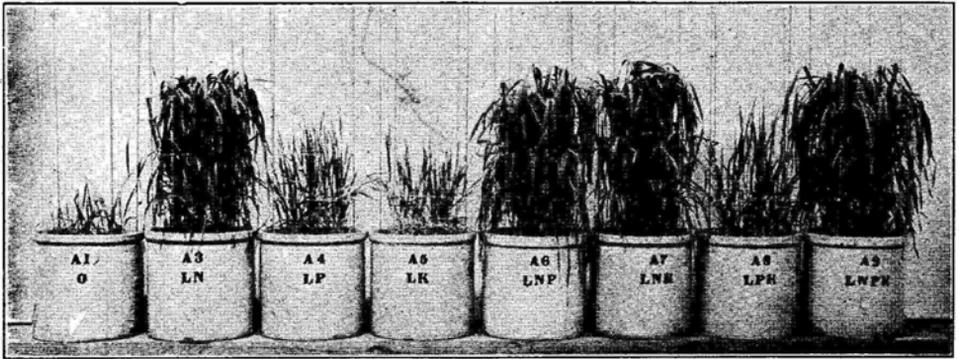


PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 17)

TABLE 17.—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

The subsurface stratum varies from 4 to 12 inches in thickness and contains about .7 percent of organic matter, or 14 tons per acre. It usually consists of a yellow or grayish yellow material containing more or less sand and gravel.

The subsoil is composed of yellow boulder clay.

The soil of this type runs together badly, and is otherwise in poor physical condition. An increase in the organic matter will not only supply nitrogen but will lessen the washing and give better tilth.

One of the best uses to which this type may 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 17 and 18, and shown photographically in Plates 7 and 8.



PLATE 8.—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 AND NITROGEN-FIXING GREEN MANURE CROPS
(Grams per pot)

Pot No.	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

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 17.

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.

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, cow-peas, and soybeans are not only worth raising for their own sake, but they have

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

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 18.

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 17 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.

(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 and carried large amounts of coarse material such as sand and gravel. The over-loaded streams deposited the debris along their courses, and in this way terraces, bench lands, or second bottom lands were formed. Finer material later deposited over this sand and gravel constitutes the present soil.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel occurs principally along the east branch of the Du Page river. It comprizes 2.78 square miles (1,779 acres), or .85 percent of the area of the county. The deposit of gravel is not buried very deeply, and hence furnishes a very effective means for natural drainage, provided there is a natural outlet.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a mealy brown silt loam with some sand, tho it rarely contains enough sand to be classed as a sandy loam. The organic-matter content averages about 5 percent, or 50 tons per acre.

The subsurface soil consists of a brown silt loam that becomes yellow at a depth of about 16 inches and passes into the subsoil at about 20 inches.

The subsurface stratum contains 2.8 percent of organic matter, or 56 tons per acre. It is somewhat sandy below 14 inches.

The subsoil varies greatly. In some places it contains a large amount of sand and fine gravel; in other places the material is coarser. The depth to gravel varies from 30 to 50 inches. Above the gravel, the subsoil is generally a yellow clayey silt, pervious and well drained.

This type requires practically the same management as brown silt loam, except that the addition of phosphorus is not of such immediate importance, because of the greater porosity of the lower strata. Alfalfa should do well where the soil is well drained and well provided with limestone.

Brown Silt Loam on Gravel (1526.4)

Brown silt loam on gravel occurs in small areas along a few of the streams, but it is found principally in the southern part of the county along the Des Plaines river. It lies slightly higher than the general level of the terrace. The type covers a total of 301 acres.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown to dark brown, loose, friable silt loam containing some sand. The organic-matter content is rather high, averaging 5 percent, or 50 tons per acre. The amount of sand varies with the depth to gravel.

The subsurface consists of a light brown silt loam which becomes lighter with depth and passes at 14 to 16 inches into a yellow, slightly clayey silt. It contains about 2.2 percent of organic matter, or 44 tons per acre.

The subsoil is made up of a somewhat sandy gravel, which it was impossible to sample with an auger. Altho gravel usually occurs at a depth of 20 to 24 inches, in some places the stratum is deeper or shallower. The top part of the gravel subsoil usually consists of coarse sand and fine gravel. Coarse gravel is apt to occur at a depth of about 40 inches, altho this is not uniformly true.

This type requires the same treatment as brown silt loam over gravel.

Yellow-Gray Silt Loam over Gravel (1536)

Yellow-gray silt loam over gravel occurs principally along the east branch of the Du Page river in the southern part of the county. It comprizes 621 acres, or .30 percent of the area of the county.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, consists of a yellow gray to brownish yellow, mealy silt loam, containing 3.4 percent of organic matter, or 34 tons per acre. The type is rather uniform in color, but varies somewhat in physical composition, in some places containing considerable amounts of sand.

The subsurface soil is a yellow or grayish yellow silt loam containing 1.3 percent of organic matter, or 26 tons per acre. The lower part of the subsurface becomes slightly heavier and more yellow than the upper part, but there is no very distinct line between the subsurface and subsoil.

The subsoil consists of a yellow silty clay containing some sand. Coarse gravel usually occurs at a depth of about 40 inches.

This type is generally well drained. Methods for improvement are the same as for yellow-gray silt loam (1034 and 1234) except that the application of phosphorus is not so necessary for a time.

Yellow-Gray Silt Loam on Gravel (1534.2)

Yellow-gray silt loam on gravel is represented by a few small areas along the east branch of the Du Page river. The type covers a total of only 45 acres.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a yellow-gray silt loam with some sand. It contains 3.2 percent of organic matter, or 32 tons per acre.

The subsurface is lighter in color than the surface soil, being a yellow silt loam. It contains 1.6 percent of organic matter, or about half as much as the surface soil. At a depth of 14 inches it becomes more clayey.

The subsoil is made up of a yellow, sandy, silty clay. The gravel appears at a depth of about 24 inches and is so coarse that it was impossible to collect a sample with the auger.

Soil treatment should be the same as for the preceding type, yellow-gray silt loam over gravel.

(d) LATE SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat is found scattered over all of Du Page county, but generally not in large areas. It occurs principally in the kettle-holes and as small areas along bottom lands. The total area is 6.54 square miles (4,186 acres), or 2 percent of the area of the county.

The surface soil, 0 to 6 $\frac{2}{3}$ inches, is a black or brown peat, more or less decomposed. The drained areas have undergone greater decomposition because of better aeration, while the moss or grass-covered peat of the undrained areas has changed but little. Organic matter is the chief constituent.

The subsurface soil, 6 $\frac{2}{3}$ to 20 inches, consists of black or brown peat which usually shows the texture of the material from which it was derived.

The subsoil, 20 to 40 inches, is usually a brown peat, altho in some areas the mineral soil constituents may form the lower part of the subsoil. This mineral material is almost invariably drab in color owing to deoxidation by organic acids.

Because of lack of drainage, this type of soil in Du Page county has not been cultivated to a large extent. It is used mostly for pasture, and probably this is the best use to which it can be put. Tile drainage is not usually satisfactory because the soft peat soon permits the tile to get out of line and this seriously

TABLE 19.—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

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

interferes with drainage. These soils frequently contain alkali that irritates the skin. The term "itch dirt" is often applied to them. Where thoro drainage can be provided either 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 19 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 acre¹ 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.

The results of the four years' tests, as given in Table 19, 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

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

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.

Medium Peat on Clay (1402)

Medium peat on clay occurs in the low swampy areas where the peat has not developed to a greater thickness than 30 inches. The total area of this type in Du Page county is 320 acres.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a brown or black peat, the amount of decomposition varying with the cultivation and drainage. It is usually slightly lower in organic-matter content than the deep peat.

The subsurface, $6\frac{2}{3}$ inches to the depth of peat, is usually a brownish peat that has not undergone a large amount of decomposition. In the classification used by this station, medium peat extends from 12 to 30 inches in depth, and in most areas the subsurface is taken as extending to the silty, clayey, or sandy layer. This gives a large variation in the thickness of the subsurface, but samples are taken to a depth of 20 inches.

The subsoil consists of a silty clay and almost invariably is of a light drab or bluish color owing to deoxidation of iron by organic acids.

If this soil 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 under *Deep Peat*, and *Black Mixed Loam*.)

Black Mixed Loam (1450)

Black mixed loam occurs in nearly all the poorly drained areas of the county, including sloughs and kettle-holes of the moraines. Many small areas are not listed in this report because they are too small to be shown on the map. The type covers a total of 39.26 square miles (25,126 acres), or 12.01 percent of the area of the county. Boulders are quite common on the surface.

The surface soil, 0 to $6\frac{2}{3}$ inches, is black in color, but varies a great deal in physical composition. It consists of a mixture of peat, peaty loam, silt loam, clay loam, sandy loam, and gravelly loam in areas too small to be mapped. The organic-matter content varies greatly, but averages about 8.3 percent, or 83 tons per acre.

The subsurface soil, $6\frac{2}{3}$ to 20 inches, shows perhaps less tendency toward variation than the surface soil. The color is usually very dark, but becomes drab with depth. There is no very distinct line between the natural subsurface and the subsoil except that of color, and in many places this is very indefinite because of the work of crayfish, whose burrows have been filled with surface soil. The subsurface contains an average of 2.4 percent of organic matter.

The subsoil consists usually of a drab boulder clay that contains large amounts of limestone.

Drainage is the first requirement of black mixed loam. Owing to the deep depressions in which the type sometimes occurs, vertical drainage would be

TABLE 20.—CROP YIELDS IN SOIL EXPERIMENTS, MOMENCE FIELD, 1904 TO 1915

Plot	Soil treatment applied	Corn	Corn	Oats	Clover	Corn	Corn	Oats	Clover	Corn	Corn	Oats	Soybeans	Value of last 8 crops	
		1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	Lower prices ¹	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	35.3	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

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.

TABLE 21.—CROP YIELDS IN SOIL EXPERIMENTS, MOMENCE FIELD, 1904 TO 1915

Plot	Soil treatment applied	Corn	Corn	Oats	Clover	Corn	Corn	Oats	Clover	Corn	Corn	Oats	Soybeans	Value of last 8 crops	
		1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	Lower prices ¹	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.

best for many small areas provided the underlying formation furnishes a natural outlet. Being so variable in composition, it is impossible to recommend any treatment that will always be suitable to this type. Alkali patches are frequently found, and these, together with peaty areas, should have applications of manure or potassium salts. If the land does not produce satisfactory crops where well drained, then the use of these materials should be considered.

In Tables 20 and 21 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 was applied in proportion to the crop yields. Where larger crops were produced, proportionately more manure was subsequently applied; and, consequently, more manure was applied to Series 300 than to Series 200. The phosphorus was 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.

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.

Black Mixed Loam on Rock (1450.5)

Black mixed loam on rock constitutes only one area of 32 acres in the extreme southern part of Du Page county. It is very poorly drained, and the nearness of the rock to the surface would indicate that satisfactory drainage would be practically impossible.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a black loam containing about 14.6 percent of organic matter, or 146 tons per acre. The subsurface, extending from $6\frac{2}{3}$ inches to rock, differs but little from the surface. It contains 12.3 percent of organic matter.

Mixed Loam (1454)

Mixed loam occurs along some of the bottom lands and consists of those areas where considerable deposit is being made. It comprises 3.69 square miles (2,362 acres), or 1.13 percent of the area of the county. As a rule, the type is rather low and poorly drained.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a black loam varying from a sandy loam to a clay loam or peat. It contains about 10.8 percent of organic matter, or 108 tons per acre.

The subsurface soil is a black loam varying in the same way as the surface soil. It contains 6 percent of organic matter, or 120 tons per acre.

The subsoil is a dark drab loam and contains 3 percent of organic matter.

The only important requirement of this type is drainage. Very few attempts, so far, have been made to put it under cultivation, it being devoted mostly to pasture.

Brown Silt Loam on Rock (1426.5)

Brown silt loam on rock occurs in a few small areas in the extreme southern part of Du Page county along the Des Plaines river. It covers a total area of only 51 acres.

The surface soil, 0 to $6\frac{2}{3}$ inches, is a dark brown silt loam that varies slightly because of recent deposits an inch or two in depth. It contains an average of 5.7 percent of organic matter, or 57 tons per acre.

The subsurface, extending from $6\frac{2}{3}$ inches to a depth of 18 to 24 inches, where rock is encountered, is a silt loam as dark or darker than the surface. The amount of organic matter is sometimes even greater than in the surface.

Where protected from overflow, the management of this type should be the same as for brown silt loam.

Stony Loam (1498)

Stony loam covers a very small area (282 acres) in the bottom land of the Des Plaines river, that overflows to the same extent as the ordinary bottom land along that stream. The stones, which consist of boulders of granite and limestone, render the land practically untillable and useless for anything but pasture or timber. At present this area is covered with a growth of forest trees, principally locust and ash.

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 trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of 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

¹25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 32.

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 cow-peas 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 land-owners 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 compost¹ 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

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

^aThese 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 ($\text{CaCO}_3\text{MgCO}_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone (CaCO_3); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or 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 gulying) 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 renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and 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 $6\frac{2}{3}$ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) 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, in-

creased 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 analyses¹ of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for

¹Reported 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 $1\frac{1}{2}$ 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 $5\frac{1}{2}$ 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.

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

- No. BULLETINS
- 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 | 9 Lake County Soils. 1915 |
| 2 Moultrie County Soils. 1911 | 10 McLean County Soils. 1915 |
| 3 Hardin County Soils. 1912 | 11 Pike County Soils. 1915 |
| 4 Sangamon County Soils. 1912 | 12 Winnebago County Soils. 1916 |
| 5 La Salle County Soils. 1913 | 13 Kankakee County Soils. 1916 |
| 6 Knox County Soils. 1913 | 14 Tazewell County Soils. 1916 |
| 7 McDonough County Soils. 1913 | 15 Edgar County Soils. 1917 |
| 8 Bond County Soils. 1913 | 16 Du Page County Soils. 1917 |

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.....	68.1	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 18 to 22 for more complete details.)

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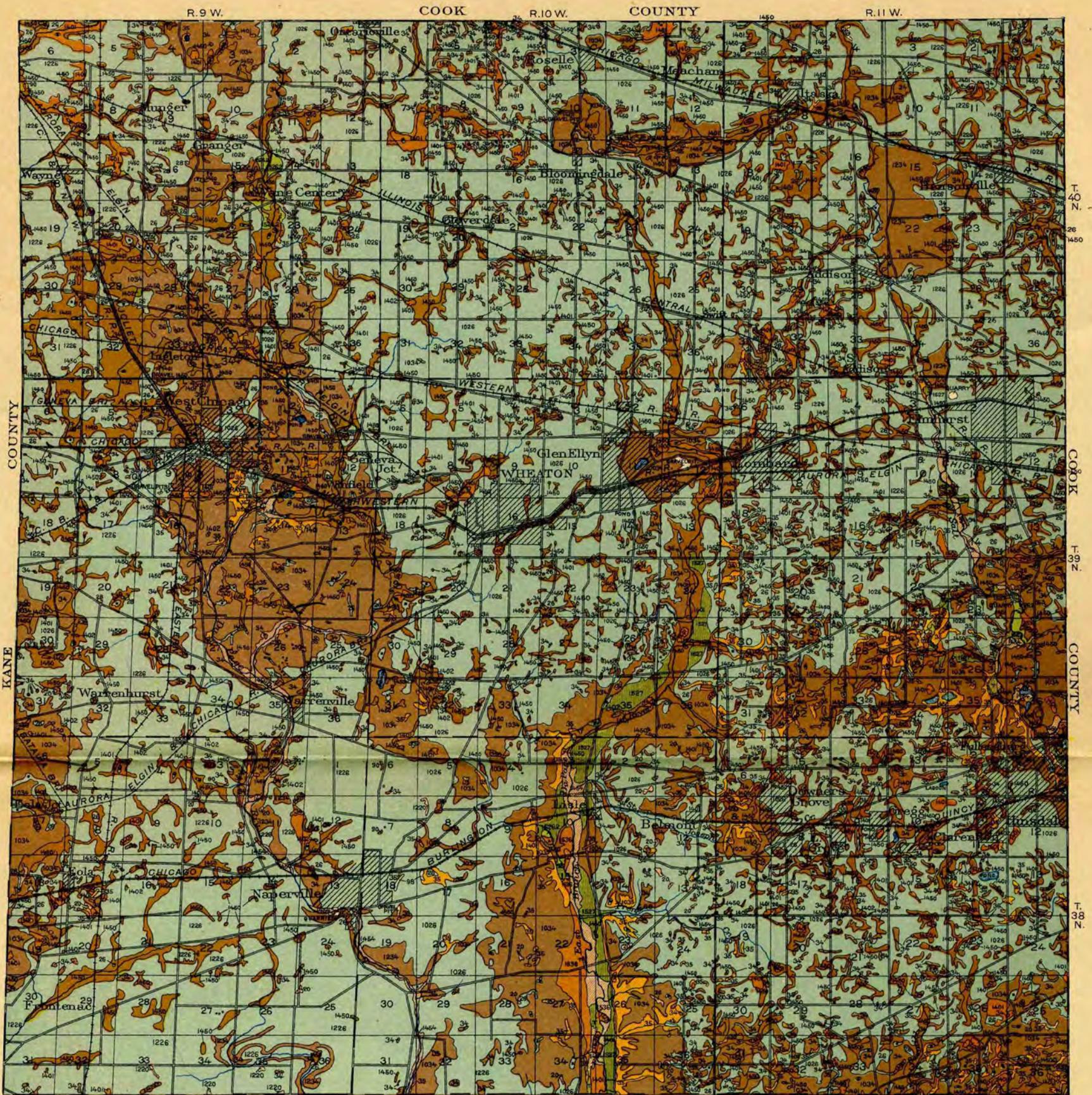
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Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, D.C. 20250-9410;
- (2) fax: (202) 690-7442; or
- (3) email: program.intake@usda.gov.

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- (a) UPLAND PRAIRIE SOILS**
- 1226 Brown silt loam
 - 1228 Black clay loam
 - 1229 Brown-gray silt loam on tight clay
 - 1290 Brown sandy loam
 - 1295 Gravelly loam
- (b) UPLAND TIMBER SOILS**
- 1234 Yellow-gray silt loam
 - 1236 Yellow silt loam
- (c) RESIDUAL SOILS**
- 39 Rock Outcrop
 - Small areas of gravelly loam
 - 1000 Late Wisconsin Moraines
 - 1200 Late Wisconsin Intermoraine areas

LEGEND

- (d) TERRACE SOILS**
- 1427 Brown silt loam over gravel
 - 1522 Brown silt loam on gravel
 - 1536 Yellow-gray silt loam over gravel
 - 1532 Yellow-gray silt loam on gravel
- (e) LATE SWAMP AND BOTTOM LAND SOILS**
- 1401 Deep peat
 - 1402 Medium peat on clay
 - 1450 Black mixed loam
 - 1405 Black mixed loam on rock
 - 1454 Mixed loam
 - 1426.8 Brown silt loam on rock
 - 1468.9 Stony loam

SOIL SURVEY MAP OF DUPAGE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

Scale 0 1/4 1/2 1 2 Miles