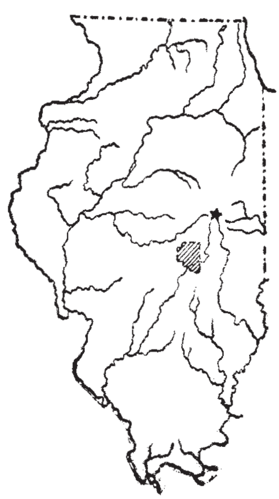
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 2

MOULTRIE COUNTY SOILS

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



URBANA, ILLINOIS, JUNE, 1911

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MOULTRIE COUNTY SOILS

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Introduction

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state the prairie soils are largely of a gray color, 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, have been selected for the first Illinois Soil Reports by counties. While subsequent County Soil Reports will be sent only to the residents of the county concerned (and to anyone else upon request), these first three are sent to the Station's entire mailing list within the State.

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.

Soil Formation

Moultrie County lies wholly within the Early Wisconsin Glaciation, but near its southern border. While it has no very distinct morainal ridges, yet the county is covered to an average depth of more than 200 feet with a deposit of glacial drift consisting generally of a mixture of clay, silt, sand, gravel, and boulders. This drift consists of the Illinoisan below and the Wisconsin above, separated by the Iowan loess carrying the old Sangamon soil. Covering the Wisconsin drift to a depth of three to six feet or more is another layer of fine-grained, loessial or wind-blown material from which the present soil has been formed. This has been modified to a considerable degree by different conditions and agencies, such as the growth of grasses, of timber, washing and drainage, which have given rise to the different soil types found in the county.

TABLE 1.—SOIL TYPES OF MOULTRIE COUNTY

Soil Type No.	Names	Area in sq. mi.	Area in acres	Percent of total
	(a) Upland Prairie Soils (Page 20)			
1126	Brown silt loam	264.42	169,229	77.52
1120	Black clay loam	15.42	9,869	4.52
	(b) Upland Timber Soils (Page 23)			
1132	Light gray silt loam on tight clay	4.75	3,040	1.39
1134	Yellow-gray silt loam	35.05	22,432	10.28
1135	Yellow silt loam	2.19	1,402	.64
	(c) Swamp and Bottom-land Soils (Page 25)			
1454	Mixed loam	13.72	8,781	4.02
	(d) Terrace Soil (Page 26)			
1554.6	Mixed loam over sand or gravel	5.51	3,526	1.61
	Totals	341.06	218,279	100.00

The only soil type in the county which includes non-tillable land is the yellow silt loam, whose topography is often so steeply sloping that it ought to be kept in forest or at least almost continuously in pasture. Of course, much of the swamp and bottom land needs more adequate drainage, which is very difficult, if not impracticable, to provide as yet in some places.

THE INVOICE AND INCREASE OF FERTILITY IN MOULTRIE 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 landowners than that soils differ in productive power. Even though 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 primarily 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 only the clovers, peas, beans, and vetches among our common agricultural plants) secure only from the soil 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 in sufficient abundance, compared with the amounts needed by plants, so that they are not known ever to limit the yield of crops.)

In Table 2 is recorded the invoice of the plowed soil, showing the total amounts of these five elements of plant food contained in each of the different types of soil in Moultrie County.

TABLE 2.—FERTILITY IN THE SOILS OF MOULTRIE 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 required
	Upland Prairie Soils								
1126	Brown silt loam	52260	4810	980	36020	8650	10430		80
1120	Black clay loam (normal phase)	72280	6480	1810	35260	14830	20460	8350	
1120	Black clay loam (lighter phase)	52600	6940	1320	32120	15080	18560	760	
	Upland Timber Soils								
1132	Light gray silt loam on tight clay	19810	1680	600	35080	6350	7390		120
1134	Yellow gray silt loam	28170	2310	680	36150	6040	6370		180
1135	Yellow silt loam	19260	1580	480	36960	6220	5180		320
	Swamp and Bottom-land Soils								
1454	Mixed loam (normal phase)	41940	4180	1260	41740	9820	13000	780	
1454	Mixed loam (lighter phase)	24420	2600	620	37040	8520	13000	7780	
	Terrace Soil								
1554.6	Mixed loam over sand or gravel	11940	1300	500	34860	5460	6300		40

These data 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 Moultrie County does not contain enough total nitrogen in the plowed soil for the production of maximum crops for ten rotations; while the upland timber soils contain as an average less than one half as much nitrogen as the prairie land.

Practically the same condition obtains with respect to phosphorus, nine-tenths of the soil area of the county containing no more of that element than would be required for twelve crop rotations if such crop yields were secured as suggested in Table A of the Appendix; and in case of the cereals it will 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 2,800 years, if only the grain is sold, or for 450 years even if total crops were removed and nothing returned. The corresponding figures are about 2,100 and 500 years for magnesium, and about 10,000 and 250 years for calcium.

Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium and, as explained in the Appendix, with 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 four times as much nitrogen as the timber lands of the same topography; and the normal black clay loam, the richest prairie land, contains about three times as much phosphorus as the upland timber soils.

On the other hand, the most significant fact revealed by the investigation of Moultrie County soils is the low phosphorus content of the common brown silt loam prairie, a type of soil which covers more than three-fourths of the entire county. The market value of this land is about $200 an acre, and yet an application of $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 were then returned to the soil either directly or in farm manure, the combined effect of the phosphorus and nitrogenous organic matter with a good rotation of crops would soon double the yield of corn on most farms.

The average yield of corn of Moultrie County for the ten years, 1901 to 1910, is 34.7 bushels per acre;* yet this county occupies the 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 40.5 bushels of corn per acre during the same ten years.

With nearly 5,000 pounds of nitrogen in the soil and an inexhaustible supply in the air, with 36,000 pounds of potassium in the same soil and with practically no acidity, the economic loss of farming such land with less than 1,000 pounds of total phosphorus in the plowed soil can only be appreciated 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 same type of soil in different counties in the same soil area as Moultrie (the Early Wisconsin Glaciation), as at Urbana in Champaign County, at Sibley in Ford County, and at Bloomington in McLean County.

RESULTS OF FIELD EXPERIMENTS AT URBANA

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

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

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

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 3.

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

Rotation	Years	Corn	Oats	Clover	Value of	Cost of
		Bushels		tons	increase	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 cents and 3 cents a pound for phosphorus in bone meal and rock phosphate, respectively.

As an average the well treated land has produced about 90 bushels of corn, 60 bushels of oats, and 2½ tons of hay per acre. These crops would remove about 130 pounds of phosphorus in the nine years, while 300 pounds

*Statistical Report, Illinois State Board of Agriculture, December 1, 1910, page 39.

PLATE 1. CORN ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE APPLIED

were applied (in bone meal and in rock phosphate, as explained below), so that the average phosphorus content of the plowed soil has been increased from about 1,100 in 1901 to 1,300 pounds per acre in 1910, about 30 pounds having been returned, as an average, in the organic manures described below.

Meanwhile the untreated land has lost about 100 pounds of phosphorus, corresponding to a reduction from 1,100 to 1,000 pounds.

As shown in Table 3, the phosphorus paid its cost the first rotation, and the third rotation it paid more than twice its cost, besides leaving the treated soil about one-third richer in phosphorus than the untreated soil.

During the first six years, 1902-1907, phosphorus was applied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal, 600 pounds of bone usually being applied once every three years on the clover sod and plowed under for corn. For the last rotation, 1908-1910, the 600 pounds of steamed bone were applied on one-half of each plot, and 1,800 pounds of fine-ground raw rock phosphate on the other half. The bone

PLATE 2. CORN ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE AND PHOSPHORUS APPLIED

costs about $25 a ton (10 cents a pound for 250 of phosphorus), and the raw phosphate about $7.50 per ton (3 cents a pound for 250 of phosphorus).

As an average of the last three years one dollar invested has paid back $2.38 from bone meal and $2.39 from raw rock phosphate in the value of the increase; and, of course, the reserve supply of phosphorus is much greater where the rock phosphate is used.

In 1910 the respective increases in yield from bone meal and rock phosphate were 15.2 and 19.6 bushels of corn, 11.9 and 12.8 bushels of oats, and 1.33 and 1.37 tons of clover hay, the larger increase being produced by the raw rock phosphate with every crop, in harmony with the cumulative effect to be expected from the increasing store of phosphorus in the soil.

As a rule, each increase given in Table 3 represents the average of duplicate tests over a period of three years. These averages are considered trustworthy, excepting, perhaps, some results on oats, due to abnormal seasons. Normally the oat crop shows a gradually increasing effect from the use of phosphorus. (The increase for oats in 1910 was 13.8 bushels in grain farming and 11 bushels in live-stock farming.)

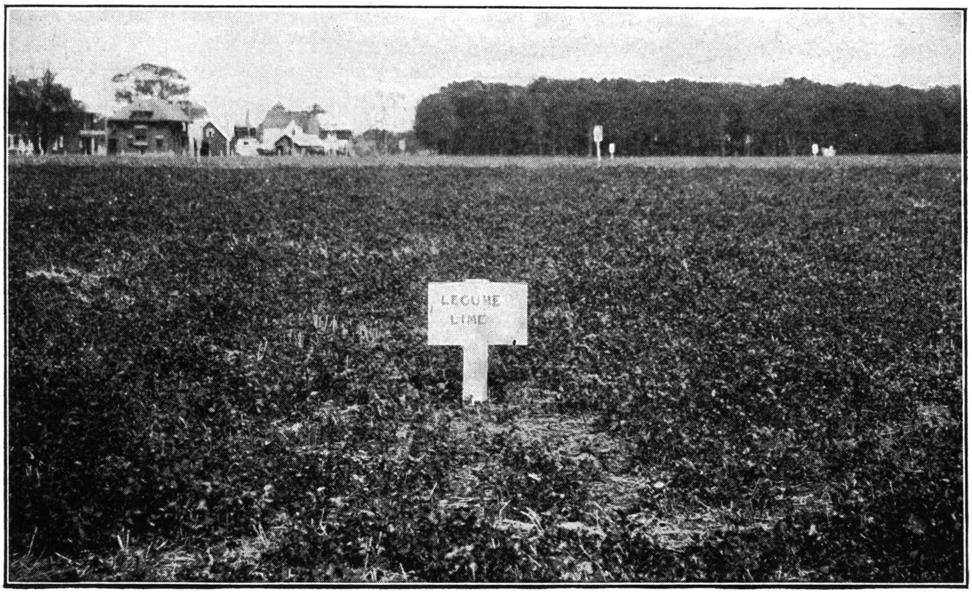

PLATE 3. CLOVER ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE APPLIED

The duplicate tests each year correspond to the two systems of farming adopted on these fields, one of which is a grain system in which the nitrogen and organic matter are maintained or increased by returning to the land all crop residues left after the grain or seed is sold. These residues include the corn stalks, straw, and all clover except the seed. This system in complete form has been practiced only during the last three years, 1908-1910, and consequently corn has not yet been grown on land where the corn stalks had been returned to the soil.

In the other system, known as live-stock farming, the crops are all harvested and used for feed and bedding, and as many tons of average manure are applied as the total number of tons of air-dry produce from the respective plots. This system in complete form has been followed only during the last six years, 1905-1910.

By computation from data reported in the Appendix, it can be determined that about twice as much phosphorus leaves the farm in grain farming as in live-stock farming; and, in consequence, it is to be expected that the application of phosphorus will produce greater effects in the grain-farming system than in live-stock farming.

Table 4 contains more complete data for the corn crops grown on these fields, including the average yields of 1895-1897, before any treatment was applied. (For full details, see Bulletin 125.)

It should be noted that no manure was applied during the first rotation, 1902-1904; and that crop residues have been returned only during the last rotation, 1908-1910. (On plots 2, 4, 6, and 8 some legume catch crops have been seeded in the corn at the time of the last cultivation, but the results have not shown any benefit where oats follow corn, because with a good growth of corn the catch crop makes but little growth the same season, and there is no opportunity for it the following spring where the land must be seeded to oats.)

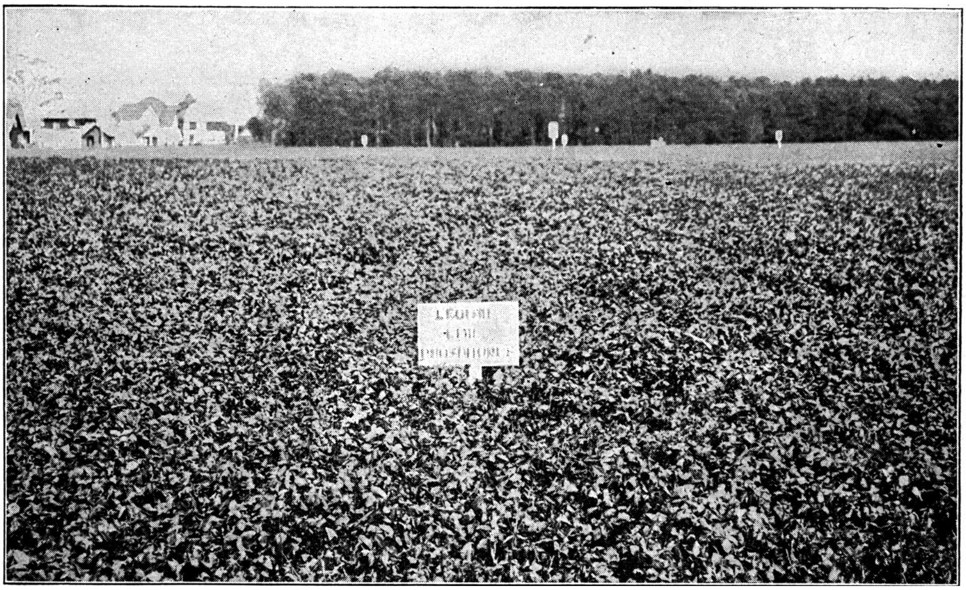

PLATE 4. CLOVER ON URBANA EXPERIMENT FIELD
LEGUME CROPS AND CROP RESIDUES PLOWED UNDER
LIMESTONE AND PHOSPHORUS APPLIED

TABLE 4.—AVERAGE CORN YIELDS PER ACRE ON URBANA EXPERIMENT FIELD, ON COMMON CORN BELT PRAIRIE SOIL: BROWN SILT LOAM

Plot No.	1	2	3	4	5	6	7	8	9
Corn, 1895-7....	61.2	63.4	61.2	63.1	66.1	65.9	65.7	64.0	65.9
Plan of treatment partially begun, 1902......	None	Residues	Manure	Residues, lime	Manure, lime	Residues, lime, phosphorus	Manure, lime, phosphorus	Residues, lime, phosphorus, potassium	Manure, lime, phosphorus, potassium
Corn, 1902-4...	75.4	77.4	75.3	78.4	80.8	88.0	88.8	90.1	90.5
Corn, 1905-7	71.5	68.5	80.5	72.3	84.8	90.4	93.2	93.8	95.6
Corn, 1908-10	49.4	51.5	69.3	58.1	74.9	83.8	86.6	86.7	90.9

Average Increase from Treatment Named: Corn, bushels

By additions	Residues	Manure	Lime	Lime	Phosphorus	Phosphorus	Potassium	Potassium
1902-4; 3 yrs............	.....	.....	1.0	5.5	9.6	8.0	2.1	1.7
1905-7; 3 yrs...........	......	9.0	3.8	4.3	18.1	8.4	3.4	2.4
1908-10; 3 yrs..........	2.1	19.9	6.6	5.6	25.7	11.7	2.9	4.3

Even though the grain system was not fully underway, the organic manures, limestone and phosphorus increased the yield of corn by 34.4 bushels per acre in grain farming, and by 37.2 bushels in live-stock farming, as an average of the last three years.

Wheat is grown on the University South Farm, in a rotation experiment started more recently. As an average of the last three years, 1908-1910, raw rock phosphate (with no previous applications of bone meal) has increased the yield of wheat by 8.4 bushels per acre, and here too the phosphorus has paid back more than twice its cost, as an average of the

PLATE 5. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND CROP RESIDUES PLOWED UNDER
AVERAGE YIELD, 35.2 BUSHELS PER ACRE

last three years, the cost being $1.87½, and the value of the increase $3.81 per acre per annum, wheat being valued at 70 cents a bushel and other crops as noted above. (Only five-sixths as much rock phosphate is applied on the South Farm as is reported above for the third rotation in the North Farm experiments, and even this application will be reduced one-half or more after the soil has become sufficiently rich for the production of maximum crops.)

Since the above was written the 1911 crop of wheat has been harvested and threshed on the University South Farm.

In the grain system of farming, the yield was 35.2 bushels per acre where catch 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 5 and 6.)

In the live-stock farming, the yield was 34.2 bushels where manure and catch 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 7 and 8.)

PLATE 6. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND CROP RESIDUES PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 50.1 BUSHELS PER ACRE

These results emphasize the cumulative effect of permanent systems of soil improvement. The value of the increase produced by phosphorus in the 1911 wheat crop alone would nearly pay for the cost of the phosphate for eight years.

RESULTS OF EXPERIMENTS ON SIBLEY FIELD

Table 5 gives results obtained during the past nine 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 humus. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when phosphorus produced an increase of 8 bushels, nitro-

PLATE 7. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND FARM MANURE PLOWED UNDER
AVERAGE YIELD, 34.2 BUSHELS PER ACRE

gen 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 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 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. Phosphorus appears to have been the first limiting element again in 1909 and 1910.

PLATE 8. WHEAT IN 1911 ON URBANA FIELD
CATCH CROPS AND FARM MANURE PLOWED UNDER
FINE-GROUND ROCK PHOSPHATE APPLIED
AVERAGE YIELD, 51.8 BUSHELS PER ACRE

In the lower part of Table 5 are shown the total values per acre of the nine crops from each of the ten different plots, the amounts varying from $140.17 to $214.96; also the value of the increase produced; first, above the untreated land; and, second, above the treatment with lime alone, corn being valued at 35 cents a bushel, oats at 30 cents and wheat at 70 cents.

Phosphorus without nitrogen produced $24.44 in addition to the increase by lime; and with nitrogen phosphorus produced $56.14 in addition to the increase by lime and nitrogen, the principal part of these increases having been made during the later years.

The results show that in 21 cases out of 36 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 $9.90, 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.

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
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
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0
103	Lime, nitrogen	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0
104	Lime, phosphorus	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0
105	Lime, potassium	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2
106	Lime, nitrogen phosphorus	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6
107	Lime, nitrogen potassium	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2
108	Lime, phosphorus potassium	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0
109	Lime, nitrogen, phosphorus, potassium	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0
110	Nitrogen, phosphorus, potassium	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4

VALUE OF CROPS PER ACRE IN NINE YEARS

Plot	Soil treatment applied	Total value of nine crops	Value of increase	
101	None	$140.17	....	Over lime
102	Lime	151.30	$11.13	
103	Lime, nitrogen	151.99	11.82	$ .69
104	Lime, phosphorus	175.74	35.57	24.44
105	Lime, potassium	140.73	.56	(-10.57)
106	Lime, nitrogen, phosphorus	208.13	67.96	56.83
107	Lime, nitrogen, potassium	164.48	24.31	13.18
108	Lime, phosphorus, potassium	165.33	25.16	14.03
109	Lime, nitrogen, phosphorus, potassium	214.96	74.79	63.66
110	Nitrogen, phosphorus, potassium	206.28	66.11	....

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 nine 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 practically the same increase ($56.05) as was produced by phosphorus over nitrogen on the Sibley field (see Plots 103 and 106).

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†
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
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09
103	Lime, nitrogen	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26
106	Lime, nitrogen, phosphorus	43.9	77.6	85.3	50.9	*	78.9	45.8	72.5	(1.67)
107	Lime, nitrogen, potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27
109	Lime, nitrogen, phosphorus potassium	52.7	80.9	90.5	51.9	*	88.4	58.1	64.2	(.42)
110	Nitrogen, phosphorus potassium	52.3	73.1	71.4	51.1	*	78.0	51.4	55.3	(.60)

VALUE OF CROPS PER ACRE IN NINE YEARS

Plot	Soil treatment applied	Total value of nine crops	Value of increase	
101	None	$132 15	....	Over lime
102	Lime	133.00	$ .85	
103	Lime, nitrogen (see text)	133.38	1.23	$ .38
104	Lime, phosphorus	189.05	56.90	56.05
105	Lime, potassium	134.24	2.09	1.24
106	Lime, nitrogen, phosphorus	179.16	47.01	46.16
107	Lime, nitrogen, potassium	130.85	(-1.30)	(-2.15)
108	Lime, phosphorus, potassium	191.40	59.25	58.40
109	Lime, nitrogen, phosphorus, potassium	183.29	51.14	50.29
110	Nitrogen, phosphorus, potassium	166.56	34.41	....

*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.

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, though fairly uniform. Otherwise all results reported in Tables 5 and 6, including more than 150 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 $56.10 for the nine years, or $6.23 an acre a year. This is $3.73 above its cost in 200 pounds of steamed bone meal, the form in which it 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 130 pounds per acre of phosphorus have been removed from the soil in the nine crops. This is equal to 11 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. The total phosphorus applied from 1902 to 1910 amounted to 225 pounds per acre. Where no phosphorus was applied the crops removed only 90 pounds of phosphorus in nine years, equivalent to only 7½ percent of the total amount (1,200 pounds) in the surface soil at the beginning (1902).

THE SUBSURFACE AND SUBSOIL

In Tables 7 and 8 are recorded the amounts of plant food in the subsurface and subsoils, 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 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

TABLE 7.—FERTILITY IN THE SOILS OF MOULTRIE 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								
1126	Brown silt loam	67420	6480	1590	72590	20160	18170	140	
1120	Black clay loam (normal phase).	71140	6220	2650	72340	30020	36350	23700	
1120	Black clay loam (lighter phase).	30040	4000	2000	65720	38720	38480	82280	
	Upland Timber Soils								
1132	Light gray silt loam on tight clay..........	16740	1840	920	70740	19120	11240		4520
1134	Yellow-gray silt loam.........	17650	2040	1100	74680	18530	10230		1840
1135	Yellow silt loam	17160	1720	1200	80520	25280	8440		6760
	Swamp and Bottom-Land Soils								
1454	Mixed loam (normal phase).	71240	6240	2000	80920	21640	28720	2200	
1454	Mixed loam (lighter phase).	48680	5680	1320	81840	20680	25920	1000	
	Terrace Soil								
1554.6	Mixed loam over sand or gravel	8960	1360	1040	73720	15440	11720		160

capillary action during 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 8.—FERTILITY IN THE SOILS OF MOULTRIE 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								
1126	Brown silt loam	29180	3720	2230	109670	46360	30790	7860	
1120	Black clay loam (normal phase).	39230	3670	3130	112730	50690	72840	126200	
1120	Black clay loam (lighter phase).	19800	2340	2280	83760	121020	510720	1638120	
	Upland Timber Soils								
1132	Light gray silt loam on tight clay...........	23280	2670	2070	112380	46770	30990		90
1134	Yellow-gray silt loam.......	18510	2360	1830	126570	41510	18380		5480
1135	Yellow silt loam	14820	2100	2040	143400	46200	16140		480
	Swamp and Bottom-Land Soils								
1454	Mixed loam (normal phase).	41760	4500	2160	127020	34260	35580	1020	
1454	Mixed loam (lighter phase).	39360	4500	1920	118200	28320	32580	5340	
	Terrace Soil								
1554.6	Mixed loam over sand or gravel.........	7980	1380	1320	101460	26340	16740		2580

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

Brown Silt Loam (1126)

This type occupies 77.5 percent of the area of the county or 264.42 square miles, equal to 169,229 acres. It has been formed from wind-blown loessial material mixed with organic matter furnished by the roots of prairie grasses that formerly grew on the native prairies. The topography varies from nearly flat to rolling, the larger part of the type being sufficiently sloping to insure good surface drainage, while the rest is in good condition for tile drainage.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, but near the boundaries it varies on the one hand to almost black as it passes toward black clay loam, and on the other to a grayish brown or yellowish brown as it grades into the timber types. It contains enough of the coarser constituents, sand and coarse silt, to make it work easily, and yet enough clay to give stability to the soil. The organic matter content varies from 3½ to 5 percent, the amount depending upon topography to a considerable extent. The lower and more poorly drained areas permitted the accumulation of a larger amount than the higher land because of ranker growth of grasses as well as less decay on account of moisture.

The thickness of the subsurface varies from 7 to 14 inches, and in color from a dark brown to a light yellowish brown silt loam, the color and depth varying with the topography, being lighter in color and shallower on the more rolling areas.

The subsoil to a depth of 40 inches is a yellow clayey silt or silty clay, somewhat plastic when wet. The color is of a brighter yellow, even somewhat reddish, where there has been good surface drainage, and of a pale yellow, approaching an olive color, where poorly drained. In some of the rolling areas the loess deposit has been partly removed by washing, thus bringing the glacial drift within 40 inches of the surface. This is of rare occurrence in Moultrie County.

In the management of this soil, one necessary thing, aside from proper drainage and good tillage, is to keep it in good physical condition or in good tilth. It is a common practice in the corn belt to pasture the corn stalks during the winter and often late in the spring, so late in fact that tramping puts the soil in bad condition for working. It is partially puddled and will be cloddy as a result. If thus tramped in the spring, the natural agencies of freezing and thawing, wetting and drying, even with the aid of ordinary tillage, fail to produce good tilth before the crop is planted and the latter necessarily suffers. This will be much worse if the season should be dry. A poor stand of corn will result, if the field is put in corn, and a compact baked soil unfavorable for growth, if put in oats. Sometimes farmers will not wait for their soils to become sufficiently dry to work well, and a puddled soil results which is very unfavorable to physical, chemical, and biological processes. This will be especially true if cropping has reduced the amount of organic matter below what is necessary to maintain good tilth. Every practicable means should be used to maintain the supply of this constituent. Clover should be grown every three or four years and the bulk of the crop turned under, either directly or after removing the seed or after feeding and bringing back all the manure. All straw should be returned to the land and plowed under if not used as bedding or fed, and stalks should be chopped up and turned under as well as weeds and trash. In this way only can the present fair supply of organic matter and its accompanying nitrogen be maintained in this soil. The supply of phosphorus as shown by field experiment is inadequate for the highest economical production, and this should be increased by turning under with the clover sod every three or four years at least one-half ton of rock phosphate per acre, and the initial application may well be a ton or more per acre.

On the lighter phase of the type and upon higher points of the better phase, the immediate use of ground limestone per acre (about two tons every four or five years) is to be recommended. In the near future, for the continued successful growing of clover, alfalfa, and other legumes, limestone will generally have to be used upon this type of soil.

Black Clay Loam (1120)

This type of soil, commonly found in the originally swampy or poorly drained areas of the Early Wisconsin Glaciation, 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 the clay and other fine material from the slightly higher uplands. On account of the good surface drainage that exists generally in this county, the black clay loam constitutes only 4.5 percent of the entire area, or 9,858 acres.

The topography of this type is flat, yet for all areas of black clay loam sufficient "outlets" for tile may be secured so that good drainage is possible

The surface stratum, 0 to 6⅔ inches, is a black, plastic clay loam containing from 5 to 7 percent of organic matter, or from 50 to 70 tons in an acre. The surface soil is naturally quite granular and consequently pervious to water. This granular character is a very desirable property for all soils, but especially for heavy ones. It keeps the soil mellow and if the granules are destroyed by working while wet or by the tramping of stock, they will be formed again by freezing and thawing and by moisture changes (wetting and drying). These produce slacking, as the process is usually termed. If, however, the humus and lime content become low, this tendency to granulate grows less and the soil becomes more difficult to work.

The subsurface stratum, from 10 to 16 inches thick, is about the same as the surface, except that it becomes lighter with depth so that the lower part of this stratum may pass into a drab or yellowish silty clay. It is pervious to water, due to the jointing or checking produced by shrinkage in times of drouth.

The subsoil below 20 inches is usually a drab or dull yellow silty clay but locally may be a yellow clayey silt. As a rule the subsoil is not so highly colored as that of the better drained types, due to the fact that the iron is not so highly oxidized in this poorly drained subsoil. The subsoil is checked and jointed somewhat the same as the subsurface.

This type presents many variations. It must be borne in mind that the boundary lines between different soil types are not always distinct but that types frequently pass from one to the other very gradually, thus giving a zone of greater or less width intermediate between the two types. The black clay loam (1120) is usually surrounded by brown silt loam (1126) and it would be expected that the two would grade into each other. This gives variations including a lighter phase containing less of clay and organic matter than the average of the type. In some areas there has been enough silty material washed in from the surrounding higher land to modify the character of the surface soil. This is true of the Eagle Pond district in Sections 14, 23, 24 and 26, in Township 14 North, Range 5 East of the Third P.M., and particularly in small areas surrounded by higher land. This change is taking place more rapidly now with annual cultivation of soil than formerly when prairie grass protected the land from washing.

The amount of coarse soil constituents, sand and gravel, varies in this type. These have been brought up to some extent from the underlying glacial drift by burrowing animals, especially crayfish, and distributed thru the soil.

Drainage is the first requirement of this type, and altho but very slightly sloping, yet this with the perviousness of the soil gives an excellent chance for surface and tile drainage. 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 and the lime removed from the soil, the former by cultivation and decomposition and the latter by cropping and leaching, the soil will attain a poorer physical condition and consequently become more difficult to work. Both the organic matter and the lime tend to develop granulation of the soil. The former should be maintained by turning under manure or clover and residues from crops, such as cornstalks, stubble and straw, and ground limestone should be applied where needed.

While this soil is one of the best in the state, yet the clay and humus which it contains 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 plants, 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 subsoil to dry out rapidly. They sometimes "block out" the hills of corn by cross cracks, severing the roots and thus confining each hill to a comparatively small area. Sometimes much damage to the crop results. While cracking may not be prevented entirely in this type, yet it may be controlled to some extent by a soil mulch to check evaporation and prevent the cracks from extending to the surface. Organic matter, as cornstalks or straw, applied to the surface in liberal amount, also makes a very satisfactory mulch, but of course this would interfere with ordinary cultivation and cropping.

This type of soil is well supplied with organic matter and nitrogen. It has about eighty percent more phosphorus than does the brown silt loam and is abundantly supplied with potassium. As a rule, it contains limestone in sufficient amounts for present use. Upon this soil it is of first importance to establish a system which will maintain the supply of actively decaying organic matter and to so handle it as to keep the soil in good tilth. Eventually the use of limestone and phosphorus may be profitable; and on the lighter phase, indicated by the lighter color and greater friability (because of its higher content of silt), applications of phosphorus can even now be made profitable in good systems of farming.

(b) UPLAND TIMBER SOILS

Light Gray Silt Loam on Tight Clay (1132)

This type comprises only 1.4 percent of the area of the county or 3,040 acres. It is found almost entirely in the southern part of the county in the timbered areas along the Kaskaskia river and its tributaries. As a rule, it occurs in small, level, but not swampy areas that have poor drainage on account of the topography and the imperviousness of the subsoil. Practically all of this type is now cleared and under cultivation, but the trees formerly growing upon it were white oak, shellbark hickory, black jack and some post oak.

The surface soil, 0 to 6⅔ inches, is a light gray silt loam, incoherent, friable, and porous. Iron concretions, varying in size from ¼ inch to a pin head are usually present in this stratum. The organic matter content is very low, being about 1½ per cent.

The subsurface is a light gray silt becoming slightly yellowish and more clayey with depth.

The subsoil below 20 inches is a compact clayey silt, yellow in color with gray or drab mottlings. The subsoil below 35 or 40 inches is usually coarser and more pervious to water.

The soil runs together after a rain, and limestone with organic matter will prevent this to a very great extent.

Some carefully conducted experiments are needed to ascertain the feasibility of tile-drainage in this land.

In the management of this type the most practical things to do are to apply limestone and phosphorus and increase the content of organic matter in every way practicable. The subsoil is tight and the growing of deep-rooting crops such as red, mammoth, or sweet clover would tend to make it more porous as well as supply the soil with organic matter and nitrogen.

Yellow-Gray Silt Loam (1134)

This type occurs in the timbered area along the Kaskaskia river and its tributaries, principally in the southern part of the county, forming strips along the streams with a broadening toward the north and east sides of the streams where the timber was protected from the prairie fires driven by the prevailing south-westerly winds.

The type occupies about 10.3 percent of the total area of the county or 22,412 acres, being next in amount to the brown silt loam. This type is sufficiently rolling for good drainage without much tendency to wash, if anything like proper care is taken of the soil.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, incoherent and mealy but not granular. It is low in organic matter content, averaging about 2¼ per cent.

The characteristic stratum in the subsurface varies from 3 to 10 inches in thickness and consists of a gray, grayish yellow, or yellow silt loam, somewhat mealy but becoming more coherent and clayey with depth. Only a small amount of organic matter is present.

The subsoil is a yellow or grayish mottled yellow clayey silt or silty clay, somewhat plastic when wet, but friable when only moist. Where erosion has occurred, glacial drift sometimes forms all or part of the subsoil.

This type is quite variable, due to the fact that it grades into so many different types. It is very probable that all or very nearly all of the timbered area was at one time a part of the prairie and the present character of the soil has been produced by the gradual invasion and long occupancy of forest growth. Certain trees, such as elm, hard maple, wild cherry, hackberry, and black walnut, were the first to spread over the prairie. Long periods (perhaps thousands of years) were required to produce much change in soil. Other trees followed the above, and the growth of grasses to which the accumulation of organic matter is largely due was gradually diminished by shading and growth of underbrush, after which little or no organic matter was added and incorporated with the soil. The leaves of the trees falling upon the surface were either burned or decayed completely without being mixed with the soil and gradually the organic matter content was reduced until a gray silt loam or a yellow-gray silt loam was the result. There is frequently a zone of land (too narrow to map) that represents a transition between the brown silt loam and the timber type in which the surface soil is brown or grayish brown and the subsurface is grayish brown to gray. This gives a phase of the type that is better than the average, especially as to its content of organic matter.

The topography is generally undulating to rolling, becoming in some places sufficiently rolling so that considerable washing may occur if not properly managed.

To prevent this washing, as well as to supply a deficient and much needed constituent, every practicable means should be employed to increase the organic matter content of this type. "Running together" is a fault of this soil that may thus be largely prevented.

The absence of limestone in the subsoil indicates the advisability of using limestone upon this soil in order to grow clover, alfalfa, and other legumes more successfully. The soil is also very deficient in phosphorus, which must be liberally supplied in any practicable system for the marked and profitable improvement of this soil.

Yellow Silt Loam (1135)

This type covers only 1,402 acres, or less than one percent of the total area of the county. It occurs as narrow irregular strips adjoining the bottom-lands of the Kaskaskia river, or as arms projecting into other types and marking the location of small streams that have eroded to considerable depth.

The topography is very rolling to broken, so steep in many places that it cannot be cultivated and much of it should not be, because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a grayish yellow, pulverulent, mealy silt loam, somewhat porous. Where much recent washing has taken place, the surface soil does not differ materially from the subsoil.

The typical subsurface varies considerably, depending upon the amount of washing that has taken place. In thickness it varies from 0 to 12 inches, the variation being due to the removal of the surface. In fact, in many places both surface and subsurface have been removed exposing the subsoil.

This latter consists of a compact yellow clayey silt but in places the glacial drift may form the whole or part of the subsoil, or occasionally it may even form the surface soil in small patches.

In the management of this type the chief 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 as much pasture or meadow as possible. If tilled, the land should be plowed deeply and contours should be followed as nearly as possible. Furrows extending up and down the slopes should be avoided. Planting and 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.)

Limestone can be used with profit on this type of soil where it is to be cropped or prepared for seeding down. Even top-dressings of limestone will usually help to increase the leguminous plants in the herbage of permanent pastures.

The application of phosphorus is not advised, unless special precautions are taken to prevent surface erosion; and, if used at all, the phosphorus should be mixed with the surface soil by disking and then plowed under, so as to put the phosphorus down where the plant roots feed, and thus reduce the danger of loss of applied phosphorus by erosion.

(c) SWAMP AND BOTTOM-LAND SOILS

Bottom-lands are usually named from their distances above the streams as first, second, third, etc. The first bottom represents the flood plain of the stream. The highest bottom is the oldest and shows the height to which the old valley was once filled.

Mixed Loam (1454)

The first bottom or overflow land along the streams in the county is called mixed loam. These small bottom lands vary a great deal in the kind of soil, and the areas of these different types are so small that it would be entirely impracticable to separate them. Moreover, the soils are changed by floods so that a separation of types would not mean very much after a few years. The total area is only 8,781 acres, or a little more than four percent of the area of the county.

The topography is generally flat, but occasionally an area is found that has undulating surface due to the overflow stream channels that give a little diversity to the topography.

The surface soil, 0 to 6⅔ inches, varies from a dark brown silt loam, or even clay loam, to a brown loam and light brown sandy loam. The lower and more nearly level areas are heaviest and blackest while the undulating areas are more loamy and sandy.

The subsurface soil is very similar to but lighter in color than the surface. There is sometimes no distinct line separating the subsurface from the subsoil, the only difference frequently being a lighter color. In the sandy areas the subsoil is generally more sandy, sometimes becoming a sand.

While the normal phase is only moderately rich and the lighter phase is rather low in nitrogen and phosphorus, the soil is usually very deep and thus affords a very extensive feeding range for plant roots. Drainage and protection from overflow are the considerations of first importance in dealing with this soil.

(d) TERRACE SOILS

Mixed Loam over Sand or Gravel (1554.6)

This type which forms only 1.6 percent of the area of the county, or 3,516 acres, occurs along the Kaskaskia proper and the West Fork of that stream. The areas are somewhat isolated and represent an old fill or bottom-land probably formed by the melting of the Wisconsin Glacier at a time when the river was overloaded with ground-up material from the melting glacier. The streams have later cut down thru this deposit and developed a new bottom that is from 10 to 30 feet below the terrace. Much of the material that filled this old valley was gravel and coarse sand which now form the underlying stratum of this type. The topography varies from almost level to a gentle slope and in some areas gently undulating.

The surface soil, 0 to 6 ⅔ inches, varies from a brown or yellow silt loam to a loam or sandy loam. The variations are in too small areas to permit their being shown separately on the map. As a general rule, there is more sand in the soil near the first bottom than farther back. This is probably due to the sand being blown up from the lower bottom-land.

The subsurface stratum is from 6 to 12 inches in thickness, being a light brown to yellow silt loam with variations of sand content similar to that of the surface soil.

The subsoil is a yellow silt varying to a sandy silt or sandy loam sufficiently open and pervious to allow good drainage. Underlying the subsoil at a depth of from three to six feet is a bed of gravel or sand that provides good underdrainage. In dry seasons where the gravel is nearest the surface, the crop may suffer from drouth because of the inability of the gravel to draw the moisture up from below on account of its coarseness and consequent low capillary power.

This soil is one of the poorest in the area in phosphorus, nitrogen, and organic matter, thus resembling the yellow silt loam, from which it receives some surface wash in places; but its topography is such as to justify the adoption of definite plans for improving this soil to a high state of productiveness. Large use of organic manures and liberal applications of phosphorus are the chief essentials, the addition of phosphorus being less important on the more sandy areas, because of the deep feeding range there afforded for plant roots.

In places the soil is acid and as an average the subsurface and subsoil are acid. In soils of such variable character the landowner should thoroly test the soil and subsoil for acidity, using a few cents' worth of blue litmus paper and following the directions given in Circular 110, "Ground Limestone for Acid Soils," which also contains directions for making a machine for spreading phosphate and limestone, and will be sent to any one free of charge upon application to the Agricultural Experiment Station.

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 No. 123, "The Fertility in Illinois Soils," which contains a colored general survey soil map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils."

Bulletin No. 94, "Nitrogen Bacteria and Legumes."

Bulletin No. 99, "Soil Treatment for the Lower Illinois Glaciation."

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 varieties 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 the 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 with proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils being carried in the field for this purpose.

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

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type will grade 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 25 to 50 percent 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 of 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 also be supplied 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 corresponds 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 though 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 nitrates, phosphates, 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 have 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 which thus furnish or liberate organic matter and inorganic food for bacteria, which, under such favorable conditions appear 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.

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 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 only from the soil 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 these 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 amount 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 crops):

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

Produce		Nitrogen, pounds	Phosphorus, pounds	Potassium, pounds	Magnesium, pounds	Calcium, pounds
Kind	Amount					
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2	..	2	..	..
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244*	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).

On the Fairfield Experiment Field in Wayne County, on the common prairie land of southern Illinois, yields have been obtained as high as 90 bushels per acre of corn, and 3½ tons of air-dry clover hay.

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 ($CaCO_3$ $MgCO_3$) which contains both calcium and magnesium, and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four to six years.

(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 of 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), cow-peas, 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 cow-peas, in which two catch crops and one regular crop of legumes are grown in three years.

A five-year rotation of corn (and clover), cow-peas, wheat, clover, 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 catch-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a catch-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, as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks.

(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 to six 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 are sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam, and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tend 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 land. 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 establish 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 59 years (1852 to 1910) 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 29.3 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 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 59 years (1852 to 1910) has been 14.4 bushels on untreated land, 38.6 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 41.7 bushels, but, where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average has been 43.3 bushels. Thus, as an average of 59 years, the use of sodium produced 1.8 bushels less wheat and 1.6 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 of the potassium, nitrogen, and organic matter, and about one-fourth of 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 supply 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, it 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 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 the 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.

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.

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

ADDED NOTE

WHEAT YIELDS PER ACRE ON BLOOMINGTON SOIL EXPERIMENT FIELD, 1911

(See page 17 for results of previous nine years.)

Brown silt loam prairie; Early Wisconsin glaciation		Wheat 1911, bushels	Increase from treatment	Value of increase
Plot	Soil treatment applied			
101	None	22.5	....	....
102	Lime	22.5	.0	....
103	Lime, nitrogen	25.6	3.1	$ 2.17
104	Lime, phosphorus	57.6	35.1	24.57
105	Lime, potassium	21.7	(-.8)	(-.56)
106	Lime, nitrogen, phosphorus	60.2	37.7	26.39
107	Lime, nitrogen, potassium	27.3	4.8	3.36
108	Lime, phosphorus, potassium	54.0	31.5	22.05
109	Lime, nitrogen, phosphorus, potassium	60.4	37.9	26.53
110	Nitrogen, phosphorus, potassium	61.0	38.5	26.95

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 the five nitrogen plots (103, 106, 107, 109, and 110). The effect of this is appreciable on the wheat (4.4 bushels increase, as an average), and will probably be much more marked on subsequent crops of corn. 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.

The plots on the Bloomington Field are one-fifth acre each; so that the wheat actually weighed was about 12 bushels from each of five plots, or exactly 58.6 bushels from a measured acre; and the fact should be emphasized that with the same treatment, and other conditions the same, this yield would have been produced on 50 acres as well as on one. A near-by 23-acre field of the same kind of land (but somewhat more undulating) was prepared in the same manner and seeded with the same kind of wheat at the same time; but no phosphorus had ever been applied to the land, and only 18½ bushels per acre were produced.

TEN 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, bus	37.0	41.7	4.7	$ 1.64
1903	Corn, bus	60.3	73.0	12.7	4.44
1904	Oats, bus	60.8	72.7	11.9	3.57
1905	Wheat, bus	28.8	39.2	10.4	7.28
1906	Clover, tons	.58	1.65	1.07	6.42
1907	Corn, bus	63.1	82.1	19.0	6.65
1908	Corn, bus	35.3	47.5	12.2	4.27
1909	Oats, bus	53.6	63.8	10.2	3.06
1910	Clover, tons	1.09	4.21	3.12	18.72
1911	Wheat, bus	22.5	57.6	35.1	24.57

Total value of increase in ten years....................$80.62
Total cost of phosphorus in ten years.................. 25.00
Net profit in ten years......................$55.62

After the first year, the phosphorus never failed to more than pay its annual cost; and, as an average of the last four years, $2.50 worth of phosphorus has produced as much as $250 worth of land, and with no extra work until harvest. (See pages 17 and 39 for more complete details.)

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