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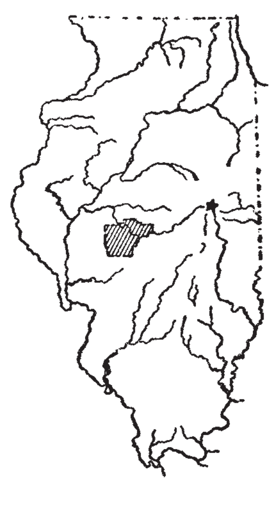
Agricultural Experiment Station

SOIL REPORT NO. 4

SANGAMON COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, AND J. E. READHIMER



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Introduction

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

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

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

Sangamon county is located in the corn belt and almost wholly within the middle Illinois glaciation, the apparent exception being a small area of about two square miles in the southern part, southeast of Auburn, which has soils peculiar to the transition zone between the lower Illinois and middle Illinois glaciations. This is probably the northern terminus of that zone.

The general topography of the county is undulating or slightly rolling. There are, however, some very flat areas, and also belts of very rolling or hilly land along the larger streams, comprising about 6¼ percent of the entire area of the county. The difference in topography is due mainly to two causes, glacial action and stream erosion. Like most of the state, this county was covered by a glacial ice sheet during what is known as the Glacial Period. During this time snow and ice accumulated in the vicinity of Hudson Bay to such an amount that it flowed southward until a point was reached where the ice melted as rapidly as it advanced.

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

The ice made many advances, and with each advance a terminal moraine was formed. This has left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is much less and more gradual.

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

The materials pushed along in this mass of ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which the ice passed. Ridges and hills were rubbed down and valleys filled, and the surface features changed entirely. Occasionally there were hills or ridges sufficiently large or the material composing them was sufficiently resistant to withstand the glacier. In such cases the glacier would flow around or over the obstacle if the ice was thick enough. When the glacier melted, the eminence would be left, in the former case free from drift, while in the latter a thin mantle of drift would cover it. A preglacial ridge in the southwestern part of the county at Lowder, sometimes taken as a glacial moraine, illustrates the latter condition.

A true glacial moraine, called the Buffalo Hart moraine, is located in the eastern part of the county, extending northwest and southeast. It enters from Christian county near Mt. Auburn, extends east of Mechanicsburg, thence to Buffalo, Buffalo Hart, and on to Elkhart in Logan county. The average width is about two miles. It is composed of a large number of more or less prominent knolls varying from 30 to 80 feet above the surrounding country. Among these knolls are shallow basins, giving the ridge a somewhat peculiar "knob-and-basin" topography. Near Buffalo Hart this ridge was partly forested and considerable erosion has occurred, giving rise to about three square miles of yellow and yellow-gray silt loam. (See also State Map in Bulletin 123.)

A deposit of boulder clay covers the entire county to a depth of from 20 to 80 feet, with an average of about 40 feet. The surface left by the glacier was slightly rolling, without very good drainage, but it was later covered by a deposit of loess.

PHYSIOGRAPHY

Sangamon county lies entirely in the drainage basin of the Sangamon river. The highest part of the county is toward the southwest, near Lowder, on the old preglacial ridge somewhat more than 700 feet above sea level. A corresponding high point is found in the northeast, on the Buffalo Hart moraine, that reaches to nearly 700 feet. The average altitude of the county is near 585 feet. The altitude of the Sangamon river where it leaves the county is 512 feet, while at the east side of the county it is 550 feet.

The valley of the Sangamon river is from 50 to 100 feet below the general upland. This has permitted the small streams entering the river to do considerable erosion, and as a result the land adjacent to the bottom land of the larger streams is cut up into hills and valleys unsuited for ordinary agriculture. Forests had extended their way up the streams and were slowly invading the adjoining prairies, before they were put under cultivation. The influence of the prevailing southwesterly wind may be seen in the greater extension of the forests to the north and east of the protecting streams, as shown in the soil types.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered Sangamon county and left a thick mantle of drift, completely burying the old soil that preceded it. After this a long period elapsed during which a deep soil was formed on the Illinois drift, known as the Old Sangamon Soil. Later other ice invasions of Illinois occurred, but they covered only the northern and northeastern parts of the state. (See State Map in Bulletin 123, Iowan and Wisconsin glaciations.) These ice sheets did not reach Sangamon county, but immense quantities of finely ground rock (rock flour) were carried south by the waters from the melting ice and deposited on the flood plains of the large streams, where it was picked up by the wind and carried over and deposited upon the land, burying the glacial material of the Illinois glaciation and the Sangamon soil to a depth of from 5 to 50 feet or more, the deeper deposit being nearer and on the east side of the streams and opposite the greatest width of bottom land. This wind-blown material, called loess, represents a mixture of all kinds of material over which the glacier passed.

Near the Sangamon river three layers of this deposit may be distinguished. The lower one is typical loess, containing shells and lime concretions. Above this is a stratum of sand of varying thickness, which is overlain by a more clayey form of loess that was probably deposited during the Wisconsin glaciation.

The Sangamon soil may sometimes be seen in cuts as a somewhat dark or bluish sticky clay, or as a weathered zone of yellowish or brownish clay.

More recently the wind has blown sand from the flood plains of the large streams onto the adjacent upland, thus giving rise to 10.9 square miles of sandy soils. After the loessial material was deposited over the surface of the country it was mixed with organic matter to a greater or less extent, and thus gradually changed into soil. Surface washing has made additional modifications.

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

It will be noted that more than half of the entire county is covered with the common prairie land, known as brown silt loam, while the black clay loam, sometimes called "black gumbo", occupying the flat upland prairie, is the second most extensive type.

Nearly 12 percent of the county consists of yellow-gray silt loam, the undulating upland soil once covered with timber; and the more rolling yellow silt loam, also timber upland, is about half as extensive.

Six other upland types aggregate only about 3 percent of the county, and nearly 9 percent consists of bottom land.

TABLE 1.—SOIL TYPES OF SANGAMON COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils			
426	Brown silt loam	468.47	299,817	53.87
420	Black clay loam	137.18	87,801	15.77
428	Brown-gray silt loam on tight clay	2.60	1,665	.30
425.1	Black silt loam on clay	10.83	6,928	1.24
	(b) Upland Timber Soils			
434	Yellow-gray silt loam	103.85	66,460	11.93
435	Yellow silt loam	54.23	34,709	6.23
432	Light gray silt loam on tight clay	3.75	2,402	.42
464	Yellow-gray sandy loam	4.64	2,971	.53
465	Yellow sandy loam	4.85	3,102	.55
481	Dune sand	1.43	914	.15
	(c) Bottom Land			
1426	Deep brown silt loam	77.65	49,696	8.93
	Total area	869.48	556,467	100.00

The accompanying maps show the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in the 2 million pounds of the surface soil, corresponding to the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present (if any) or the amount of limestone required to neutralize the acidity existing in the soil.*

THE INVOICE AND INCREASE OF FERTILITY IN SANGAMON COUNTY SOILS

SOIL ANALYSIS

In order to avoid complication and confusion in the practical application of 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. For all practical purposes the average is most trustworthy and sufficient, as will be seen from Bulletin 123, which reports the general soil survey of the state, and in which are reported 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 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, as explained in the Appendix. As there stated, probably no agricultural fact is more generally known by farmers and land-

*The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all samples analyzed, with the single exception of the limestone for three samples of brown silt loam, one each for surface, subsurface, and subsoil. With this exception, no limestone was found in analyzing 51 samples of this soil type; and it seemed unwise to include the abnormal exception in making the averages.

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 the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, and seven from the soil, altho 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 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 not known ever to limit the yield of crops.)

As stated, the data in Table 2 represent the total amounts of plant food found in two million pounds of the surface soil, which corresponds to an acre of soil about 6⅔ inches deep, including at least as much soil as is ordinarily turned with the plow, and representing that part of the soil with which we incorporate the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement. This is the soil stratum upon which we must depend in large part to furnish the necessary plant food for the production of the crops grown, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, but if the fertility of the surface soil is maintained at a high point, then the strong and vigorous plants will have power to secure more plant food from the subsurface and subsoil than would be the case with weak, shallow-rooted plants.

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

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

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

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

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
426	Brown silt loam	51680	4070	1030	34620	7470	9280		50
420	Black clay loam	63570	5040	1330	31870	11090	15990	2850	
428	Brown-gray silt loam on tight clay........	30490	2700	680	35530	5320	8630	350	
425.1	Black silt loam on clay.......	58260	4800	1120	31360	10440	14750	240	
	Upland Timber Soils								
434	Yellow-gray silt loam..	26160	2300	1010	35970	5390	7100		30
435	Yellow silt loam	10240	920	820	40020	7210	6440		470
432	Light gray silt loam on tight clay..........	19040	1880	720	33000	5280	6740		20
464	Yellow-gray sandy loam...	15000	1640	720	36980	6540	5960		40
465	Yellow sandy loam........	11580	1260	620	36640	5020	4240	840	
481	Dune sand.. ..	9140	780	480	23430	3010	4480		20
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam..	51140	4450	1630	41350	10630	11700	700	

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

On the other hand, the potassium is sufficient for 25 centuries if only the grain is sold, or for 425 years even if the total crops were removed and nothing returned. The corresponding figures are about 2,000 and 500 years for magnesium, and about 10,000 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 these elements we must also consider the heavier loss by leaching.

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

The variation among the different soil types with respect to their content of important plant-food elements is also very marked. Thus, the prairie soils contain from three to five times as much nitrogen as the timber lands of the same topography; and the black clay loam, the richest prairie land, contains twice as much phosphorus as the poorest upland soils. (The black clay loam of the middle Illinois glaciation is lower in phosphorus than the corresponding type in the more recent formations, as the early and the late Wisconsin.)

On the other hand, the most significant fact revealed by the investigation of Sangamon county soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than one-half of the entire county. The market value of this land is about $200 an acre, and yet an application of $30 worth of fine-ground raw rock phosphate would double the phosphorus content of the plowed soil. Such an application properly made would also double the yield of clover in the near future; and, if the clover was then returned to the soil either directly or in farm manure, the combined effect of phosphorus and nitrogenous organic matter with a good rotation of crops would in time double the yield of corn on most farms.

The average yield of corn for Sangamon county for the ten years 1902 to 1911 was 40.9 bushels per acre;* yet this county occupies a most favored position in the most southern lobe of the corn belt of the United States. Meanwhile, Boone county, on the Wisconsin line, nearly 200 miles farther north, has averaged 41.5 bushels of corn per acre during the same ten years.

With 4,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 34,000 pounds of potassium in the same soil and with practically no acidity, the economic loss in farming such land with only 1,000 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that the crop yields could be doubled by adding phosphorus,—and without change of seed or season and with very little more work than is now devoted to the fields.

Fortunately, some definite field experiments have already been conducted on this most extensive type of soil in Sangamon county, and also for longer periods on similar soil in several other counties, as at Virginia in Cass county, at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county.

RESULTS OF FIELD EXPERIMENTS AT AUBURN

A field of ten acres of common prairie land was selected on the farm of Mr. B. F. Workman, about five miles west of Auburn, on which experiments were begun in 1905. The field was divided into two series of plots, corn being grown on one series for two years and then on the other series, while the first series grew oats one year and clover the next, thus providing for a four-year rotation of corn, corn, oats, and clover, corn being represented every year, and the oats and clover in alternate years. No experimental data were secured from Series 100 during the first two years, but a crop of cowpeas was grown and plowed under on all plots in that series in 1906.

In Table 3 are recorded the results secured from eight plots in each series, four of these plots having received applications of raw rock phosphate, while the other four received no phosphate, but were otherwise treated the same.

It is of special interest to note that the effect of phosphorus on the corn crop is marked whenever the seasonal conditions are favorable for corn. Thus, when the plots not receiving phosphorus have produced 50 bushels or more per acre, the increase from phosphorus has averaged from 7.8 bushels in 1907 to 11.0 bushels in 1908, and to 16.9 bushels in 1911; but, when certain other factors of influence have held the yield of corn below 50 bushels, phosphorus has produced little or no effect, except for the first year, when the low yield was due to a poor stand of corn and not to adverse weather

*Statistical Report, Illinois State Board of Agriculture, December 1, 1911, page 36.

TABLE 3.—EXPERIMENTS WITH RAW ROCK PHOSPHATE ON BROWN SILT LOAM PRAIRIE, AUBURN FIELD

Crops and yields per acre			Without phosphorus				With phosphorus				Average gain for phosphorus
Series	Year	Plot No.	2	3	4	5	6	7	8	9	
100	1905	No experiment									
200	1905	Corn, bu	41.7	39.3	41.7	42.1	48.1	46.3	48.9	49.7	7.0
100	1906	Cowpeas (turned)									
200	1906	Corn, bu	42.1	40.6	34.9	38.4	42.9	41.3	39.8	37.6	1.4
100	1907	Corn, bu	54.1	61.9	64.5	61.1	68.6	68.1	69.6	66.4	7.8
200	1907	Oats, bu	26.6	26.1	25.9	24.2	35.9	30.5	31.3	36.7	7.9
100	1908	Corn, bu	39.0	51.3	52.6	38.5	54.1	59.2	59.2	53.0	11.0
200	1908	Clover, tons	.91	2.12	1.69	.58	.77	.85	1.98	2.19	.12
100	1909	Oats, bu	48.1	48.4	52.0	43.3	44.7	50.5	55.5	55.8	3.7
200	1909	Corn, bu	43.0	48.3	41.4	32.8	36.2	25.8	39.2	48.5	3.9
100	1910	Clover, tons		2.31	1.76	2.25	3.23		3.06	3.06	1.01
200	1910	Corn, bu	46.0	49.5	45.5	38.6	40.8	44.6	39.9	58.6	1.1
100	1911	Corn, bu	48.2	60.6	40.0	51.0	57.5	76.1	65.9	68.0	16.9
200	1911	Oats, bu	40.6	43.0	43.0	36.6	43.3	45.8	55.0	59.1	10.0

Average gain for phosphorus		
	Corn, bu	5.9
	Oats, bu	7.2
	Clover, tons	.57

The cost of phosphorus per acre per annum is $1.87½; but during the seven years the increase produced has not only more than paid the total cost, but the phosphorus content of the treated land has been increased from about 1000 pounds to 1300 pounds per acre of plowed soil.

conditions. As an average of these four years, phosphorus has increased the yield of corn by 10.7 bushels per acre; but when the poor years are included, the average increase is reduced to 5.9 bushels, this figure representing the average of twenty-eight different comparable tests.

The three crops of oats showed an average increase of 7.2 bushels, and the two clover crops averaged .57 ton more hay on the phosphated land.

On the whole, the data from favorable seasons strongly indicate a cumulative or increasing effect from the phosphate treatment, as we have reason to expect, and as is shown in the latest crops of corn, oats, and clover, the increase amounting to about 25 percent for oats, 34 percent for corn, and 48 percent for clover.

It should be noted that the phosphate has already more than paid its cost; but of equal importance, at least, is the fact that the soil is being positively enriched in that element; and after a few more rotations the amount applied for each year may be very greatly reduced.

On Plots 2, 4, 7, and 9 some cover crop, such as cowpeas or clover, has usually been seeded between the corn rows at the time of the last cultivation. In many cases this has decreased the yield of corn for that year, and the data thus far secured do not justify the practice in central or northern Illinois, especially where oats follow corn.

Since 1908 crop residues, including the corn stalks and oat straw, have been returned to Plots 2 and 7, and the second crop of clover was plowed under in 1908, and all clover except the seed in 1910, on these plots. The results thus far secured are not sufficient to justify drawing conclusions in regard to this practice, but it may be noted that the largest yield of corn during the seven years was on Plot 7 in 1911.

Plots 5 and 6 receive no organic manures; but farm manure has been applied to the clover sod and plowed under for corn, since 1907, on plots 3, 4, 8, and 9, the rate of application being as many tons of fresh manure as the number of tons of air-dry produce from the respective plots. As an average, the manure has increased the yield of corn by 4.6 bushels (1907 to 1911) and the yield of oats by 7.7 bushels (1909 to 1911).

RESULTS OF FIELD EXPERIMENTS AT VIRGINIA

The Virginia experiment field was established in 1902, on a ten-acre tract of land belonging to the farm of Mr. George Conover, about three miles southeast of Virginia, in Cass county, on brown silt loam prairie, somewhat above the average of the type in productive power.

A three-year rotation was begun on three different series of plots in order that each crop might be represented every year. During the first six years corn, oats, and cowpeas were grown, but since 1908 the rotation has been corn, oats, and clover.

As an average of two tests each year, for the first 7 years (1902 to 1908), phosphorus, applied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal, produced increases in yield per acre amounting to 6.8 bushels of corn (from 67.3 to 74.1 bushels); while the average yield of oats was increased by .4 bushel (from 43.9 to 44.3 bushels), and the average yield of hay was increased by only .04 ton (from 2.13 to 2.17 tons per acre).

During the next three years (1909 to 1911) the phosphorus increased the average yields by 10.5 bushels of corn (from 70.2 to 80.7 bushels), by 13.1 bushels of oats (43.3 to 56.4 bushels), and by .69 ton of hay (1.42 to 2.11 tons per acre).

It is of interest to compare the seven years' results at Auburn with the first seven years' results at Virginia, the two fields being on the same soil type in the same soil area. When the Virginia experiments were begun, one ton of steamed bone meal, containing 250 pounds of phosphorus (which is the amount applied to one acre in ten years at Virginia), cost less than $25, but in recent years the price has been advanced to $28 to $30 per ton. Thus, at safe prices for produce, the bone meal fell far short of paying its cost during the first seven years at Virginia, altho it much more than paid for the annual expense during the next three years.

At Auburn two and one-half times as much phosphorus is applied in raw rock phosphate at $7.50 per ton, but the annual cost is only $1.87½ per acre, compared with $2.50 to $3.00 for the bone meal used at Virginia.

On the other hand, the results ultimately secured at Virginia were to be expected, because the chemical analysis of the soil shows that phosphorus is not abundant, and its continued use must finally produce marked increases in crop yields in good systems of farming. The fact is that the first limiting element on the Virginia field was not phosphorus but nitrogen; and, this being the case, no marked effect could be produced by phosphorus until the nitrogen was relatively increased, which has been gradually accomplished by the use of legume crops and farm manure.

In another series of experiments on the Virginia field, commercial nitrogen is applied in a four-year rotation of corn, corn, oats, and wheat. Counting the corn at 35 cents a bushel, oats at 30 cents, and wheat at 70 cents, we find that 100 pounds of nitrogen per acre per annum (in dried blood) produced $42.31 increase in ten years; the yearly addition of 25 pounds of phosphorus in 200 pounds of steamed bone meal raised the increase to $58.96; and 40 pounds of potassium per annum, together with the nitrogen and phosphorus, raised the total increase to $60.67.

If we count the cost at 15 cents a pound for nitrogen, 10 cents a pound for phosphorus, and 6 cents a pound for potassium, we find that for each dollar invested the nitrogen paid back 28 cents, the phosphorus 67 cents, and the potassium 7 cents. As an average of the four years 1908 to 1911, the phosphorus, costing $2.50 per annum, paid back $3.15 under these conditions.

During six of the ten years, corn was grown in both of the rotation systems at Virginia. In the four-year rotation, without legumes or manure, the average yield was 50.4 bushels of corn per acre where lime and bone meal were applied, but, where these materials were applied in the three-year rotation, the six-year average yield of corn was 74.6 bushels in the grain system, with some crop residues plowed under, and 77.0 bushels per acre where farm manure was applied in addition to the lime and phosphorus.

Thus legumes in rotation and some crop residues plowed under in grain farming increased the six-year average yield of corn by 24.2 bushels, and farm manure and legumes in rotation increased the yield by 26.6 bushels; while 100 pounds of commercial nitrogen in about 800 pounds of dried blood, costing $15 to $20 per acre per annum, increased the yield by only 19.5 bushels. (The lime and phosphorus were provided alike on all plots involved in these comparisons.)

At least two very important lessons are taught by these results from the Virginia field: First, when nitrogen has become the limiting element in a soil, nothing else can take its place, and, even tho phosphorus may also be deficient, its addition will not produce marked or profitable results until provision is made to raise the nitrogen limit. Second, the growing of legumes in rotation on the farm and the use of crop residues or farm manure may produce even better results than high-priced commercial nitrogen.

RESULTS OF FIELD EXPERIMENTS AT URBANA

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

As an average of the three years 1902 to 1904, phosphorus increased the crop yield per acre by .68 ton of clover, 8.8 bushels of corn, and 1.9 bushels of oats.

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

During the third course of the rotation, 1908-1910, the average increases produced by phosphorus were 1.05 tons of clover, 18.7 bushels of corn, and 8.4 bushels of oats.

For convenient reference the results are summarized in Table 4.

TABLE 4.—EFFECT OF PHOSPHORUS ON BROWN SILT LOAM AT URBANA
(Average increase per acre)

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

*Prices used are 35 cents a bushel for corn, 30 cents for oats, $6.00 a ton for clover hay, 10 and 3 cents a pound for phosphorus in bone meal and rock phosphate, respectively.

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

Wheat is grown on the University South Farm in a rotation experiment started more recently. As an average of the last four years, 1908-1911, raw rock phosphate (with no previous applications of bone meal) has increased the yield of wheat by 10.3 bushels per acre; and here too the phosphorus has paid back about twice its cost, as an average of the last four years, the cost being $1.87½, and the value of the increase $3.28 per acre per annum, wheat being valued at 70 cents a bushel and other crops as noted above. These are the average results from two systems of farming, one known as grain farming, and the other as live-stock farming.

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

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

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

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

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 5 gives results obtained during the past ten years from the Sibley soil experiment field, located in Ford county on typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting ele-

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

ment of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitrogen without phosphorus produced no increase, but nitrogen and phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appears to have become the most limiting element, the increase in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels of corn. By comparing the corn yields for the four years 1902, 1903, 1906 and 1907, it will be seen that the untreated land has apparently grown less productive, whereas on land receiving both phosphorus and nitrogen the yield has appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of

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

72 bushels, or more than twice as much, was produced where lime, nitrogen, and phosphorus had been applied, altho these two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910, the highest yielding plot exceeded that of 1902, while the untreated land produced less than half as much. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment is seen. Phosphorus appears to have been the first limiting element again in 1909, 1910, and 1911.

In the lower part of Table 5 are shown the total values per acre of the ten crops from each of the ten different plots, the amounts varying from $147.41 to $227.46; also the value of the increase produced above the untreated land, corn being valued at 35 cents a bushel, oats at 30 cents and wheat at 70 cents. Phosphorus without nitrogen produced $27.74 in addition to the increase by lime; and, with nitrogen, phosphorus produced

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

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

VALUE OF CROPS PER ACRE IN TEN YEARS

Plot	Soil treatment applied	Total value of ten crops	Value of increase
101	None	$147.41	
102	Lime	159.07	$11.66
103	Lime, nitrogen	159.83	12.42
104	Lime, phosphorus	186.81	39.40
105	Lime, potassium	148.29	.88
106	Lime, nitrogen, phosphorus	220.49	73.08
107	Lime, nitrogen, potassium	171.51	24.10
108	Lime, phosphorus, potassium	176.46	29.05
109	Lime, nitrogen, phosphorus, potassium	227.46	80.05
110	Nitrogen, phosphorus, potassium	217.31	69.90

$60.66 in addition to the increase by lime and nitrogen. The results show that in 23 cases out of 40 the addition of potassium decreased the crop yields.

By comparing Plots 101 and 102, and also 109 and 110, it will be seen that the average increase by lime was $10.90, or more than $1.00 an acre a year, suggesting that the time is near when limestone must be applied to these brown silt loam soils.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Table 6, giving all of the results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the ten years' work on the Bloomington field tell the same story as those from the Sibley field. The rotations differed by the use of clover and by discontinuing the use of commercial nitrogen, after 1905, on the Bloomington field, in consequence of which phosphorus without commercial nitrogen (Plot 104) produced an even larger increase (80.62) than was produced by phosphorus over nitrogen on the Sibley field (see Plots 103 and 106).

It should be stated that a draw runs near Plot 110 on the Bloomington field and the crops on that plot are sometimes damaged by overflow or imperfect drainage; also that in 1902 the stand of corn on the Bloomington field was poor, tho fairly uniform. Otherwise all results reported in Tables 5 and 6, including 200 tests, are considered reliable, and they furnish much information and instructive comparisons.

Wherever nitrogen was provided, either by direct application or by the use of legume crops, the addition of the element phosphorus produced very marked increases, the average value being $70.64 for the ten years, or $7.06 an acre a year. This is $4.56 above its cost in 200 pounds of steamed bone meal, the form in which is was applied to these 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); and a liberal use of clover or other legumes is suggested as the only practical and profitable method of supplying the nitrogen, the clover 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 best treated plots 140 pounds per acre of phosphorus have been removed from the soil in the ten crops. This is equal to 12 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 80 years they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus was applied, the crops removed only 95 pounds of phosphorus in ten years, equivalent to only 8 percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902). The total phosphorus applied from 1902 to 1911 amounted to 250 pounds per acre.

TABLE 6.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

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

Value of Crops per Acre in Ten Years

Plot	Soil treatment applied	Total value of ten crops	Value of increase
101	None	$147.90	
102	Lime	148.75	$ .85
103	Lime, nitrogen (see text)	151.30	3.40
104	Lime, phosphorus	229.37	81.47
105	Lime, potassium	149.43	1.53
106	Lime, nitrogen, phosphorus	221.30	73.40
107	Lime, nitrogen, potassium	149.96	2.06
108	Lime, phosphorus, potassium	229.20	81.30
109	Lime, nitrogen, phosphorus, potassium	225.57	77.67
110	Nitrogen, phosphorus, potassium	209.26	61.36

*Clover smothered out by previous very heavy wheat crop. After the clover hay was harvested all ten of the plots were seeded to cowpeas and the crop was plowed under later on all plots as green manure for the 1907 corn crop.

†The figures in parentheses represent bushels of clover seed; the others, tons of clover hay (in two cuttings) in 1910.

THE SUBSURFACE AND SUBSOIL

In Tables 7 and 8 are recorded the amounts of plant food in the subsurface and the subsoil, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in Tables 7 and 8 is that the upland timber soils are usually more strongly acid in the subsurface and subsoil than in the surface, thus emphasizing the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during the periods of partial drouth, which are also critical periods in the life of such plants as clover. Thus, while the common brown silt loam prairie soil is practically neutral, the upland soils that are or were timbered are already in need of limestone as a rule; and, as already explained, they are much more deficient in phosphorus and nitrogen than the common prairie.

TABLE 7.—FERTILITY IN THE SOILS OF SANGAMON COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
426	Brown silt loam	69390	5740	1760	68290	17790	17850		100
420	Black clay loam	73730	5980	2070	63730	22830	27060	3260	
428	Brown-gray silt loam on tight clay..........	31680	2760	1120	70660	15180	16880		100
425.1	Black silt loam on clay.......	67660	5540	1780	63500	22140	24800	1760	
	Upland Timber Soils								
434	Yellow-gray silt loam..	16880	2150	1760	73250	14570	12170		390
435	Yellow silt loam	13460	1540	1880	74780	16920	11400		2080
432	Light gray silt loam on tight clay.........	12000	2040	1280	64440	12640	10000		920
464	Yellow - gray sandy loam. .	17880	2000	1760	68480	16560	8920		1760
465	Yellow sandy loam..........	5760	1440	1720	77200	19080	9800		400
481	Dune sand......	5090	690	790	41410	6520	8480		30
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam.........	73870	6640	2450	78730	23110	22350	650	

TABLE 8.—FERTILITY IN THE SOILS OF SANGAMON COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Limestone requir'd
	Upland Prairie Soils								
426	Brown silt loam	39610	4090	2330	99930	38860	29750		180
420	Black clay loam	30710	2990	3070	93620	47060	89180	189150	
428	Brown-gray silt loam on tight clay....	37110	3720	2490	97650	36810	33000		270
425.1	Black silt loam on clay.	28890	3090	2640	96780	39420	41790	30330	
	Upland Timber Soils								
434	Yellow-gray silt loam..........	17860	2750	3120	105970	34220	19130		5990
435	Yellow silt loam	13320	1710	1950	109680	31470	21780		840
432	Light-gray silt loam on tight clay..........	28500	3300	2220	100740	40020	18540		4140
464	Yellow - gray sandy loam...	14520	1920	3000	110640	28680	27060	50220	
465	Yellow sandy loam..........	4980	1920	3060	111900	37560	18660		4680
481	Dune sand......	7640	1040	1190	62110	9780	12720		50
	Swamp and Bottom-Land Soils								
1426	Deep brown silt loam...	58580	5200	2740	116580	32720	30140	1160	

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

This class of soils comprises 619 square miles, or 71 percent of the entire area of the county. They are usually dark in color due to a large organic-matter content.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses whose net work of roots has been protected from complete decay by imperfect aeration, due to the covering of soil and the moisture it contained. The tops have been burned or have almost completely decayed. From a sample of Champaign county virgin sod of "blue stem", one of the most common prairie grasses, it was determined that an acre of this soil contained 13½ tons of roots to a depth of 7 inches. Many of these roots died each year and by partial decay formed the humus of these dark prairie soils. In upland forests no such quantity of roots is found in the surface soil. The vegetable matter consists of leaves and twigs, which fall upon the surface and either are burned by forest fires or undergo complete decay. There is very little chance for these to become mixed with the soil. As a result the organic-matter content has been lowered by the growth of forests until in some parts of the state a low condition of apparent equilibrium has been reached. All of these prairie soils can be improved by phosphorus and organic manures, and limestone is usually needed. The different types differ chiefly in degree of richness, as is seen from Table 2.

Brown Silt Loam (426)

This is the most important as well as the most extensive type of soil in the county, covering an area of 468.47 square miles, equivalent to 299,817 acres, or 53.87 percent of the entire area.

The type is generally sufficiently rolling for fair surface drainage, altho there are some exceptions where the land is so flat as to require artificial drainage. There are many draws or swales, which are frequently "seepy" and should have at least one line of tile to carry off this seepage water. In some cases two lines of tile may be necessary, one on each side. In the morainal regions and along some of the small streams, the brown silt loam is quite rolling, giving a lighter colored and shallower phase of the type.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly drained areas. The physical composition varies to some extent but is normally a silt loam containing from about 70 to 80 percent of the different grades of silt.

The clay content, usually 10 to 12 percent, increases as the type approaches black clay loam (420) and becomes greatest in the poorly drained areas. The sand varies from 7 to 15 percent and increases as the bottom land of the large streams is approached.

The organic matter varies from 3½ to 5 percent, with an average of 4½ percent, or 45 tons per acre. Where the type passes into brown-gray silt loam on tight clay (428), the organic matter becomes lower. The growth of forest trees on the upland in this climate reduces the organic matter and ultimately changes the original brown prairie soil into the yellow-gray silt loam (434). The first trees to invade the dark prairie soils are wild cherry, hackberry, ash, black walnut, and elm. (A black walnut soil is recognized generally by farmers as being one of the best timber soils. It still contains, as a rule, a large amount of the organic matter that accumulated from the prairie grasses.)

The subsurface is represented by a stratum varying from 5 to 14 inches in thickness, the great difference being due to the topography, the stratum being thinner on the more rolling areas and thicker on the level areas. Its physical composition varies in the same way as the surface soil, but generally it contains a slightly larger amount of clay. Locally, the subsurface may become quite heavy, as where the type grades toward the black silt loam on clay. As the type approaches brown-gray silt loam on tight clay (428), the subsurface becomes lighter in color and the upper subsoil becomes heavy or contains more clay.

The color of the subsurface varies from a dark brown or almost black to a light brown or yellowish brown. In general it becomes lighter with depth, passing gradually into the yellow subsoil. The color is due to the organic matter and to the oxidation of the iron.

The organic matter averages 1.8 percent.

The natural subsoil begins at from 12 to 21 inches beneath the surface of the soil and extends to an indefinite depth, but is usually sampled to 40 inches. It varies from a yellow to a drabbish yellow clayey silt. In the more level areas it is of a drab color mottled with yellow blotches, while in the more rolling areas better drainage has allowed better oxidation of the iron to take place, giving the yellow to brownish yellow color. The upper 8 to 12 inches of the subsoil usually contains more clay than the lower part, the coarser material being coarse silt or fine sand.

The subsoil is generally pervious to water, permitting good drainage. Exceptions are found where the type grades toward the brown-gray silt loam on tight clay (428). In this case the subsoil becomes much less pervious, forming rather a poor phase of the type.

While this type is generally in fair physical condition, yet the continuous growing of corn, or corn and oats, with the burning of the stalks and possibly the oat stubble, is destroying the tilth; the soil is becoming more difficult to work, runs together more, and aeration, granulation, absorption, and moisture movement are interfered with. This condition of poor tilth is becoming very serious on many farms and is one of the factors that limit the crop yield.

The remedy is to increase the organic-matter content by plowing under crop residues such as corn stalks, straw, clover, etc., instead of selling them from the farm or burning them, as is often practiced at present. The stalks should be thoroly cut up with a stalk cutter or sharp disk, and turned under. Likewise the straw should be got back onto the land in some practical way, either directly or in manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or in manure, instead of being sold as hay, except where manure can be brought back. The addition of fresh organic matter is of even greater importance because of its nitrogen content, and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the soil and phosphorus from the phosphate contained in or applied to the soil, as seen from the results of experiments on the Virginia field reported above. The addition of limestone to this soil is also becoming important. For permanent maintenance, about 2 tons of limestone and ½ ton of fine-ground rock phosphate should be applied every four or five years, and enough organic matter should be plowed under to furnish the nitrogen required by the crops desired, as shown in Table A of the Appendix. Heavier initial applications of phosphate may well be made.

Black Clay Loam (420)

This type of soil (420) represents the originally swampy and poorly drained areas of the middle Illinois glaciation, and is frequently called "gumbo" because of its sticky character. Its formation in these low places is due to the accumulation of organic matter and the washing in of clay and fine silt from the slightly higher adjoining lands. This type covers 137.18 square miles, equivalent to 87,801 acres, and occupies 15.77 percent of the total area of the county. The topography is so flat that in the larger areas the problem of getting a sufficient outlet for drainage has caused some difficulty.

The surface stratum is a black granular clay loam with from 5 to 6 percent of organic matter. The average is 5.5 percent, or 55 tons per acre. The wet condition of this soil has allowed a greater accumulation of organic matter than on the more rolling areas of brown silt loam (426).

The surface soil is naturally quite granular, and hence pervious to water. This property of granulation is important to all soils, but especially to heavy ones. The soil is kept mellow, and if the granules are destroyed by puddling (as by working or the tramping of stock while the ground is wet), they will be formed again by freezing and thawing or by moisture changes (wetting and drying). These natural agencies produce "slacking", as the process is usually termed. If, however, the organic matter or lime content becomes low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface extends to a depth of from 10 to 16 inches below the surface stratum. It differs from the surface in color, becoming lighter with depth, the lower part of the stratum passing into a drab or yellowish silty clay.

It is quite pervious to water, due to the jointing or checking produced by the shrinkage in times of drouth. The amount of organic matter varies from 2.5 to 4 percent, with an average of 3.1 percent.

The subsoil is usually a drab or dull yellow silty clay, but locally may be a yellow silt or clayey silt. As a rule the iron is not so highly oxidized, due to poor drainage. The subsoil is checked and jointed, making it pervious to water and easy to drain. In many areas the subsoil contains large numbers of concretions of iron hydrate and sometimes of limestone (calcium carbonate).

This type presents many variations. Here as elsewhere the boundary lines between different soil types are not always distinct, but types frequently pass from one to the other very gradually, thus giving an intermediate zone of greater or less width. Variations between black clay loam (420) and brown silt loam (426) are very likely to occur, since these are usually adjoining types. This gives a lighter phase of black clay loam (420), with a smaller organic-matter content than the average, and a heavier phase of brown silt loam (426), with a larger amount of organic matter than usual. (In composition, the gradation zone is intermediate between the two normal types adjoining.) Again, in some areas of black clay loam there has been enough silty material washed in from the surrounding higher lands to modify the character of the surface soil. This change is taking place more rapidly now with the annual cultivation of soil than formerly when washing was largely prevented by prairie grass.

Drainage is the first requirement of this type, which, altho it has but little slope, yet affords a good chance for tile drainage because of its perviousness. Keeping the soil in good physical condition is very essential, and thoro drainage helps to do this to a great extent. As the organic matter is destroyed by cultivation and nitrification and the lime removed by cropping and leaching, the physical condition becomes poorer, and consequently the working of the soil more difficult. Both the organic matter and the lime tend to develop granulation in the soil. The former should be maintained by turning under manure, clover, and crop residues, cornstalks and straw, the very things this land needs, instead of burning them, as is commonly practiced. Ground limestone should be applied when needed to keep the soil sweet.

While this soil is one of the best in the state, yet the clay and humus contained in it give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, the soil shrinks. This results in the formation of cracks up to two inches or more in width, and extending with lessening width to a depth of a foot or more. These cracks allow the subsurface and subsoil to dry out rapidly. They sometimes "block out" the hills of corn, severing the roots and doing considerable damage to the crop. While cracking may not be prevented entirely in this type, yet good tilth with a soil mulch will do much toward that end.

Altho this soil is still moderately rich, its phosphorus content is not high, and it may well be increased to at least 2000 pounds per acre in the plowed soil, the nitrogen being maintained by means of legume crops and farm manure, as explained in the Appendix.

Brown-Gray Silt Loam on Tight Clay (428)

This type is found principally in the southern part of the county and represents a type of the transition zone between the lower and the middle Illinois glaciations. The type occurs in extensive areas in the counties south of Sangamon county. The small areas in Sangamon county usually represent some poorly drained places, altho in the northwest part of the county, in Township 17 North, and Ranges 5, 6, and 7 West, there are areas where the soil naturally seems to have a rather tight clay subsoil.

The type is generally flat, with poor drainage, principally due to the character of the subsoil. It occupies 2.6 square miles, or 1665 acres, only .3 percent of the total area.

The surface soil, 0 to 6⅔ inches, is a light brown or grayish brown silt loam, containing some fine sand and coarse silt which give it a peculiar mealy "feel." The organic-matter content varies from 2.2 to 3.5 percent, according to its relation to other types, being greater where it approaches brown silt loam (426) or black silt loam on clay (425.1) and less where it passes toward yellow-gray silt loam.

The subsurface is represented by a stratum from 10 to 12 inches thick. The color varies from a brown to a gray silt loam, or the upper part of this stratum may be brown and the lower gray. It differs in physical composition from the surface in having less organic matter, the average amount being 1.3 percent.

The subsoil consists of a stratum of clay, beginning at from 16 to 18 inches beneath the surface and varying from 10 to 20 inches in thickness. It is frequently underlain by pervious silt.

Primarily this soil in this county needs good drainage. Lines of tile must be placed nearer each other than in brown silt loam, because of the almost impervious character of the subsoil. Care should be taken to increase the organic matter by proper rotation and turning under crop residues or farm manure. Where this is done, the phosphorus content also should be increased by liberal use of fine-ground rock phosphate. For the best results, limestone should also be applied. The initial application may well be from 3 to 5 tons per acre, and subsequent additions about 2 tons every four or five years.

Black Silt Loam on Clay (425.1)

This type comprises only 1.24 percent of the area of the county but covers a total area of 10.83 square miles, or 6,928 acres. It occurs mostly in small areas over the county, usually adjoining areas of black clay loam (420) or brown-gray silt loam on tight clay (428). As a general thing, with about the same topography as black clay loam (420), it does not permit of as good underdrainage, because of the fact that the subsoil is somewhat tight. This is especially true where the type approaches the brown-gray silt loam on tight clay (428).

The surface soil, 0 to 6⅔ inches, is a black silt loam, varying on the one hand toward a black clay loam, and on the other to a brown-silt loam. When thoroly drained, it is naturally granular and in good tilth, but the same precautions must be taken in regard to this type as with black clay loam.

The organic-matter content is about the same as that of the black clay loam, varying from 5.5 to 6.5 percent and averaging about 60 tons per acre in the surface soil.

The subsurface stratum varies from 8 to 14 inches in thickness, and in color from black or dark brown to a drab or yellowish drab, becoming lighter with depth. The proportion of clay increases somewhat with depth, and usually the lower part of this stratum is a clay. The subsoil resembles that of the black clay loam.

This soil type is moderately rich, but its productive power can be increased by means of phosphorus and fresh organic manures, both of which are necessary if permanent systems of soil maintenance are to be practiced. Limestone also should be applied, especially where the subsoil is devoid of that important material.

(b) UPLAND TIMBER SOILS

Yellow-Gray Silt Loam (434)

This type occurs in the outer timber belts along the Sangamon river and its tributaries, covering 11.93 percent of the county, or 103.85 square miles (66,460 acres). The topography is sufficiently rolling for good surface drainage without much tendency to wash if proper care is taken.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, incoherent and mealy but not granular. The amount of organic matter varies from 1.8 to 2.3 percent, or an average of 20 tons per acre.

The subsurface stratum varies from 3 to 10 inches in thickness, the greatest variation being due to topography. In color it is a gray, grayish yellow, or yellow silt loam, somewhat mealy but becoming more coherent and clayey with depth, with only .72 percent of organic matter.

The subsoil is a yellow, or grayish yellow mottled, clayey silt or silty clay, somewhat plastic when wet, but friable when only moist, and pervious to water. The type is quite variable, due to the fact that it grades into so many different types. There is frequently a transition zone between two types and this gives a variation in both.

In the management of this type one of the first things is the maintenance or increase of organic matter in order to give better tilth, to supply or liberate plant food, prevent "running together," and, in some of the more rolling phases, to prevent washing. Another essential is the application of ground limestone in order to grow clover, alfalfa, and other legumes more successfully. This soil is also deficient in phosphorus, and this must be supplied in any system of profitable, permanent improvement of this type. The chief difference physically between this soil and the common prairie is in the smaller amount of organic matter in the surface and subsurface of the timber lands, which, consequently, are also poorer in nitrogen and often somewhat poorer in phosphorus, because the nitrogen is contained only in the organic matter, while phosphorus is contained in both organic and mineral forms. Initial applications of 1 ton of fine-ground phosphate plowed under with clover or manure, and of 2 to 5 tons of limestone, may well be made, with subsequent applications of ½ ton of phosphate and 2 tons of limestone per acre every four or five years.

Yellow Silt Loam (435)

This type covers about 6.23 percent of the area of the county, equivalent to 54.23 square miles or 34,709 acres. It occurs on the inner timber belts along the streams as the hilly and badly eroded land, usually only in narrow, irregular strips with arms extending up the small streams. The topography is very rolling and so badly broken that it should not be cultivated as a rule, because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow pulverulent, mealy silt loam. This varies a great deal, due to recent washing. In some places the real subsoil may be exposed.

The typical subsurface varies considerably with the amount of washing. In thickness it varies from 0 to 12 inches, the variation being due to the removal of the surface and part of the subsurface. The subsoil is a compact, yellow, clayey silt.

In the management of this type the most important thing is to prevent general surface washing and gullying. If it is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow a great deal of pasture and meadow. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible, both in plowing and planting. Furrows extending up and down the slopes should be avoided. Cultivation should be done in the same direction as plowing. Every means should be employed to maintain and increase the organic-matter content to help hold the soil and keep it in good physical condition so it will absorb a large amount of water and thus diminish the run-off. (See Circular 119.)

When this soil is to be prepared for seeding down, it may well be treated with five tons per acre of ground limestone, in order to encourage the growth of clover and thus to make possible the accumulation of nitrogen, the element in which this type is most deficient. As a rule it is not advisable to try to enrich this soil in phosphorus, because of the fact that erosion is sure to occur to some extent, and the phosphorus supply will thus be renewed from the subsoil.

One of the most profitable crops to grow on this land is alfalfa, and to get this well started requires liberal use of limestone, thoro inoculation, and a moderate application of farm manure. If the manure is not available, it is well to apply about 500 pounds per acre of acid phosphate, mix it with the soil, by disking if possible, and then plow it under, the 5 tons of limestone being applied after plowing and 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.

Light Gray Silt Loam on Tight Clay (432)

Only a comparatively small total area of this type is found in the county. It aggregates .42 percent, equivalent to 3.75 square miles or 2402 acres. The areas are generally small, distributed irregularly along the Sangamon river, South Fork, and Horse Creek. The larger areas occur in Town 15, Ranges 3 and 4 West. The topography is flat, with poor drainage, altho not swampy. These areas were usually protected from the prairie fires by streams or broken land on the southwest. This type is practically all cleared of the white oak, hickory, black jack, and post oak that formerly covered it.

The surface soil is a white or very light-gray silt loam, incoherent, friable and porous. Round iron concretions are usually present. The organic-matter content is low, being about 1.6 percent, or 16 tons per acre 6⅔ inches deep.

The subsurface is a light gray silt extending to a depth of 16 to 18 inches, becoming more clayey with depth and containing only .5 percent of organic matter.

The subsoil is a tight, compact, clayey silt, yellow with gray mottlings. Below 36 inches the subsoil is usually coarser and more pervious.

This soil is very deficient in organic matter and lacking in lime, and is necessarily in poor physical condition. The soil runs together badly and does not hold moisture well, owing to the strong capillarity in the surface and subsurface strata. In the management of this soil, ground limestone and rock phosphate should be added and the content of organic matter increased in every practical way. Deep-rooting crops, such as red, mammoth or sweet clover, would loosen the tight clay subsoil as well as supply the soil with organic matter and nitrogen. Crop residues should be plowed under, by all means, to bring the soil into better tilth. Where not well drained, alsike will grow better than red clover, and pasturing is one of the best uses of this land, altho it may well be liberally enriched in limestone and phosphorus before seeding down, and alsike and white clover should be included in the mixture of grass seed.

Yellow-Gray Sandy Loam (464)

This type occupies .53 percent of the county, or 4.64 square miles (2,971 acres), and is found near the larger streams, the sand having been derived from the bottom land and transported by the wind. It occurs mostly on the east and north sides of the bottom land, with an apparent exception where the upland on the south side of the Sangamon river juts out into the bottom land in Township 16 North, Ranges 4 and 5 West. These broad areas extend out far enough to catch the sand blown up by the westerly winds.

The topography varies to a considerable extent, in places resembling that ordinarily found in the upland, while in others it has a dune character.

The surface soil, 0 to 6⅔ inches, is a light brownish yellow to grayish-yellow sandy loam. The sand is mostly medium but mixed with some coarse and considerable fine sand.

The subsurface is a yellowish gray or yellow sandy loam but varies a great deal, in some places being only a silty material covered by a layer that constitutes the sandy loam, while in others this stratum runs into sand and continues partly or entirely thru the subsoil.

This soil is low in organic matter, the surface containing 1.3 percent, or 13 tons per acre. Care must be taken to use every means to increase the organic-matter content. This is especially necessary to provide nitrogen for the soil, and, secondarily, to liberate plant food and put the soil in better physical condition.

No field experiments have been conducted on this soil type; but from experiments on more sandy land at Green Valley in Tazewell county (see Bulletin 123), it is doubtful if the addition of phosphorus will prove profitable wherever the subsoil is very sandy, thus permitting a very deep feeding range for the plant roots. From 2 to 5 tons per acre of limestone should be applied, with renewed applications of 2 tons per acre every four or five years. Sufficient legume crops, crop residues, or farm manure should be plowed under to provide the nitrogen needed by the non-leguminous crops to be grown (see Appendix). This soil is especially well adapted to alfalfa when properly treated with limestone and well inoculated, farm manure being used to give the alfalfa a good start.

Yellow Sandy Loam (465)

This type covers an area of 4,845 square miles, or 3,102 acres, being .55 percent of the area of the county. It occurs in the same region as the yellow-gray sandy loam (464).

The topography is very rolling and hilly. Care must be taken to prevent washing, altho there is not the danger from this cause that there is in the case of silt loams.

The surface soil, 0 to 6⅔ inches, is a light brown to yellow sandy loam. All grades of sand are found, but medium sand predominates. This stratum contains only 1 percent of organic matter, or 10 tons per acre.

The subsurface varies from a yellow sandy loam to a sand, and this sand continues to forty inches. As a rule this land should be left in forest, but where cropped large use should be made of legumes. While the surface soil contains a small amount of limestone (probably in the form of light pieces of shells blown with the sand from the bottom lands), liberal use of ground limestone would be helpful for growing legumes, especially for alfalfa.

Dune Sand (481)

The sand dunes occupy part of the upland sandy tracts in various places, but usually only small isolated areas, the largest being not more than 80 acres.

The entire area occupied by the type is 1.43 square miles, or 914 acres, constituting only .15 percent of the county. Dune topography characterizes this type.

The surface is a light brown sand passing into a yellow sand that constitutes both the subsurface and subsoil. The organic-matter content is exceedingly low, being only .4 percent, or 4 tons per acre. This indicates a low nitrogen content, and every practical means should be taken to increase the organic matter for the purpose of furnishing nitrogen as well as to prevent blowing of soil.

Liberal use of limestone (preferably dolomite, because of the low magnesium content of this soil) is especially important for the improvement of this sand soil; and legumes should be the principal crops grown. While this soil is the lowest in phosphorus of all the types in the county, it is very doubtful if any form of phosphorus can be applied with profit. The soil is abnormal in physical character, being so open and porous that the feeding range afforded the plant roots is very great. The air easily penetrates such soil, so that oxidation and liberation of plant food occur at much greater depths than in heavier soils. Furthermore, the phosphorus is contained in both organic and mineral forms, and the mineral phosphorus may be associated with calcium and iron compounds not locked up in the sand grains.

Next to limestone and organic matter, the addition of kainit is to be recommended for the improvement of this sand soil, especially to get a good start with alfalfa, cowpeas, or other legumes. The kainit furnishes soluble salts, including potassium which, tho present in the sand in considerable amount, is chiefly locked up in the sand grains. (Any one interested in sand soil is advised to study Bulletin 123.)

(c) SWAMP AND BOTTOM-LAND SOILS

Deep Brown Silt Loam (1426)

The bottom-land soil is derived from material washed from the upland. It must therefore have some relation to the uplands. It differs in being more variable as to physical composition than any single upland type, and the brown color extends into it to greater depth. The bottoms along streams vary from a few rods to a mile or more in width. These lands occupy 77.65 square miles, equivalent to 49,696 acres, and constitute 8.93 percent of the entire area of the county. The topography is flat or with very slight undulations that represent old stream or overflow channels. Better drainage is needed in much of this area.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing from 3.5 to 5.3 percent of organic matter, the average being 4.4 percent, or 44 tons per acre. It is probably easier to maintain the organic matter in this type than in the upland because of the occasional overflow and the consequent deposition of material rich in this constituent. The physical composition of the soil varies from a clay loam to a sandy loam, but the areas of these extreme types, especially the latter, are so small and so changeable that it really does not mean very much to show them on the map as the next flood may change their boundaries.

The subsurface is brown silt loam, becoming lighter with depth. It contains an average of 3.2 percent of organic matter.

The subsoil is a yellowish drab silt loam, varying in physical composition either to a clayey silt or to a sandy loam or even a sand in the lower subsoil.

The type is quite productive where proper drainage is secured; and as a rule no soil treatment is recommended except good farming. Even the systematic rotation of crops is not important where the land overflows occasionally, but where it is protected from overflow a rotation including legume crops should be practiced, and ultimately provision would need to be made for the enrichment of such protected land.

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 of Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall we use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Some Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"

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 149.

SOIL SURVEY METHODS

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

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

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of roads, railroads, etc.

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

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

SOIL CHARACTERISTICS

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

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

The common soil constituents are indicated in the following outline:

CONSTITUENTS OF SOILS

Soil Constituents	Organic Matter	Comprising undecomposed and partially decayed vegetable material	
	Inorganic Matter	Clay	.001 mm.* 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

*25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

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

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

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

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

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

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

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

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

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

Sands—Soils with more than 75 percent of sand.

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

Gravels—Soils with more than 50 percent of gravel.

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

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

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

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which this is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and 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 cornstalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly

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

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

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

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

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

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

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

CROP REQUIREMENTS

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

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

Produce: Kind	Produce: Amount	Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
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	
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*	42	51	16	4
Total in four crops		510*	77	322	68	168

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

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

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

METHODS OF LIBERATING PLANT FOOD

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

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

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

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

PERMANENT SOIL IMPROVEMENT

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

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or in preparing the land for alfalfa, five tons per acre of ground limestone may well be used for the first application.

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

First year, corn (with some winter legume, such as red clover, alsike, sweet clover, or alfalfa, or a mixture, seeded on part of the field at the last cultivation).
Second year, oats or barley or wheat (fall or spring) on one part and cowpeas or soybeans where the winter catch crop is plowed down late in the spring.
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 wheat grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

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

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

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

Good three-year rotations are:

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

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

To avoid clover sickness it may sometimes be necessary to substitute red clover or alsike for the other in about every third rotation, and at the same time to discontinue their use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

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

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

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

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

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

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

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

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

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

On soils which are subject to surface washings, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top dressings if necessary, and occasional 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. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The deep-rooting clover crop is an advantage to subsequent crops because of that characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter: and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

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

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

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

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure will be lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus in average live-stock farming, they retain less than one-tenth of the potassium, from the food consumed; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

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

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

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

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

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

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

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

CALCIUM AND MAGNESIUM

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

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

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

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

ADDED NOTE

CORN YIELDS PER ACRE ON BLOOMINGTON SOIL EXPERIMENT FIELDS, 1912

(See page 17 for results of previous ten years)

Brown silt loam prairie; Early Wisconsin glaciation		Corn 1912, bushels	Increase from treatment	Value of increase
Plot	Soil treatment applied			
101	None	55.2		
102	Lime	47.9	-7.3	$-2.55
103	Lime, crop residues	62.5	7.3	2.55
104	Lime, phosphorus	74.5	19.3	6.75
105	Lime, potassium	57.8	2.6	.91
106	Lime, residues, phosphorus	86.1	30.9	10.81
107	Lime, residues, potassium	58.9	3.7	1.29
108	Lime, phosphorus, potassium	79.2	24.0	8.40
109	Lime, residues, phosphorus, potassium	83.4	28.2	9.87
110	Residues, phosphorus, potassium	78.3	23.1	8.08

No commercial nitrogen has been applied to this field since 1905; but clover was grown in 1906 and 1910; also a catch crop of cowpeas was grown after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover (except the seed) was plowed under on five nitrogen plots (103, 106, 107, 109, and 110). The effect of this is already appreciable (4.4 bushels of wheat and 7.9 bushels of corn increase as an average) and will probably be much more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the ten years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil.

The clover roots and stubble contain no more nitrogen than this soil would furnish to the clover crop, 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 still remaining in this soil, and the future years will undoubtedly witness a gradually increasing difference, in the yields of grain crops, between Plots 104 and 106, and between Plots 108 and 109.

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

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

Total value of increase in eleven years	$ 89.02
Total cost of phosphorus in eleven years	27.50
Net profit in eleven years	$ 61.52

After the first year the phosphorus never failed to more than pay its annual cost; and, as an average of the last four years, the increase produced by the phosphorus is worth as much as the total crops produced on the land not receiving phosphorus. (See pages 17 and 41 for more complete details.)

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