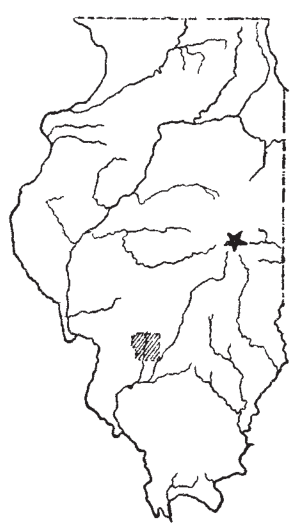
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 8

BOND COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
J. H. PETTIT, and O. S. FISHER



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INTRODUCTORY NOTE

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

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

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

BOND COUNTY SOILS

By Cyril G. Hopkins, J. G. Mosier, J. H. Pettit, and O. S. Fisher

Bond county is located nominally in the lower Illinois glaciation, but much of the area, especially the northwestern part, extends over the broad transition zone between the lower and the middle divisions of the Illinois glaciation, and for this reason some of the soil types are rather better than the average soils of the same type in southern Illinois.

This zone seems once to have been an extensive morainal region. Altho some moraines still exist as long ridges, most of them have been reduced by erosion to rounded hills, so that only 4¼ percent of the county is now covered by such formation. Other hilly lands, formed largely by stream erosion, occupy more than 16 percent of the area.

The topography of the more extensive undulating and level uplands was probably produced very largely by the influence of an ice sheet which once covered this region. Like most of the state, this county was overlain by an ice sheet during what is known as the Glacial period. During that period accumulations of snow and ice in parts of Canada became so great that they pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country, the ice gathered up all sorts and sizes of stone and earthy materials, including masses of rock, boulders, pebbles, and smaller particles. Some of these materials were carried for hundreds of miles and rubbed against the surface rocks or against each other until ground into powder. When the limit of advance was reached, where the ice largely melted, this material would accumulate in a broad undulating ridge, or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier would recede and leave the moraine of glacial drift to mark the outer limit of the ice sheet.

The ice made many advances and with each advance and recession a terminal moraine was formed. These moraines are now seen as broad ridges that vary from one to ten miles in width. Thruout the state these advances and recessions of the ice sheet left a system of terminal moraines (irregularly concentric with Lake Michigan) having generally a steep outer slope while the inner slope is longer and more gradual. (See state map in Bulletin 123.)

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

Ridges and hills were rubbed down, valleys filled, and surface features changed entirely.

As the glacier melted in its final recession, the material carried in the great mass of ice was deposited somewhat uniformly, yet not entirely so, over the intermorainal tracts, leaving extensive areas of level, undulating, or rolling plains.

The depth of glacial drift in Bond county varies from a few feet to more than 200 feet, as shown by borings for wells and mines. A thickness of 204 feet was determined by a boring in Greenville. Leverett's estimate for the average thickness of the drift in the county is 85 feet.

The lower Illinois glaciation is characterized by light-colored soils which are usually strongly acid, whereas in the middle and upper Illinois glaciations the darker colored corn-belt soils predominate.

PHYSIOGRAPHY

The highest point in Bond county, 650 feet, is in section 30, township 7 north, range 2 west, while the lowest, about 430 feet, is in the Kaskaskia bottoms in the southeast corner of the county. This gives a difference in altitude of 220 feet. The following are the altitudes in feet above sea level of some stations and towns: Greenville, 555; Hookdale, 503; Mulberry Grove, 549; Perrion, 517; Pocahontas, 498; Reno, 585; Sorento, 591; Stubblefield, 510; Smithboro, 548; Tamalco, 465; Baden Baden, 495; Old Ripley, 540; Pleasant Mound, 515.

The entire county lies in the drainage basin of the Kaskaskia or Okaw river, the general slope being from north to south. About three-fourths of the area is drained thru Shoal creek and its tributaries and thence into the Kaskaskia, while about one-fourth of the area along the east side is drained directly into the Kaskaskia by means of small tributaries. (Beaver creek is a tributary of Shoal creek.) The large streams of the county have cut valleys varying from 25 to 125 feet below the upland, the deeper ones being in the northern part of the county. These valleys have permitted considerable erosion by the small tributaries, and as a result the upland adjacent to the larger streams is usually cut up into hills and valleys unsuited to ordinary agriculture. Before the land was put under cultivation, forests had advanced up the streams and were slowly invading the prairies, thus producing a belt of timber soil along the streams.

SOIL MATERIAL AND SOIL TYPES

The Illinois glacier covered Bond county and left a thick mantle of drift, completely burying the old soil that preceded it. Then a long period elapsed, during which a soil known as the old Sangamon soil was formed on the surface of this drift. Later other ice invasions occurred, but they covered only the northern part of the state. (See state map in Bulletin 123, Iowan and Wisconsin glaciations.)

These later ice sheets did not reach Bond county, but finely ground rock (rock flour) in immense quantities was carried south by the waters from the melting ice and deposited on the flooded plains, where, when dry, it was picked up by the wind, carried farther, and finally deposited on the surface, burying the old Sangamon soil[1] to a depth of 5 to 20 feet or more. This wind-blown material,

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

called loess, is a mixture of all kinds of material over which the glacier passed. It may be recognized as a yellow, fine-grained material naturally free from glacial pebbles, usually underlain by the pebble-bearing drift.

After the loessal material was deposited over the country, the surface stratum became mixed with more or less organic matter and thus was gradually changed into soil. Surface washing has produced other changes.

The soils of Bond county are divided into the four following classes:

(1) Upland prairie soils. These were originally covered with wild prairie grasses, the partially decayed roots of which have been the chief source of the organic matter. The flat prairie land, naturally poorly drained, contains the higher amount of organic matter because the grasses and roots grew more luxuriantly there and were largely preserved from decay by the higher moisture content of the soil.

(2) Upland timber soils, including those zones along stream courses over which forests once extended. These soils contain less organic matter than the upland prairie soils, because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires or suffered almost complete decay. The timber lands may be divided roughly into three classes: the level, the undulating, and the hilly areas.

(3) Ridge soils, including those on morainal ridges, most of which have been forested. They may be divided into pervious and tight (almost impervious). The former class includes some of the best soils of the county, while the soils of the latter class are among the poorest.

(4) Bottom-land soils, including the flood plains along streams.

TABLE 1.—SOIL TYPES OF BOND COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 24)			
330	Gray silt loam on tight clay	121.49	77 754	32.66
328	Brown-gray silt loam on tight clay	61.49	39 354	16.54
329	Drab silt loam	2.46	1 574	.66
331	Deep gray silt loam	2.19	1 401	.59
325.1	Black silt loam on clay	2.48	1 587	.67
	(b) Upland Timber Soils (page 33)			
334	Yellow-gray silt loam	48.76	31 206	13.13
335	Yellow silt loam	60.09	38 458	16.15
332	Light gray silt loam on tight clay	16.45	10 528	4.42
332.1	White silt loam on tight clay	.68	435	.18
	(c) Ridge Soils (page 42)			
235	Yellow silt loam	12.41	7 942	3.33
233	Gray-red silt loam on tight clay	1.44	922	.39
245	Yellow fine sandy silt loam	1.98	1 267	.53
	(d) Bottom-Land Soils (page 44)			
1331	Deep gray silt loam	26.22	16 781	7.05
1326	Deep brown silt loam	13.74	8 794	3.70
	Total	371.88	238 003	100.00

Table 1 shows the area of each type of soil in the county, and its percentage of the total area. The accompanying map shows the location and boundary lines of every type of soil in the county, even down to areas of a few acres; and in

Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type (the plowed soil of an acre about 6⅔ inches deep). In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize the acidity existing in the soil.[1]

THE INVOICE AND INCREASE OF FERTILITY IN BOND COUNTY SOILS

SOIL ANALYSIS

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

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

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

[1]The figures given in Table 2 (and in the corresponding tables for subsurface and subsoil) are the averages for all determinations, with some exceptions of limestone or acidity present. Some soil types, particularly those which are subject to erosion, may vary from acid to alkaline, especially in the subsurface or subsoil; and in such cases abnormal results are discarded, a report of the normal conditions being more useful than any average of figures involving both plus and minus quantities.

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

As already stated, the data in Table 2 represent the total amounts of plant-food elements found in 2 million pounds of surface soil in Bond county, which corresponds to an acre about 6⅔ inches deep. This includes at least as much soil as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soils of Bond county do not contain in the plowed soil more than enough total nitrogen for the production of maximum crops for twenty-two years; while the upland timber soils contain, as an average, even less nitrogen than the prairie land.

With respect to phosphorus, the condition differs only in degree, nearly nine-tenths of the soil area of the county containing no more of that element than would be required for ten crop rotations if such yields were secured as are

TABLE 2.—FERTILITY IN THE SOILS OF BOND COUNTY

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

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay	25 620	2 640	770	27 410	4 710	5 200		560
328	Brown-gray silt loam on tight clay	29 490	2 840	670	31 040	4 590	6 210		100
329	Drab silt loam	36 400	3 640	720	29 780	6 320	7 500		120
331	Deep gray silt loam	29 460	2 840	680	24 180	3 780	4 040		960
325.1	Black silt loam on clay	56 540	4 760	1 020	32 540	9 820	15 540		20
	Upland Timber Soils								
334	Yellow-gray silt loam	26 440	2 530	470	35 500	5 870	5 320		320
335	Yellow silt loam	22 110	2 068	696	36 024	6 444	5 040		940
332	Light gray silt loam on tight clay	18 780	1 760	740	26 980	4 720	4 110		280
332.1	White silt loam on tight clay	14 860	1 360	660	30 120	4 380	5 400		1 400
	Ridge Soils								
235	Yellow silt loam	21 340	1 940	740	38 940	5 400	8 240		20
233	Gray-red silt loam on tight clay	35 700	3 600	820	25 600	7 140	6 580		400
245	Yellow fine sandy silt loam	23 120	2 650	720	39 040	5 700	9 850		30
	Bottom-Land Soils								
1331	Deep gray silt loam	33 200	3 120	1 640	37 240	9 160	7 380		80
1326	Deep brown silt loam	23 420	2 100	1 100	34 480	7 080	9 760		20

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

On the other hand, the potassium is sufficient for 20 centuries if only the grain is sold, or for 300 years even if the total crops should be removed and nothing returned. The corresponding figures are about 1,200 and 300 years for magnesium, and about 5,000 and 120 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 fact that loss by leaching is far greater than by cropping.

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

The variation among the different types of soil in Bond county with respect to their content of important plant-food elements is also very marked. Thus, the richest prairie land (black silt loam on clay) contains about twice as much phosphorus and nitrogen as the common upland timber soils; and the bottom lands are still richer in phosphorus. The most significant facts revealed by the investigation of the Bond county soils are the lack of limestone and the low phosphorus content of the common upland types, which cover nearly 90 percent of the entire county. And yet both of these deficiencies can be overcome at a relatively small expense by the application of ground limestone and fine-ground raw rock phosphate; and, after these are provided, clover can be grown and nitrogen thus secured from the inexhaustible supply in the air. If the clover were then returned to the soil, either directly or in farm manure, the combined effect of limestone, phosphorus, and nitrogenous organic matter, with a good rotation of crops, would in time double or treble the yield of wheat, corn, and other crops, on most farms.

Until the supply of decaying organic matter has been made adequate, some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter. The evidence thus far secured, however, indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for decaying organic matter, which contains some potassium and liberates additional supplies from the soil.

Fortunately, some definite field experiments have already been conducted on some of these most extensive types of soil in the lower Illinois glaciation, as at DuBois in Washington county, at Fairfield in Wayne county, and at Raleigh in Saline county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of southern Illinois.

Results of Field Experiments at DuBois

In Tables 3 and 4 are recorded some exceedingly valuable and instructive data. These results have been secured by twelve years of actual trial on the most common type of soil in Bond county, gray silt loam on tight clay, which is also a very common type in Washington county, where the DuBois experiment field is located.

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS, DUBOIS FIELD: NOT TILE-DRAINED

Plot	Gray silt loam on tight clay; lower Illinois glaciation / Soil treatment applied	Corn 1902	Oats 1903	Wheat 1904	Clover 1905	Corn 1906	Oats 1907	Wheat 1908	Soybeans 1909	Corn 1910	Oats 1911	Clover 1912[1]	Wheat 1913
		Bushels or tons per acre											
101	None	6.4	9.4	6.3	1.25	30.3	18.8	.8	3.5	25.8	13.1	.46	7.7
102	Lime	6.7	16.2	6.5	1.57	35.2	28.8	8.0	6.7	26.2	24.1	40	8.7
103	Lime, crop res.	5.9	18.1	11.0	1.78	38.0	38.1	8.5	7.2	33.6	31.9	(.92)	14.7
104	Lime, phos.	13.4	25.9	25.0	2.42	38.7	43.8	17.8	8.5	17.6	40.9	1.02	21.0
105	Lime, potas.	11.6	27.5	16.2	2.22	48.8	37.2	14.8	9.3	65.6	29.1	.81	16.8
106	Lime, res., phos.	9.3	25.0	32.7	2.30	32.3	46.6	19.8	8.2	30.0	35.9	(2.42)	29.7
107	Lime, res., potas.	6.8	23.8	20.2	2.34	43.6	43.8	16.5	7.8	67.6	29.1	(3.92)	21.0
108	Lime, phos., potas.	12.4	30.0	27.5	2.86	48.9	50.0	20.8	9.5	73.2	35.3	1.34	30.2
109	Lime, res., phos., potas.	10.4	29.1	33.3	2.83	46.3	46.6	19.7	7.8	73.2	38.8	(3.00)	30.2
110	Res., phos., potas.	2.0	25.6	27.3	2.59	39.9	36.9	10.0	6.3	66.8	26.6	(1.67)	10.7
	Average Increase: Bushels or Tons per Acre												
	For lime	.3	6.8	.2	.32	4.9	10.0	7.2	3.2	.4	11.0	-.06	1.0
	For residues	-.8	1.9	4.5	.21	2.8	9.3	.5	.5	7.4	7.8	.52	6.0
	For phosphorus	6.7	9.7	18.5	.85	3.5	15.0	9.8	1.8	-8.6	16.8	.62	12.3
	For potassium	4.9	11.3	9.7	.65	13.6	8.4	6.8	2.6	39.4	5.0	.41	8.1
	For res., phos. over phos.	-4.1	-.9	7.7	-.12	-6.4	2.8	2.0	-.3	12.4	-5.0	1.40	8.7
	For phos., res. over res.	3.4	6.9	21.7	.52	-5.7	8.5	11.3	1.0	-3.6	4.0	1.50	15.0
	For potas., res., phos. over res., phos.	1.1	4.1	.6	.53	14.0	0.0	-.1	-.4	43.2	2.9	.58	.5

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
101	None	$58.39	
102	Lime	79.33	$20.94
103	Lime, residues	100.88	42.49
104	Lime, phosphorus	131.37	72.98
105	Lime, potassium	133.18	74.79
106	Lime, residues, phosphorus	151.37	92.98
107	Lime, residues, potassium	156.06	97.67
108	Lime, phosphorus, potassium	171.32	112.93
109	Lime, residues, phosphorus, potassium	180.83	122.44
110	Residues, phosphorus, potassium	130.23	71.84

Value of Increase per Acre in Twelve Years		Cost of increase
For lime	$20.94	$10.00?
For residues	21.55	?
For phosphorus	52.04	30.00
For *residues* and phosphorus over phosphorus	20.00	?
For *phosphorus* and residues over residues	50.48	30.00
For *potassium*, residues, and phosphorus over residues and phosphorus	29.46	30.00

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

Has tile drainage been profitable? There are 120 comparisons which bear on the answer to this question, and the average of all these results summarized in terms of value shows that the tile drainage has paid $5.59 per acre in twelve years, or 47 cents per acre for each year; whereas it would require at least $1.20 an acre a year to pay 6 percent interest on the cost of the tile drainage, the lines of tile being laid five rods apart at a cost of not less than $20 per acre.

TABLE 4.—CROP YIELDS IN SOIL EXPERIMENTS, DUBOIS FIELD: TILE-DRAINED

Gray silt loam on tight clay; lower Illinois glaciation		Corn 1902	Oats 1903	Wheat 1904	Clover 1905	Corn 1906	Oats 1907	Wheat 1908	Soybeans 1909	Corn 1910	Oats 1911	Clover 1912[1]	Wheat 1913
Plot	Soil treatment applied	Bushels or tons per acre											
111	None	1.4	17.2	3.3	1.29	32.5	13.1	4.3	3.3	27.4	12.2	.40	6.7
112	Lime	3.3	17.2	11.5	1.72	33.6	23.8	11.0	6.2	29.0	19.4	.66	16.5
113	Lime, crop res.	2.7	20.6	9.2	1.79	31.7	30.0	14.5	6.7	36.6	27.2	(1.83)	21.5
114	Lime, phos.	6.5	27.5	28.3	2.27	29.7	31.9	19.2	7.2	22.2	30.9	.71	22.8
115	Lime, potas.	4.9	27.2	14.7	2.16	47.5	46.3	16.2	7.8	64.2	26.6	.85	21.8
116	Lime, res., phos.	8.0	33.8	31.2	2.44	30.5	45.9	19.5	8.8	39.4	35.6	(2.50)	37.2
117	Lime, res., potas.	7.3	27.2	23.3	2.52	48.3	39.1	18.5	10.2	74.6	32.2	(2.75)	28.8
118	Lime, phos., potas.	14.1	25.6	32.2	2.95	55.2	44.4	23.0	10.3	76.4	33.4	1.31	30.8
119	Lime, res., phos., potas.	10.4	31.9	30.5	2.89	51.6	42.2	21.3	11.3	75.8	38.8	(2.33)	29.5
120	Res., phos., potas.	4.8	33.1	28.2	2.79	50.7	35.3	12.0	6.7	65.4	28.1	(1.83)	24.0
Average Increase: Bushels or Tons per Acre													
For lime		1.9	.0	8.2	.43	1.1	10.7	6.7	2.9	1.6	7.2	.26	9.8
For residues		–.6	3.4	–2.3	.07	–1.9	6.2	3.5	.5	7.6	7.8	1.17	5.0
For phosphorus		3.2	10.3	16.8	.55	–3.9	8.1	8.2	1.0	–6.8	11.5	.05	6.3
For potassium		1.6	10.0	3.2	.44	13.9	22.5	5.2	1.6	35.2	7.2	.19	5.2
For res., phos. over phos.		1.5	6.3	2.9	.17	.8	14.0	.3	1.6	17.2	4.7	1.79	14.4
For phos., res. over res.		5.3	13.2	22.0	.65	–1.2	15.9	5.0	2.1	2.8	8.4	.67	15.7
For potas., res., phos. over res., phos.		2.4	–1.9	–.7	.45	21.1	–3.7	1.8	2.5	36.4	3.2	–.17	–7.7

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
111	None	$ 57.66	
112	Lime	88.97	$ 31.31
113	Lime, residues	108.25	50.59
114	Lime, phosphorus	121.82	64.16
115	Lime, potassium	133.59	75.93
116	Lime, residues, phosphorus	161.83	104.17
117	Lime, residues, potassium	166.36	108.70
118	Lime, phosphorus, potassium	178.08	120.42
119	Lime, residues, phosphorus, potassium	181.63	123.97
120	Residues, phosphorus, potassium	150.62	92.96

Value of Increase per Acre in Twelve Years		Cost of increase
For lime	$31.31	$10.00?
For residues	19.28	?
For phosphorus	33.85	30.00
For *residues* and phosphorus over phosphorus	40.01	?
For *phosphorus* and residues over residues	53.58	30.00
For *potassium*, residues, and phosphorus over residues and phosphorus	19.80	30.00

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

Is the application of lime and phosphorus of benefit on this type of soil? The answer to this question is found in the fact that the value of the twelve crops on the untreated land amounted to only $58.02, whereas the value of the increase produced by lime and phosphorus was $68.58, as an average of the two series. In other words, this treatment has resulted in an increase greater than the crop produced by the unaided land, raising the crop values from $58.02 to $126.60, counting corn at 35 cents a bushel, oats at 30 cents, wheat at 70 cents, hay at $6 a ton, clover seed at $6 a bushel, and soybeans at $1 a bushel—prices that are probably sufficiently below the ten-year average to provide for the expense of application and of harvesting and marketing the increase. It should be stated, too, that the application of lime and phosphorus has produced a marked improvement in the quality of the crops (especially in the wheat and clover), for which credit is not given in these values.

The materials used per acre in these experiments were as follows: 5 tons of slaked burned lime (applied only at the beginning of the experiments), 2400 pounds of steamed bone meal (800 pounds for each four-year rotation), and 1200 pounds of potassium sulfate (400 pounds for each rotation). Other investigations (reported in Circulars 110, 127, 157, 165, and 168) have shown that ground natural limestone and fine-ground natural rock phosphate are more economical and profitable forms of lime and phosphorus, and that the same effect produced by potassium sulfate can also be secured at much less expense either by means of decaying organic matter (from crop residues, green-manure crops, or farm manure), or by the use of less expensive soluble salts, such as kainit, as shown in the Appendix. If ground limestone had been used on the DuBois field, $10 would have paid for the full equivalent of the slaked lime applied, and allowing $30 for the bone meal (its actual cost), we find that the increase produced has paid for the materials and left a net profit of $2.38 per acre per annum, or 70 percent above the cost. As an average of both series, lime alone has paid back $26.12 per acre in twelve years, and phosphorus used in addition to lime and crop residues has paid back $52.03. Furthermore, about one-third of the lime applied and at least two-thirds of the phosphorus applied still remain in the soil for the benefit of future crops.

The potassium (kalium) applied during the twelve years has cost $30, and when applied in addition to lime, phosphorus, and crop residues, it has produced increases valued at $24.63, leaving a loss of 45 cents per acre per annum. Furthermore, the potassium removed is equal to the total amount applied.

On five duplicate plots in the DuBois field commercial nitrogen was used either alone or with other elements during the first three years, but at a large financial loss and with no apparent residual effect. Since 1907, a system has been adopted for these plots which supplies both nitrogen and organic matter by means of crop residues. A study of the detailed results shows an increasing effect from the organic matter thus supplied. The value of the increase produced by the crop residues during the last rotation (four years) was $13.89 per acre where they were used over lime, and $22.79 where they were used over both lime and phosphorus, this representing the average of the two series of plots. The corresponding figures for the gross return from $45 worth of commercial nitrogen used during the first rotation are $2.16 and $4.21.

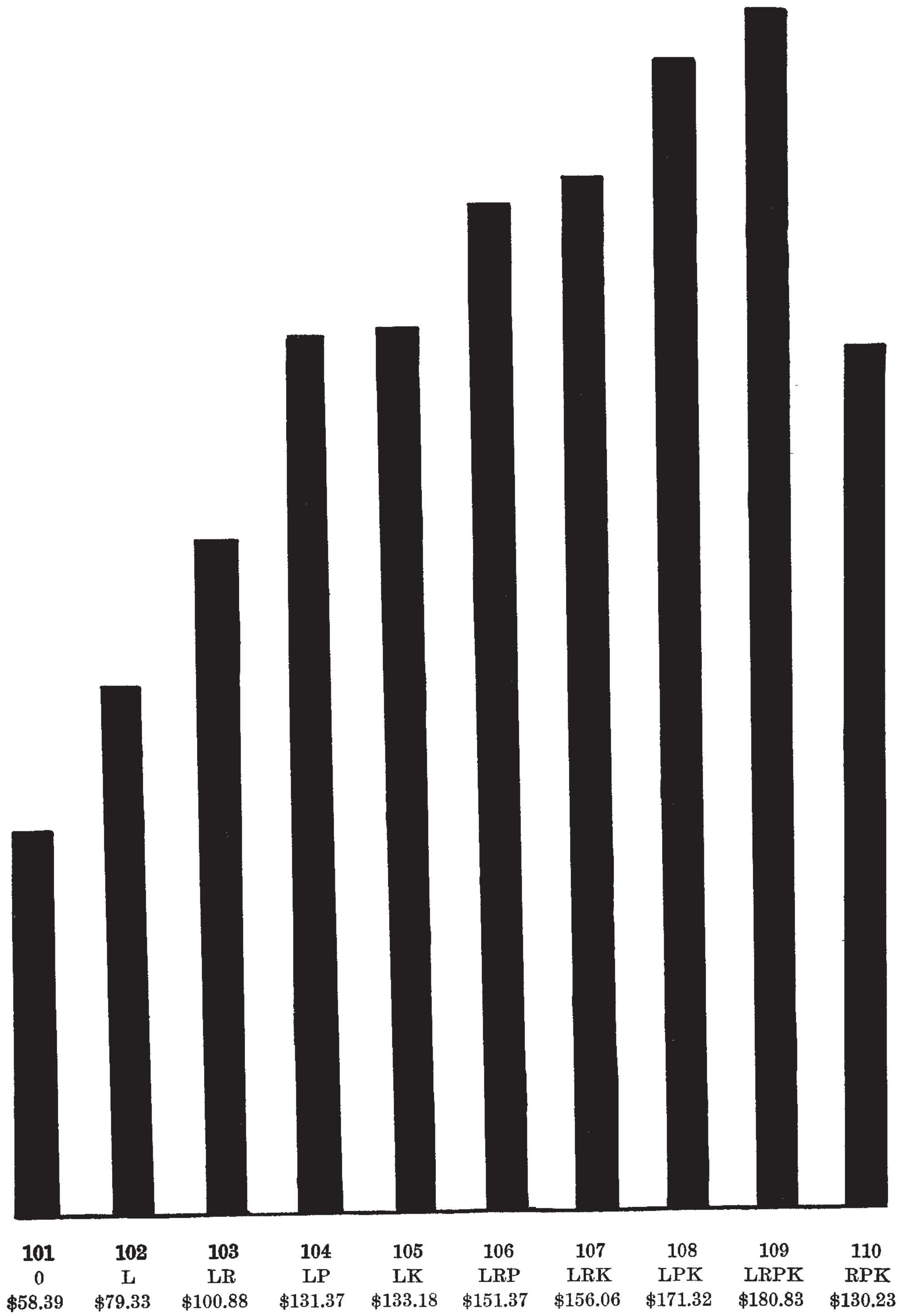

PLATE 1.—CROP VALUES FOR TWELVE YEARS
DUBOIS EXPERIMENT FIELD; LAND NOT TILE-DRAINED

(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium)

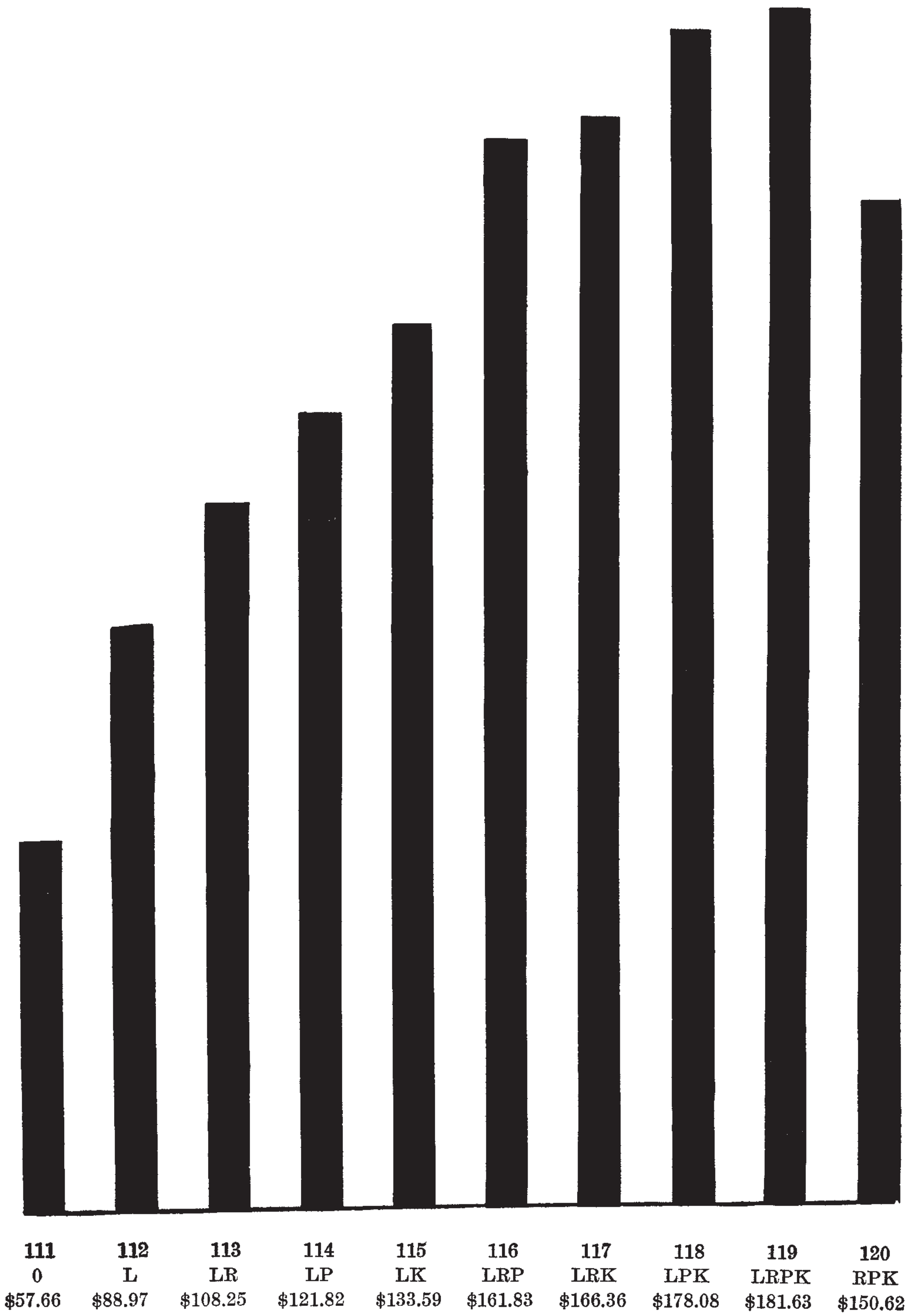

PLATE 2.—CROP VALUES FOR TWELVE YEARS
DUBOIS EXPERIMENT FIELD; LAND TILE-DRAINED
(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium)

It should be kept in mind that the first clover to be plowed under on the DuBois field was in 1912, the system of supplying nitrogen in crop residues having been practiced only since 1907, and the clover having failed in 1908 owing to drouth. The small soybean crop of 1909 furnished but little straw, and the other straw and corn stalks are of slow action, so that final conclusions cannot yet be drawn as to the benefit of crop residues when the system is fully under way. Of course these organic residues are provided not only to furnish nitrogen, but also to aid the liberation of mineral plant food, especially potassium. In this connection a study of the effect of potassium is important.

It is an interesting fact that in aggregate value and on the corn crop, potassium has produced thus far an even larger benefit than phosphorus. Either one of these elements has paid well when used without the other; whereas neither has paid its cost when used in addition to the other.

The soil type of the DuBois field contains in 2 million pounds of surface soil about 800 pounds of phosphorus and 25,000 pounds of potassium. After limestone and organic matter carrying nitrogen have been supplied, phosphorus is the only addition that is absolutely essential for the maintenance of plant food in permanent rational systems of farming.

A summary of the twelve years' results shows, as an average of the two series, a crop value of $58.02 per acre from the unfertilized land, and increased values as follows:

For lime alone	$ 26.12	or	45	percent
For nitrogen and organic matter over lime	20.41	or	24	percent
For phosphorus as a further addition	52.03	or	50	percent
For potassium as a final addition	24.63	or	16	percent
For total increase over untreated land	$123.19	or	212	percent

Thus arranged, the field results are in harmony with what might be expected from the chemical composition of the soil. It should be noted that, of the $24.63 credited to potassium, $13.93, or more than half, is due to its very marked effect upon the corn crop of 1910, when the corn on all potassium plots seemed to possess unusual power of resistance against adverse conditions, including an attack by chinch bugs. The corn crop of 1906 also showed benefit from potassium, $6.14. Thus $20.07, or four-fifths of the benefit, was produced in two of the twelve crops. With the inadequate supply of active organic matter thus far provided, potassium applied without phosphorus seems to have influenced the liberation of phosphorus from the soil itself, so that the benefit of this stimulating action, combined with the possible direct benefit of soluble potassium applied for its own sake, has exceeded temporarily the direct benefit of applied phosphorus. It must be plain, however, that no system can be permanent which does not provide for the application of phosphorus; and that if one desires to make the most rapid progress in the improvement of such soil, he should use limestone, phosphorus, and kainit, until the supply of organic manures becomes sufficient to render the continued use of kainit unprofitable. From the information given in the Appendix, it will be seen that kainit produces greater benefit than potassium sulfate, and at less expense; so that, while potassium sulfate in addition to phosphorus has been used with loss on the DuBois field, if kainit were substituted for sulfate it might add to the total profits, at least until the soil could be well filled with active organic matter from crop residues or farm manure.

The beneficial effect of soluble potassium where no phosphorus has been added, over a period of twelve years, on the DuBois field, and the fact that sodium, an element which has no value as plant food, produced exactly the same increase as potassium over a period of twice twelve years on Broadbalk field at Rothamsted, only support the following statement quoted on page 208 of Bulletin 123, "The Fertility in Illinois Soils".

"In considering the general subject of culture experiments for determining fertilizer needs, emphasis must be laid on the fact that such experiments should never be accepted as the sole guide in determining future agricultural practice. If the culture experiments and the ultimate chemical analysis of the soil agree in the deficiency of any plant-food element, then the information is conclusive and final; but if these two sources of information disagree, then the culture experiments should be considered as tentative and likely to give way with increasing knowledge and improved methods to the information based on chemical analysis, which is absolute."[1]

RESULTS OF FIELD EXPERIMENTS AT FAIRFIELD

The Fairfield experiment field is divided into four tracts of ten acres each, and cultivated in a four-year rotation, consisting of corn, cowpeas or soybeans, wheat, and clover. If the clover fails, cowpeas or soybeans may be substituted for that season; if the winter wheat fails, oats may be substituted in the spring.

One half of the field, or twenty acres, is tile-drained, while the other half has only the ordinary surface drainage as commonly provided by plowing in rather narrow lands and keeping the middle furrows open. On both the tiled and the untiled land grain farming is practiced on one half and live-stock farming on the other half. A part of each of these divisions is treated with two tons of limestone and one ton of fine-ground raw rock phosphate, per acre, every four years, while another part is not so treated.

In the system of grain farming, all produce except the grain or seed is returned to the land, while in the live-stock farming all produce (or its equivalent) is used for feed and bedding and the manure returned to the land in proportion to the crop yields produced during the previous rotation. Thus, if the land treated with manure, limestone, and phosphate produces, as an average in one rotation, one-half larger crops than the land which receives manure alone, then one-half more manure is applied to that land for the following rotation. Likewise, in the grain system, the clover and other crop residues returned are in proportion to the yield produced during the rotation on the respective parts of the field. It should be stated that during the first rotation the manure was applied in the same amount (8 tons per acre) on all fields in the live-stock system.

The regular plan is to apply the phosphate and plow it under with manure or other organic matter, and to apply the limestone immediately after the ground is plowed for wheat, in order that the limestone may be mixed with the surface soil in the preparation of the seed-bed where clover is to be seeded the following

[1]Taken from "Culture Experiments for Determining Fertilizer Needs," by C. G. H. in Cyclopedia of American Agriculture, Volume I, page 475.

spring. However, the time and method of application are very secondary matters; the important thing is to get the limestone and phosphate on the land and well mixed with the plowed soil, altho it is better to mix one with the soil before applying the other, because when applied in intimate contact with each other the limestone tends temporarily to lessen the availability of the phosphorus, probably by immediately neutralizing the nitric, carbonic, and organic acids produced in the decay of organic matter.

At $1.25 a ton for limestone and $7.50 a ton for rock phosphate, the cost of those materials for four years amounts to $10 an acre. After three or four rotations, however, the phosphate applications will be reduced to about one-half ton, which will reduce the annual expense to about $1.50 per acre. This expense would be practically covered by an increase of 4 bushels of corn, 1½ bushels of cowpeas or soybeans, 2 bushels of wheat, or ¼ ton of hay, at very moderate prices.

In Tables 5, 6, 7, and 8 are recorded the crop yields obtained since experiments were begun on four different series of plots on the Fairfield field.[1] Only two series were under experiment during the first year (1905), and all the first four years are to be considered as preliminary, in part because of the impossibility of securing the ordinary benefits of a four-year rotation during the first rotation period, in part because during the first four years, in the live-stock system, the manure was applied uniformly regardless of crop yields, and, in particular, because the present plan of returning crop residues was not begun until the end of the first four years, whereas the use of manure was begun the

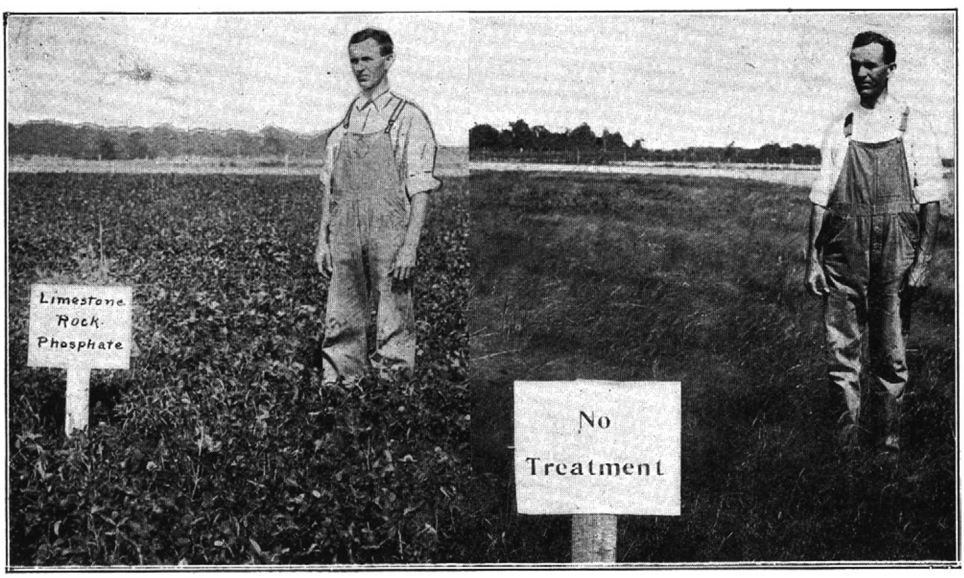

PLATE 3.—CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. (THE FIRST CROP, SHOWN IN PHOTOGRAPHS, WAS CLIPPED AND LEFT ON THE LAND; THE SECOND CROP PRODUCED NO CLOVER SEED ON THE UNTREATED LAND, BUT 1⅕ BUSHELS WERE HARVESTED WHERE THE LIMESTONE AND PHOSPHATE WERE APPLIED WITH NO POTASSIUM SALTS)

[1]Other parts of this experiment field are used for investigations relating to crop production, such as the testing of varieties.

first year (1905) on Series 100, the second year (1906) on Series 400, the third year (1907) on Series 300, and the fourth year (1908) on Series 200.

In the fall and winter of 1905-06 a system of tiling with a good grade and a satisfactory outlet was laid. Four-inch tiles were placed only four rods apart, the two lines on the east half of each series about 20 to 24 inches deep and the two on the west half about 36 to 40 inches deep. Before the ditches were filled, the tile in Series 400 was covered with about 4 inches of gravel, that in Series 300 with 4 inches of cinders, and that in Series 200 with 6 inches of straw. In Series 100 the tile was covered with only the natural dirt. Some of the tiled land of this field is more nearly level than the untiled land, altho the entire field is what would be called level prairie land.

As an average of all results reported in Tables 5, 6, 7, and 8, from these four series of plots, the tile drainage has paid $9.11 per acre in eight years, or $1.14 per acre for each year; whereas it would require at least $1.50 an acre a year to pay 6 percent interest on the cost of the tile drainage, which was not less than $25 per acre. It may be added, however, that for the last four years the average increased value resulting from tiling has been $1.80 per acre per year, which would pay a fair rate of interest on the investment if the cost of tiling did not exceed $30 per acre.

While it is very possible that, with the continued use of clover (the "best subsoiler") in the rotation, the tile drainage may ultimately prove to be a profitable investment, it is plain that the first requisites for the improvement of this soil are limestone, phosphorus, and organic matter.

PLATE 4.—CLOVER ON FAIRFIELD EXPERIMENT FIELD, 1910. (THE FIRST CROP, SHOWN IN PHOTOGRAPH, MADE ⅗ TON OF FOUL GRASS WITH BUT LITTLE CLOVER WHERE MANURE ALONE WAS USED, AND 2⅔ TONS OF CLEAN CLOVER HAY WHERE THE SAME AMOUNT OF MANURE WAS USED WITH LIMESTONE AND PHOSPHATE WITH NO POTASSIUM SALTS)

TABLE 5.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 100

Plot	Gray silt loam on tight clay; lower Illinois glaciation — Soil treatment applied	Corn 1905	Soybeans 1906	Wheat 1907	Clover 1908	Corn 1909	Soybeans 1910	Wheat 1911	Clover[1] 1912	Value 1st 4 years	Value 2d 4 years
		Bushels or tons per acre								Value per acre	
	Land Tile-drained										
103	Residues, limestone, phosphorus	26.5	1.0	15.1	1.03	31.2	20.1	13.2	(.35)	$27.03	$42.36
106	Residues, limestone, phosphorus	43.5	1.3	15.6	1.03	33.7	21.6	16.1		33.62	46.77
109	Crop residues	51.3	1.4	11.8	.90	48.5	18.5	4.8	(.15)	33.02	39.74
110	Farm manure	57.0		3.8	.65	39.4	18.1	5.3	.70	27.91	39.80
113	Manure, limestone, phosphorus	57.0		19.8	1.55	39.0	26.6	25.6	2.21	43.11	71.43
116	Manure, limestone, phosphorus	67.5	2.9	17.9	1.23	41.6	26.2	26.3		46.44	72.43
	Land not Tile-drained										
123	Residues, limestone, phosphorus	26.6	.8	13.1	.90	37.9	20.8	11.1	(.39)	$24.68	$44.17
126	Residues, limestone, phosphorus	28.4	1.8	8.4	1.33	25.3	19.5	4.2		25.60	33.64
129	Crop residues	13.1		0.0	.67	17.7	10.3	.7	(.00)	8.61	16.98
130	Farm manure	47.0		1.5[2]	.64	18.7	10.8	.7	.34	21.34	19.88
133	Manure, limestone, phosphorus	59.6	.5	12.0	1.80	30.0	20.2	10.6	1.73	40.56	48.50
136	Manure, limestone, phosphorus	59.1	.8	14.3	1.55	36.9	21.8	18.3		40.86	57.91
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	31.2	1.2	13.0	1.07	32.0	20.5	11.1	(.37)	$27.73	$41.73
	Crop residues	32.2	.7	5.9	.79	33.1	14.4	2.8	(.08)	20.82	28.36
	Farm manure	52.0	.7	2.7	.65	29.0	14.4	3.0	.52	24.63	29.84
	Manure, limestone, phosphorus	60.8	1.0	16.0	1.53	36.9	23.7	20.2	1.97	42.74	62.57
	Organic manures, limestone, phosphorus	46.0	1.1	14.5	1.30	34.4	22.1	15.7		$35.23	$52.15
	Organic manures	42.1	.7	4.3	.72	31.0	14.4	2.9		22.72	29.10
	Increase due to limestone and phosphorus	3.9	.4	10.2	.58	3.4	7.7	12.8		$12.51	$23.05

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

[2] Estimated.

Table 6.—Crop Yields in Soil Experiments Fairfield Field: Series 200

Plot	Gray silt loam on tight clay; lower Illinois glaciation	Soybeans 1905	Wheat 1906	Clover[1] 1907	Corn 1908	Cowpeas 1909	Wheat 1910	Clover[2] 1911	Corn 1912	Value 1st 4 years	Value 2d 4 years
Plot	Soil treatment applied	Bushels or tons per acre								Value per acre	
	Land Tile-drained										
203	Residues, limestone, phosphorus	3.0	1.3	.47	22.4	3.9	29.41	(.00)	40.7	$14.57	$38.72
206	Residues, limestone, phosphorus	2.4		.52	22.2	3.9	30.0	(.00)	38.1	14.20	38.23
209	Crop residues	3.3	.3	.20	28.5	8.3	20.2	(.00)	22.3	14.69	30.25
210	Farm manure	1.6	1.2	.51	37.9	8.4	20.9	.41[3]	22.3	18.76	33.30
213	Manure, limestone, phosphorus	1.8	2.8	.90	39.0	6.6	38.1	.99	60.6	22.81	60.42
216	Manure, limestone, phosphorus	1.8	2.0	.78	35.3	6.8	36.8		54.5	20.23	57.57
	Land not Tile-drained										
223	Residues, limestone, phosphorus	2.7	2.8	.80	30.9	11.6	31.6	(.00)	29.7	$20.28	$44.11
226	Residues, limestone, phosphorus	2.9	1.2	.76	21.2	4.9	28.6	(.00)	7.4	15.72	27.51
229	Crop residues	2.2		.61	15.6	3.8	7.2	(.00)	1.6	11.32	9.40
230	Farm manure	1.6	1.6	.66	30.3	6.4	16.4	.39[3]	4.0	17.29	21.62
233	Manure, limestone, phosphorus	.8	1.1	.85	38.3	7.7	35.2	.85	22.0	20.07	45.14
236	Manure, limestone, phosphorus	2.9	5.3	1.20	40.4	7.1	36.7		23.8	27.95	46.22
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	2.8	1.7	.64	24.2	6.1	29.9	(.00)	29.0	$16.19	$37.14
	Crop residues	2.8	.1	.40	22.0	6.0	13.7	(.00)	12.0	13.00	19.83
	Farm manure	1.6	1.4	.59	34.1	7.4	18.7	.40	13.1	18.02	27.46
	Manure, limestone, phosphorus	1.8	2.8	.93	38.2	7.0	36.7	.92	40.2	22.77	52.34
	Organic manures, limestone, phosphorus	2.3	2.2	.79	31.2	6.6	33.3		34.6	$19.48	$44.74
	Organic manures	2.2	.8	.49	28.0	6.7	16.2		12.6	15.51	23.65
	Increase due to limestone and phosphorus	.1	1.4	.30	3.2	−.1	17.1		22.0	$ 3.97	$21.09

[1] Mostly redtop.

[2] Figures in parentheses indicate bushels of seed; the others tons of hay.

[3] Mostly weeds and foul grass.

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 300

Plot	Gray silt loam on tight clay; lower Illinois glaciation — Soil treatment applied	Clover 1906	Corn 1907	Cowpeas 1908	Oats 1909	Clover[1] 1910	Corn 1911	Soybean hay 1912	Wheat 1913	Value 1st 4 years	Value 2d 4 years
		Bushels or tons per acre								Value per acre	
	Land Tile-drained										
303	Residues, limestone, phosphorus	.09	40.8	5.7	37.5	(1.45)	34.3	1.58	14.3	$31.77	$40.19
306	Residues, limestone, phosphorus	.15	37.2	9.6	34.2		34.9	1.80	14.3	33.78	41.72
309	Crop residues	.10	32.1	4.7	25.8	(.00)	25.9	.53	.6	24.27	12.67
310	Farm manure	.25	35.3	5.4	30.8	.76[2]	30.5	1.29	3.1	28.49	25.15
313	Manure, limestone, phosphorus	.40	50.5	10.3	30.2	3.94	39.8	1.66	19.8	39.44	61.39
316	Manure, limestone, phosphorus	.48	48.5	12.7	44.4		36.6	2.68	25.7	45.88	70.52
	Land not Tile-drained										
323	Residues, limestone, phosphorus	.49	39.0	8.4	33.6	(1.95)	34.0	1.87	14.0	$35.07	$44.62
326	Residues, limestone, phosphorus	.51	51.8	9.5	37.8		39.2	1.56	17.0	42.03	46.68
329	Crop residues	.20	34.2	5.3	29.9	(.00)	24.2	.97	2.2	27.44	15.83
330	Farm manure	.39	42.1	7.4	34.2	1.06[2]	31.8	.99	3.2	34.74	25.67
333	Manure, limestone, phosphorus	.40	52.7	9.0	32.5	3.71	34.0	2.15	15.0	39.59	57.56
336	Manure, limestone, phosphorus	.56	52.0	9.7	47.5		28.8	2.04	16.6	45.51	56.20
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	.31	42.2	8.3	35.8	(1.70)	35.6	1.70	14.9	$35.66	$43.31
	Crop residues	.15	33.1	5.0	27.9	(.00)	25.0	.75	1.4	25.86	14.25
	Farm manure	.32	38.7	6.4	32.5	.92	31.0	1.14	3.1	31.62	25.41
	Manure, limestone, phosphorus	.46	50.9	10.4	38.7	3.82	34.8	2.13	19.3	42.61	61.42
	Organic manures, limestone, phosphorus	.38	46.6	9.3	37.2		35.2	1.92	17.1	$39.13	$52.36
	Organic manures	.23	35.9	5.7	30.2		28.0	.94	2.2	28.74	19.83
	Increase due to limestone and phosphorus	.15	10.7	3.6	7.0		7.2	.98	14.9	$10.39	$32.53

[1] Figures in parentheses indicate bushels of seed; the others tons of hay.

[2] Mostly weeds and foul grass.

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, FAIRFIELD FIELD: SERIES 400

Gray silt loam on tight clay; lower Illinois glaciation		Corn 1906	Cowpeas 1907	Wheat 1908	Cowpeas 1909	Corn 1910	Soybeans 1911	Wheat 1912	Soybeans 1913	Value 1st 4 years	Value 2d 4 years
Plot	Soil treatment applied	Bushels per acre								Value per acre	
	Land Tile-drained										
403	Residues, limestone, phosphorus	34.8	3.5	16.0	5.0	55.1	10.6	12.5	9.9	$31.88	$48.53
406	Residues, limestone, phosphorus	38.2	3.1	14.0	7.2	60.9	12.4	13.2	10.5	33.47	53.45
409	Crop residues	32.6	3.2	5.3	7.2	44.4	11.5	1.7	9.9	25.52	38.13
410	Farm manure	41.0	3.4	10.6	6.9	43.8	10.2	2.1	9.3	32.07	36.30
413	Manure, limestone, phosphorus	50.8	8.2	21.8	6.7	66.9	14.7	13.3	12.2	47.94	59.62
416	Manure, limestone, phosphorus	49.2	7.7	21.3	6.5	64.9	15.2	13.1	11.7	46.33	58.79
	Land not Tile-drained										
423	Residues, limestone, phosphorus	47.2	8.0	14.9	5.8	60.9	11.7	14.0	13.4	$40.75	$56.21
426	Residues, limestone, phosphorus	38.6	2.4	10.0	4.8	57.7	13.4	9.3	11.0	27.71	51.10
429	Crop residues	33.0	1.8	2.8	6.5	37.6	9.1	1.0	7.5	21.81	30.46
430	Farm manure	40.3	2.2	1.4	5.4	47.5	8.8	1.1	8.2	22.68	34.40
433	Manure, limestone, phosphorus	48.8	6.6	15.1	4.7	63.6	10.6	13.6	11.4	38.95	53.78
436	Manure, limestone, phosphorus	53.0	4.3	16.3	6.0	65.1	15.5	10.4	12.1	40.26	57.67
	Average of both Tiled and Untiled Land										
	Residues, limestone, phosphorus	39.7	4.2	13.7	5.7	58.7	12.0	12.2	11.2	$33.45	$52.32
	Crop residues	32.8	2.5	4.0	6.9	41.0	10.3	1.3	8.7	23.67	34.29
	Farm manure	40.7	2.8	6.0	6.1	45.7	9.5	1.6	8.8	27.37	35.35
	Manure, limestone, phosphorus	50.4	6.7	18.6	6.0	65.1	14.0	12.6	11.9	43.37	57.47
	Organic manures, limestone, phosphorus	45.0	5.4	16.1	5.9	61.9	13.0	12.4	11.6	$38.41	$54.90
	Organic manures	36.8	2.7	5.0	6.5	43.3	9.9	1.4	8.8	25.52	34.82
	Increase due to limestone and phosphorus	8.2	2.7	11.1	-.6	18.6	3.1	11.0	2.8	$12.89	$20.08

As a general average of both systems of farming on both the tiled and the untiled land, on all series, the increases produced by limestone and phosphorus during the first rotation were valued at $9.94[1] an acre, or about the cost of these materials delivered at most railroad stations in southern Illinois. The values of the increases in the second rotation averaged $24.19, or nearly two and one-half times the cost of the second application of both limestone and phosphate. These increases should be still further augmented in the third rotation because of the larger amount of organic manures to be returned to the better yielding land and because of the continued positive enrichment of the soil in phosphorus and limestone.

During the first four years, the limestone and phosphate, costing $10, produced a gain valued at $7.42 when applied without organic matter, and a gain of $12.46 when applied with farm manure; and during the second four years the increases due to $10 worth of limestone and phosphate were valued at $19.44 when applied with crop residues and $28.93 when applied with farm manure. By referring to the Appendix (page 57), it will be seen that on the Fairfield field potassium salts have produced almost no effect when used in connection with farm manure; whereas the largest effect thus far secured from limestone and phosphate has been obtained where these materials are applied with farm manure. It will be noted, however, that their effect was greater with crop residues during the second rotation than with farm manure during the first. Since the use of crop residues in these experiments was not begun until four years after the first application of manure, no conclusion is justified as to whether the residue system or the manure system will ultimately prove best for this soil. The important thing is that the soil can be profitably enriched by either. A cross comparison of the average crop values of the four series of plots shows the value of four crops as $25.41 with the use of farm manure and $24.18 with the use of crop residues, and perhaps this is reasonably trustworthy. Where limestone and

TABLE 9.—CROP VALUES PER ACRE, FAIRFIELD EXPERIMENT FIELD

First Rotation: Average of Four Series				
Soil treatment	None	Farm manure	Limestone Phosphate	Farm manure Limestone Phosphate
Value of four crops	$20.84	$25.41	$28.26	$37.87
Second Rotation: Average of Four Series				
Soil treatment	Crop residues	Farm manure	Crop residues Limestone Phosphate	Farm manure Limestone Phosphate
Value of four crops	$24.18	$29.51	$43.62	$58.45

[1]Attention is here called to the fact reported in the Appendix (page 57) that at Fairfield where potassium salts are applied to one half of the land under experiment they produce practically no effect on the manured land, while the effect is very appreciable on the unmanured land. Altho the potassium salts are applied to one half of the check plots the same as to one half of the land receiving limestone and phosphorus, so that the $9.94 is the actual increase produced by the limestone and phosphorus above the return from the land otherwise treated the same, nevertheless there is a possibility that on part of the land represented in this result the effect of the potassium salts was different where used with limestone and phosphorus than where used alone. No potassium salts had been applied to the land where the accompanying photographs were taken.

phosphate are also used, the corresponding values are $37.87 with manure and $43.62 with residues, but this is not a fair comparison because the last value ($43.62) was secured where two applications of limestone and phosphate had been made (see Table 9).

In Table 9 are summarized concisely the results of the eight years' work. When considered in relation to the possible profitable improvement of the most extensive soil type in Bond county, the importance of these figures can scarcely be estimated. It should be remembered, too, that this soil is also the most common type in about twenty counties in southern Illinois.

Here we have untreated, well-rotated land producing $20.84 per acre in four years; while $58.45 is the value at the same prices for the same four crops on land receiving three natural fertilizers—farm manure, ground limestone, and fine-ground raw rock phosphate. If it costs $5 an acre a year to farm the un-

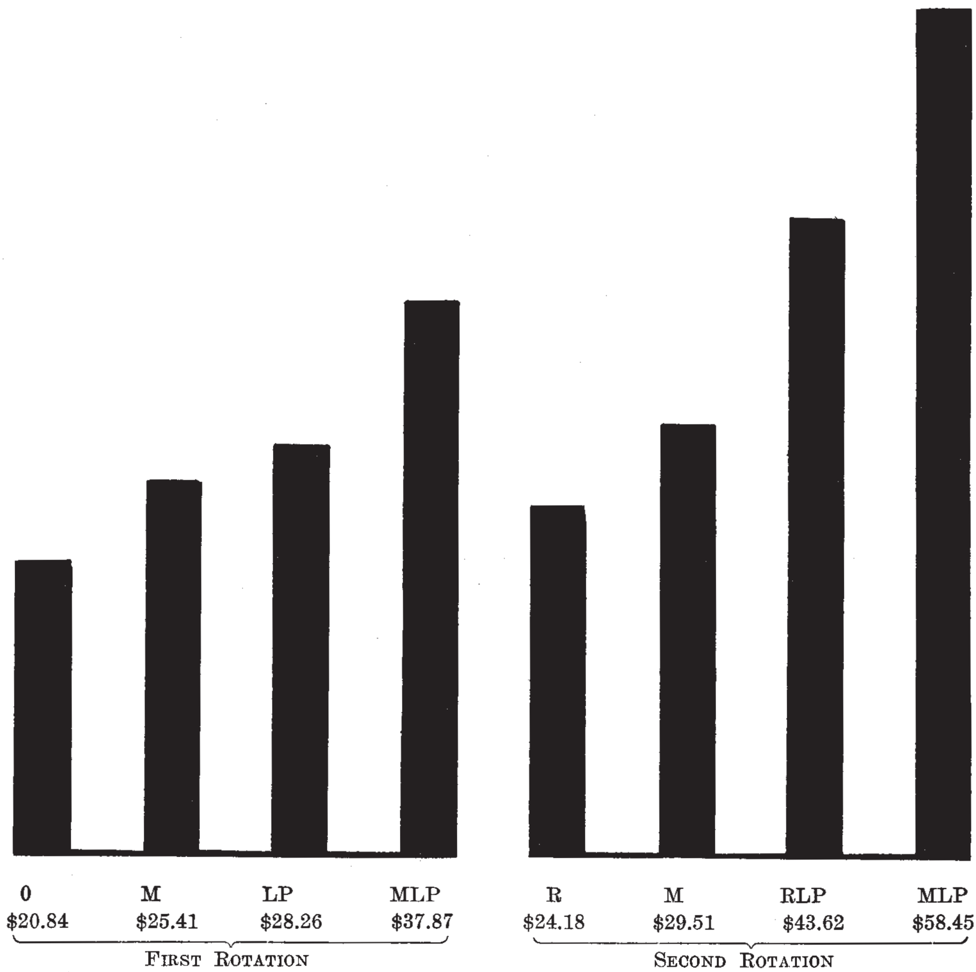

PLATE 5.—CROP VALUES FOR FOUR YEARS FAIRFIELD EXPERIMENT FIELD

(L=lime or limestone; R=residues; P=phosphorus; K=potassium, or kalium; N=nitrogen; M=manure) treated land, only 21 cents remains to pay the taxes, with nothing for interest; moreover, the practice of leaving land untreated means a gradual soil depletion, which leads only to future poverty and ruin. If the land would sell at $50 an acre and if money is worth 5 percent, then there is essentially an annual expense of $2.50 an acre for which there is no return; but if $2.50 per acre per annum is invested in limestone and phosphate in a rational system of farming, it pays back an average of 100 percent during the first rotation, and of 194 to 289 percent during the second rotation; and this is in addition to the returns from the crop residues and farm manure. Moreover, this is a system of positive soil enrichment which leads to the protection of property and to prosperity.

The crop residues include the corn stalks, straw from wheat or oats and from soybeans or cowpeas, cover crops, and all clover except the seed. In the live-stock system as many tons of fresh manure are applied to the land as the average number of tons of air-dry produce taken off in crops during the previous rotation—an amount easily produced by using the crops for feed and bedding.

The prices used in all these computations are 35 cents a bushel for corn, 30 cents for oats, 70 cents for wheat, $1 for soybeans and cowpeas, $6 for clover seed, and $6 a ton for hay. These prices are stated conservatively in order to avoid any possible exaggeration. If higher prices were used, the computed returns from the land and treatment would of course be increased accordingly. In some localities the expense of hauling will be greater than in others; but it is believed that the prices used provide ample margin for average conditions. The data are reported in detail so that any one can make other computations if desired.

Results from some other field experiments are recorded in connection with the description of individual soil types.

THE SUBSURFACE AND SUBSOIL

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil of Bond county. It should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the common soils of the county are much more strongly acid in the subsurface and the subsoil than in the surface. This emphasizes the importance of having plenty of limestone in the surface to neutralize the acid moisture which rises from the lower strata by capillary action during periods of partial drouth, which are critical periods in the life of such plants as clover. Thus, while the deep brown silt loam bottomland and the black silt loam on clay of the prairie are practically neutral, the vast areas of the common soils of the county are greatly in need of limestone; and, as already explained, the extensive upland soils are markedly in need of phosphorus and nitrogen.

TABLE 10.—FERTILITY IN THE SOILS OF BOND COUNTY

Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay	26 100	2 990	1 530	57 540	10 970	9 500		3 070
328	Brown-gray silt loam on tight clay	26 460	2 700	1 740	63 820	10 160	10 400		300
329	Drab silt loam............	43 400	4 160	2 040	61 560	12 120	15 800		280
331	Deep gray silt loam.......	27 720	3 200	1 080	53 800	7 800	9 600		5 600
325.1	Black silt loam on clay.....	91 680	7 320	1 880	63 120	20 600	31 160		40
	Upland Timber Soils								
334	Yellow-gray silt loam......	21 240	2 600	1 340	75 500	14 620	8 520		5 200
335	Yellow silt loam...........	16 980	2 120	1 270	73 820	15 400	8 570		4 080
332	Light gray silt loam on tight clay	11 560	1 400	1 260	60 160	14 260	7 320		10 020
332.1	White silt loam on tight clay	7 960	1 000	1 480	61 400	11 560	10 080		960
	Ridge Soils								
235	Yellow silt loam..........	15 520	2 080	1 000	82 400	12 960	13 840		80
233	Grey-red silt loam on tight clay	44 960	4 800	1 440	54 000	24 240	12 760		5 880
245	Yellow fine sandy silt loam	18 520	2 340	1 620	79 900	18 280	11 100		320
	Bottom-Land Soils								
1331	Deep gray silt loam.......	23 480	2 720	2 200	74 000	16 080	10 280		4 320
1326	Deep brown silt loam......	30 200	2 880	1 800	69 040	14 120	14 600		160

TABLE 11.—FERTILITY IN THE SOILS OF BOND COUNTY

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
330	Gray silt loam on tight clay	27 900	3 340	2 850	88 940	36 180	21 210		2 050
328	Brown-gray silt loam on tight clay...........	19 650	2 760	2 520	97 290	35 730	31 830		often
329	Drab silt loam..........	36 060	3 720	3 180	89 580	27 300	22 860		540
331	Deep gray silt loam.....	37 920	3 720	2 280	79 560	31 620	15 600		18 300
325.1	Black silt loam on clay...	34 920	3 060	2 760	94 260	37 620	39 840		120
	Upland Timber Soils								
334	Yellow-gray silt loam....	16 260	2 190	2 580	118 140	31 470	18 030		12 540
335	Yellow silt loam.........	12 790	2 170	2 090	105 290	32 240	12 910		15 070
332	Light gray silt loam on tight clay	15 840	2 070	2 670	96 480	30 090	11 460		21 720
332.1	White silt loam on tight clay	10 560	1 860	2 820	96 540	38 700	18 000		25 380
	Ridge Soils								
235	Yellow silt loam........	14 220	2 280	2 520	121 260	35 700	21 060		2 340
233	Grey-red silt loam on tight clay	20 220	2 040	1 980	114 600	48 120	38 040		often
245	Yellow fine sandy silt loam	21 060	2 760	2 960	116 040	37 260	24 780		2 010
	Bottom-Land Soils								
1331	Deep gray silt loam.....	12 060	2 040	3 060	108 240	26 520	11 880		20 100
1326	Deep brown silt loam....	21 540	2 520	2 580	106 140	15 840	19 380		420

INDIVIDUAL SOIL TYPES

(a) Upland Prairie Soils

The upland prairie soils of Bond county occupy 190 square miles, or 51 percent of the entire area of the county. Because of their larger content of organic matter, they are usually darker in color than the upland timber soils of similar topography.

The accumulation of organic matter in the prairie soils is due to the growth of prairie grasses that once covered them, and whose network of roots has been protected from complete decay by imperfect aeration resulting from the covering of fine soil material and the moisture it contains. The tops of these prairie grasses contributed little organic matter, as they were usually burned by prairie fires or soon became almost completely decayed from exposure to the air. Because of its great age and the loss of mineral plant food by leaching, the most common prairie soil of the lower Illinois glaciation has finally become incapable of supporting such a rank vegetation as the more recently formed and more fertile prairies of the corn belt in central and northern Illinois. Consequently, the southern Illinois prairies are not so rich in organic matter and nitrogen as the corresponding corn-belt soils; indeed, they differ but little from the best timber soil.

Gray Silt Loam on Tight Clay (330)

Gray silt loam on tight clay is the predominating soil type in the lower Illinois glaciation. It covers 121.49 square miles (77,754 acres), or 32.66 percent of the area of the county. In topography it is nearly level or gently undulating, tho somewhat rolling in places.

The type varies primarily in: (1) the organic-matter content; (2) the topography and consequent surface drainage; and (3) the thickness, depth, and density of the tight clay layer underlying it. Where adjoining the somewhat rolling areas of this or other types, or in the vicinity of ridges, this type has received some wash, which has buried the tight clay layer to such a depth that it is less objectionable, and in such places the soil is better than the average soil of this type. On the other hand, where erosion has been somewhat active, the tight layer is near the surface, making a very unproductive soil.

This type contains many small areas known as "scalds" or "scald spots," readily recognized in the plowed field by their light color. On these spots the ordinary surface soil, and in many cases the subsurface soil, is partly or entirely absent, leaving the subsoil on or very near the surface. Ordinarily these spots constitute only a few square rods; occasionally, tho very rarely, one is found covering an acre or more. These "scalds" are very irregular in their occurrence, some fields being almost free from them while others contain many. Bracted plantain (*Plantago aristata*) of stunted growth is a common plant on these "scalds."

The surface stratum, 0 to 6⅔ inches, is a friable silt loam, varying in color from a light to a dark gray and containing sufficient clay to make it slightly plastic when wet. A few small gravels of quartz and concretions of hydrated iron oxid are sometimes found in it. The organic-matter content varies from 1.9 to 2.6 percent; in other words, from 19 to 26 tons per acre, or an average of 22 tons. The surface soil is fairly pervious to water, but the low organic-matter content, and the consequent lack of granulation, renders it in poor tilth, causing it to "run together" readily with heavy rains or with freezing and thawing when very wet. The chief variation in the surface stratum is due to the variation in the organic-matter content. Analysis shows from 10 to 13 percent of the various grades of sand and from 70 to 80 percent of silt.

The subsurface stratum varies greatly in thickness. In many of the "scalds" it is entirely absent, while in other places the depth to the subsoil is two feet or more. The average thickness is about 13 inches. It contains 1.1 percent of organic matter, and consists of a silt loam varying in color from gray to almost white. The upper part of the stratum is sometimes about the same color as the surface soil, but ordinarily the plow-line marks the beginning of a much lighter colored soil, which becomes still lighter with depth and passes into a distinct light gray layer deficient in organic matter, close-grained, very compact when dry, and very slowly pervious to water. When saturated, it is soft, and posts may be driven thru it readily. A few small quartz gravels and some concretions of hydrated iron oxid are sometimes present.

The natural subsoil lies at an average depth of about 20 inches from the surface, but the distance varies from only a few inches on the "scalds" to two feet or more on the best phase of the type. It is usually made up of two distinct layers. The upper layer, extending from the subsurface to an average depth of 30 to 36 inches, consists of tight clay, sometimes erroneously called "hard-pan," while the lower subsoil is friable, porous, and silty. The tight clay stratum varies from 4 to 12 inches in thickness and is usually a close, silty clay, reddish or yellowish in color, very sticky and gummy when wet, and very hard when dry. Water percolates thru it very slowly.

Because of the level topography and the tight clay subsoil, the drainage of this type is, as a rule, rather poor. It is still a question whether the type can be tile-drained profitably; experiments are now in progress with the view of answering this question.

The soil is strongly acid and low in nitrogen content. It is in poor physical condition; it "runs together" badly during rains, is too compact for good aeration, and is very unfavorable for moisture movement. Therefore in the management of this type the chief essentials are the application of limestone and the increase of organic-matter content by every practical means.

Limestone is needed, not only to correct soil acidity, but to supply calcium as plant food as well. It also increases granulation, or flocculation, and thus improves the tilth. About two tons per acre of ground limestone should be applied every four or five years, and the initial application may well be from four to six tons.

In order to increase the organic-matter content, all forms of vegetation, such as weeds, manure, straw, corn stalks, etc., should be plowed under and no part of them burned. Legume crops, such as cowpeas, soybeans, and red, alsike, or sweet clover, should be grown and turned back into the soil, or fed and the manure returned. Probably no crop will prove better adapted to adding organic matter and nitrogen to the soil than the common sweet clover (*Melilotus alba*), a deep-rooting plant which will also help to loosen the tight subsoil and make it more pervious. In order to grow this clover, the soil must be sweetened with ground limestone and well inoculated with nitrogen-fixing bacteria.

This type is also markedly deficient in phosphorus, especially for the growing of such crops as wheat and clover; hence in permanent systems of improvement a liberal use of phosphorus is essential. This is applied most economically in the form of fine-ground natural rock phosphate, which should be plowed under in intimate contact with farm manure, clover, or cowpeas. If one-half ton per acre is applied every four or five years, the phosphorus content of the soil will be maintained or slowly increased, but an application of one or two tons at one time gives still better results. With the increase in organic matter, the phosphorus content of the plowed soil should be raised finally to at least 2,000 pounds per acre, which will require altogether about five tons of rock phosphate.

This system of permanent soil improvement can be hastened, and sometimes with profit during the early years, by applying about 600 pounds of kainit per acre to be plowed under with the initial application of rock phosphate. The action of kainit is explained in the Appendix (see page 57). If used at all it should be with the understanding that it serves in part, at least, as a soil stimulant; and that when plenty of decaying organic matter is provided, the use of kainit may not be profitable. The benefit derived from ground limestone, where a heavy application is made, seems to include some of the effect of soluble salts and to make the use of kainit less important.

For results of field experiments on this soil type, see Tables 3 to 9.

Brown-Gray Silt Loam on Tight Clay (328)

Brown-gray silt loam on tight clay covers 61.49 square miles (39,354 acres), or 16.54 percent of the entire county. The principal area is located between the east and the west branches of Shoal creek. Other large areas are found near Smithboro and east of Stubblefield. With few exceptions the topography is flat or only slightly undulating.

This type contains many "scalds" where the subsoil comes to the surface or injuriously near it, usually less than ten inches. These "scalds" are very irregular in their occurrence, some fields being devoid of them, while others contain many. They are indicated by their lighter color, distinctly seen when the ground is plowed.

The surface soil, 0 to 6⅔ inches, is a dark gray to a brown mealy silt loam, varying in color with its gradation toward other types. It contains about 2.4 percent of organic matter, or 24 tons per acre. The amount varies from 2.1 to 3 percent, or from 21 to 30 tons per acre. The mineral part of the soil is composed of 80 to 85 percent of the different grades of silt with 10 to 12 percent of sand, and some clay. Coarse silt seems to be the most abundant constituent. The soil is porous, friable, and easy to work.

The subsurface stratum varies greatly in thickness and color. Its average thickness is from 10 to 12 inches, altho it is entirely absent in some places, such as "scalds," and 18 inches thick in others. It consists chiefly of a grayish brown silt loam, the color becoming lighter with depth. Usually there is a distinct gray or grayish brown layer from 2 to 10 inches thick just above the subsoil. Where the type grades into gray silt loam on tight clay (330), this gray layer in some places becomes quite well developed. On the other hand, where the type grades toward brown silt loam this layer becomes quite indistinct.

The subsoil is found at variable depths, from only a very few inches from the surface on the "scalds" to 20 inches or more on the better phases. It consists of two distinct layers. The upper stratum, from 5 to 16 inches thick, is a plastic, gummy, yellow, drab or dark olive-colored clay, very tight and nearly impervious to water. Below it is a clayey silt, friable and pervious, of a yellow color, or yellow with drab mottlings.

The upper layer of the subsoil is too nearly impervious to allow good drainage, so that special surface drainage in the form of dead furrows must be provided. Probably the lower, flatter land of this type should be tile-drained, the lines of tile being placed not over five rods apart. This opinion is based merely upon observation and reported experience, as no definite experiments in tile drainage have been conducted on this type.

In the improvement of this type practically the same methods should be employed as for the gray silt loam on tight clay (330). All crop residues and legume crops not fed on the farm should be turned back into the soil in order to provide nitrogen, liberate mineral plant food, and aid in the physical improvement of the soil. Deep-rooting crops should be grown in order to loosen up the subsoil and provide more rapid percolation of water and air.

This type contains no limestone, and is usually somewhat acid. However, it is not so sour as the gray silt loam on tight clay, and this fact, together with the higher content of calcium and organic matter and some ability to grow clover in favorable seasons, has made it a more productive soil, generally, than the gray prairie. It has been much used for wheat, and possibly because of the many crops removed, this type in Bond county is, as an average, more deficient in phosphorus than the more extensive gray silt loam on tight clay. Where it has long been cropped it is also very poor in active organic matter, so that nitrogen is one of the important factors which now limit the yield of grain crops.

In Table 12 are given the data secured from twelve years' field investigations on brown-gray silt loam on tight clay, on the soil experiment field near Mascoutah, St. Clair county, which almost corners Bond county on the southwest. These data are from a part of the Mascoutah field where commercial nitrogen, phosphorus, and potassium have all been used in readily available form in order to secure information as quickly as possible. The regular applications per acre have been 100 pounds of nitrogen in 700 pounds of dried blood every year, and 800 pounds of steamed bone meal and 400 of potassium sulfate every four years, corresponding to 25 pounds of phosphorus and 42 of potassium for each year of the rotation.

At the time these experiments were begun the claim was commonly made, especially by lime manufacturers, that small amounts of slaked lime should be applied frequently to soils. (The product was sold under the name of "hydrated" lime at $6 to $10 per ton.) On the Mascoutah field this material was tried, 400 pounds per acre in 1902 and 700 pounds in 1903. No further applications were made until 1909, when the use of ground limestone was begun. At that time 1½ tons per acre was applied, and four years later 2 tons per acre was applied. The first distinct indication of benefit from lime alone appeared in 1913.

Nitrogen is clearly the element of greatest benefit on the Mascoutah field, as shown by the fact that the dried blood has increased the crop values, in twelve years, from $91.05 to $135.50, a gain of $44.45. In comparison, phosphorus has produced an increase valued at $16.60, and potassium an increase valued at only $10.63, when used singly. All other results harmonize well with these values, except those from Plot 507, which indicate a very marked influence from potassium. In fact, the crop values from this plot, which has received lime, nitrogen, and potassium, are $15.17 higher than those from Plot 509, which has received lime, nitrogen, phosphorus, and potassium. However, nearly $13 of this

TABLE 12.—CROP YIELDS IN SOIL EXPERIMENTS, MASCOUTAH FIELD

Brown-gray silt loam on tight clay; middle Illinois glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912[1]	Wheat 1913
Plot	Soil treatment applied	Bushels per acre											
501	None	32.5	43.4	17.5	9.1	31.7	29.1	8.8	20.7	8.8	11.6		9.8
502	Lime	32.0	38.9	22.5	7.8	30.8	31.9	6.6	17.5	8.8	11.2		15.5
503	Lime, nitro	24.2	47.1	40.0	16.7	53.1	45.8	12.2	20.8	12.4	19.8		32.5
504	Lime, phos	34.4	39.3	68.7	15.0	21.6	24.8	9.1	20.2	6.8	14.6		14.5
505	Lime, potas	37.5	47.8	25.6	15.7	22.3	32.5	10.6	18.0	10.4	17.0		12.3
506	Lime, nitro., phos.	46.1	69.9	44.1	25.3	56.7	58.8	28.8	32.7	32.4	39.2		33.5
507	Lime, nitro., potas.	59.6	77.4	43.1	30.2	59.6	70.0	37.2	30.7	32.0	48.8		27.0
508	Lime, phos., potas.	53.9	49.0	33.1	20.0	19.6	38.1	12.2	22.3	15.2	19.6		18.8
509	Lime, nitro., phos., potas.	47.8	70.5	37.8	28.3	49.6	70.0	30.3	33.7	34.4	37.4		28.3
510	Nitro., phos., potas.	47.7	52.6	35.9	26.3	42.9	65.3	32.2	33.7	34.8	28.6		30.5
	Average Increase: Bushels per Acre												
	For nitrogen	–7.8	8.2	17.5	8.9	22.3	13.9	5.6	3.3	3.6	8.6		17.0
	For phosphorus	2.4	.4	46.2	7.2	–9.2	–7.1	2.5	2.7	–2.0	3.4		–1.0
	For potassium	5.5	8.9	3.1	7.9	–8.5	.6	4.0	.5	1.6	5.8		–3.2
	For nitro., phos. over phos	11.7	30.6	–24.6	10.3	35.1	34.0	19.7	12.5	25.6	24.6		19.0
	For phos., nitro. over nitro	21.9	22.8	4.1	8.6	3.6	13.0	16.6	11.9	20.0	19.4		1.0
	For potas., nitro., phos. over nitro., phos.	1.7	.6	–6.3	3.0	–7.1	11.2	1.5	1.0	2.0	–1.8		–5.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops	Value of increase
501	None	$ 90.60	
502	Lime	91.05	$ .45
503	Lime, nitrogen	135.50	44.90
504	Lime, phosphorus	107.65	17.05
505	Lime, potassium	101.68	11.08
506	Lime, nitrogen, phosphorus	192.01	101.41
507	Lime, nitrogen, potassium	207.21	116.61
508	Lime, phosphorus, potassium	124.75	34.15
509	Lime, nitrogen, phosphorus, potassium	192.04	101.44
510	Nitrogen, phosphorus, potassium	178.95	88.35

Value of Increase per Acre in Twelve Years		Cost of increase
For nitrogen	$44.45	$180.00
For phosphorus	16.60	30.00
For *nitrogen* and phosphorus over phosphorus	84.36	180.00
For *phosphorus* and nitrogen over nitrogen	56.51	30.00
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	.03	30.00

[1] The oat crop failed in 1912.

difference is found in the first five crops, which suggests the possible influence of some unknown factor in Plot 507, such as the presence of an old stack bottom. But even if this abnormal effect during those years is disregarded, the data still show a slightly greater benefit from nitrogen and potassium (507) than from nitrogen and phosphorus (506), altho in 1913 a marked superiority of phosphorus appears in this comparison.

Here again on this highest yielding plot (507) we meet what seems to be the stimulating influence of the soluble potassium salt. If, however, the treatment used on this plot were practiced, it would lead ultimately only to failure and land ruin, for it makes no provision for the restoration or the maintenance of phosphorus, which is unquestionably the most deficient of the five most important elements of plant food. The only guide toward a safe practice for permanent systems of improvement is the chemical composition of the soil.

In the lower part of Table 12 is shown the influence of each element in a rational order of application. From the composition of the soil it is clear that both nitrogen and phosphorus must be supplied for permanent systems of farming, altho there may be some question as to which of these two is most needed, because of imperfect knowledge of the condition of the organic matter and of the rate of decomposition under unknown future weather conditions. It must be plain, however, that if potassium is to be used for its own sake, it should pay a profit when applied in addition to both nitrogen and phosphorus.

In considering these three elements, nitrogen, phosphorus, and potassium, we find that, starting with $91.05 (the value of the crops for twelve years when lime alone was used), the increases per acre in crop values have been as follows:

For nitrogen over lime	$ 44.45
For phosphorus as a further addition	56.51
For potassium as a final addition	.03
For total increase	$100.99

This demonstration of more than doubling crop values is highly important, for it shows the possibilities of soil treatment; but of still more importance is the development of methods of producing the same results with profit to the producer. Applied nitrogen has produced exceedingly marked gains, but never enough to pay its cost in commercial form; and while phosphorus has paid nearly 200 percent on the investment in steamed bone meal when used in addition to nitrogen, the profit is more than offset by the nitrogen deficit.

On another part of the Mascoutah field, investigations are in progress where nitrogen is secured by the slower but less expensive practice of growing legumes in the crop rotation and returning to the soil the crop residues or farm manure. In Table 13 are shown for direct comparison the results secured where commercial nitrogen is used and those where these rational means of securing nitrogen are employed, both on lime-phosphorus plots and on plots where lime, phosphorus, and potassium are applied. The records are taken from the legume rotation of the same crops as were grown in identical years in the experiments reported in Table 12. It will be seen that the rotations differ only by the substitution of a legume crop for one corn crop. The final averages, including duplicate experiments (except for the potassium), may be considered trustworthy, within rather narrow limits. The data of the first four years are averaged separately because during those years the residue and manure systems were not well under way.

TABLE 13.—CROP YIELDS IN SOIL EXPERIMENTS, MASCOUTAH FIELD

Rotation system	Corn, corn, oats, and wheat		Corn, oats, wheat, and clover		Corn, oats, wheat, and clover	
Soil treatment	Lime Nitro. Phos.	Lime Nitro. Phos. Potas.	Lime Residues Phos.	Lime Residues Phos. Potas.	Lime Manure Phos.	Lime Manure Phos. Potas.
1902 Corn, bu.	46.1	47.8	39.6	45.3	42.7	47.1
1903 Corn, bu.	69.9	70.5	50.8	56.8	43.1	58.9
1904 Oats, bu.	44.1	37.8	36.9	33.4	32.8	39.4
1905 Wheat, bu.	25.3	28.3	25.9	28.2	26.3	31.2
Value of four crops	$71.54	$72.55	$60.84	$65.49	$58.28	$70.76
1906 Corn, bu.	56.7	49.6	57.1	57.3	54.1	49.1
1907 Corn, bu.	58.8	70.0	70.0	84.3	73.0	93.0
1908 Oats, bu.	28.8	30.3	9.7	11.3	10.6	13.1
1909 Wheat, bu.	32.7	33.7	32.0	32.7	32.7	33.2
1910 Corn, bu.	32.4	34.4	28.6	36.0	27.2	35.2
1911 Corn, bu.	39.2	37.4	38.2	29.4	29.6	32.8
1912 Oats, failed						
1913 Wheat, bu.	33.5	28.3	33.5	34.7	32.3	30.2
Value of eight crops	$120.47	$119.48	$116.63	$123.02	$113.05	$121.84
Av. value of eight crops	$119.97		$119.82		$117.44	

Where commercial nitrogen has been used, the crop values for the last eight years average $119.97, with a total cost for nitrogen of $120.00; but where crop residues have been used as a source of nitrogen, the average crop value is $119.82, or within 15 cents of that produced with commercial nitrogen. Nearly the same results have been secured where the nitrogen is supplied in farm manure in quantities easily produced from the crops grown on the land.

These data show that altho practically the same aggregate gross values are secured with "home-grown" nitrogen as with the purchased product, the securing of these values requires that the crop of clover seed in the grain system or the clover hay in the live-stock farming shall bring as large a return as the corn crop which it replaces. Even if no value is assigned to the clover crop, the cost of the nitrogen secured by these rational methods is only about one-fourth its cost in commercial form.

Drab Silt Loam (329)

Some of the low and more poorly surface-drained areas of the prairie land have received deposits of finer material washed in from the slightly higher surrounding land, and in these places a greater amount of organic matter has accumulated, more particularly in the surface and the subsurface strata, owing to the more luxuriant growth of vegetation and the better conditions for preventing complete decay. This finer material and the greater accumulation of organic matter have given rise to a type of soil, the drab silt loam (329), which is darker in color, better in texture, and somewhat more productive than the surrounding gray silt loam on tight clay (330), the ordinary prairie land of this glaciation. Drab silt loam in Bond county covers an area of 2.46 square miles (1,574 acres), or .66 percent of the county.

The surface soil, 0 to 6⅔ inches, is a drab to a dark gray. Altho silts form the chief constituent, this stratum always contains some fine sand and, in the poorly drained areas, enough clay to give it some tenacity. The organic matter averages 3.1 percent, or 31 tons per acre.

The subsurface stratum varies from a brownish gray to a light drab, frequently with blotches of iron oxid. The amount of clay varies considerably, the stratum in some areas being very silty, while in others it has sufficient clay to make it plastic; in either case it is pervious to water.

The subsoil, 20 to 40 inches beneath the surface, is a drab to yellowish gray silt or clayey silt. In many areas the subsoil is quite heavy, yet sufficiently pervious so that tile drains should work well.

This type needs underdrainage to bring it to its best condition of tilth and productiveness. The physical composition, texture, and structure indicate that tile drainage would be of great benefit, but actual field experiments are necessary to determine how satisfactorily tile will work.

Besides thoro drainage, one of the most important points in the management of this type is the maintaining or even the increasing of the organic matter in order to provide sufficient nitrogen to meet the needs of large crops of corn and other non-legumes to be grown in the crop rotation. This can best be done by practicing a rotation of crops in which a legume is used as often as practical and by turning back into the soil all crop residues. If these crops are fed on the farm, the manure should be put back with as little waste as possible. This type in Bond county is very deficient in phosphorus and contains no limestone, altho it is not markedly acid; hence both phosphate and limestone should be used.

Deep Gray Silt Loam (331)

Deep gray silt loam occupies low areas in the southeastern part of Bond county where silt has been carried in from the higher lands to such a depth that all evidence of a clay subsoil has been buried to a depth of more than 40 inches. It covers 2.19 square miles (1,401 acres), or .59 percent of the county.

The surface soil, 0 to 6⅔ inches, is a gray to dark gray silt loam, changing in shade as it grades into other types. It contains 2.4 percent of organic matter, or 24 tons per acre.

The subsurface is a silt loam, lighter in color than the surface, and containing 1.2 percent of organic matter.

The subsoil is a gray to drab silt, differing from the subsurface in that it contains less organic matter and has layers of clay or clayey silt developed locally.

The low organic-matter content of this type indicates the necessity of maintaining or increasing the supply by every practical means. Owing to the character of the subsoil, crops growing on this type have a decided advantage over those on gray silt loam on tight clay (330), provided the subsoil is thoroly drained. The greater porosity and deeper feeding range are of no avail when water is present in excess.

Among the prairie soils of Bond county, this type is the most acid and the most deficient in calcium and magnesium; it is also very poor in phosphorus. Phosphate should be applied liberally in connection with organic matter; dolomitic limestone (such as can be secured from Grafton and from most northern Illinois deposits) will probably give even better results than the more common limestone.

Black Silt Loam on Clay (325.1)

Black silt loam on clay represents low prairie land that was originally swampy. In position, this type corresponds to the black clay loam in the middle and upper Illinois and early Wisconsin glaciations. In Bond county it covers 2.48 square miles (1,587 acres), or .67 percent of the county. The areas are widely scattered; one of the largest is found south of Old Ripley and two others of considerable size east of Greenville.

The surface soil, 0 to 6⅔ inches, is a heavy black silt loam varying in some places to a clay loam. It contains 4.9 percent of organic matter, or 49 tons per acre, an amount sufficient to make it quite granular and keep it in good physical condition if properly drained.

The subsurface extends 15 to 18 inches below the surface soil and is a dark clayey silt loam containing about 4 percent of organic matter.

The subsoil consists of a clay, varying in color from dark to light drab.

The presence of clay and organic matter imparts to this type of soil the property of shrinkage to a very marked degree, and in times of drouth large cracks a foot or more in depth are formed, which sever the roots and damage the crop to some extent. Drainage and good cultivation prevent this to a considerable degree. After drainage, rotation of crops and turning under crop residues such as corn stalks, straw, etc., together with good tillage, is all that is necessary to keep the soil in good physical condition.

This black silt loam is by far the richest prairie soil in the county, not only in phosphorus and nitrogen, but also in calcium and magnesium; it is somewhat the richest, too, in potassium. The ratio of nitrogen to carbon is 1 to 12, which indicates that the organic matter is more active as well as more abundant in this type than in the other prairie types in Bond county, in which the ratio is only 1 to 10. (Read "Supply and Liberation of Plant Food" in the Appendix.) A liberal use of phosphorus with clover in rotation is needed for marked improvement in crop yields on such soil.

No field experiments have been conducted on black silt loam on clay, but its composition is practically the same as the most extensive soil type in the corn belt, the common brown silt loam. When well drained and well farmed with a good crop rotation including clover, phosphorus is the single factor which holds the crop yields far below what they would otherwise be. Thus, on the brown silt loam at the Bloomington soil experiment field, the values per acre of eleven crops (1902-1912) on four different plots where no phosphorus was applied were $165.52 (with lime), $173.17 (with lime, crop residues[1]), $169.66 (with lime, potassium), and $170.57 (with lime, residues,[1] potassium); whereas the corresponding values on four other adjoining or intervening plots whose treatment differed only by the addition of phosphorus were $255.44, $251.43, $256.92, and $254.76. Other essentials are so much better provided than phosphorus that the addition of this element paid 300 percent on the investment.

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[1]No values are assigned to crop residues plowed under until they reappear in increased yields of subsequent crops.

(b) Upland Timber Soils

The upland timber soils of Bond county aggregate 126 square miles, or more than one-third of the area. They are usually lighter in color than the prairie soils, because of the more nearly complete decay of the residues of timber vegetation. In upland forests these residues consist of fallen leaves, branches, and dead trees, which become almost completely decomposed thru exposure to the oxygen of the air and to fungi. Even the large roots of trees thru exposure at the stump decay rapidly in the surface soil. Occasional forest fires help to complete the destruction. (As already explained, the most common prairie soil of the lower Illinois glaciation, because of its great age and the loss of mineral plant food by leaching, has been reduced in organic-matter content to about the condition of the undulating timber land.)

Yellow-Gray Silt Loam (334)

Yellow-gray silt loam in Bond county covers 48.76 square miles (31,206 acres), or 13.13 percent of the area of the county. It is found along the streams and generally lies between the eroded zone of yellow silt loam (335) and the prairie types. In topography it is usually undulating, but it varies from nearly level to quite rolling. The normal slopes are long and gentle, but in places very short, abrupt slopes of yellow silt loam occur, which are too small in area to be shown separately on the map.

The surface drainage is generally good. Erosion takes place on many slopes where no means are taken to prevent it. While this type was once generally timbered, it is also sometimes found extending into the prairie along natural drainage channels, and as these particular areas represent recent erosion of the prairie, "scalds," or tight-clay outcrops, are often found, the presence of which renders these narrow areas very inferior to the type as a whole, and in some places, almost worthless. These "scald" areas are rarely over two or three acres in extent and more frequently are only a fraction of an acre, often occurring as narrow strips along the streams or draws.

The surface soil, 0 to 6⅔ inches, is a yellow to grayish yellow silt loam. The freshly plowed surface when first dry after a rain takes on a decidedly grayish appearance. The type varies to a lighter color as it grades into light gray silt loam on tight clay (332), to a darker color as it grades into the prairie types (330 and 328), and to a more yellowish color as it approaches the yellow silt loam. It contains some fine sand, and locally, in small areas, quite appreciable amounts, but the principal constituent is silt of various grades. The organic-matter content is 2.28 percent, or about 23 tons per acre. The surface soil is porous and friable but "runs together" badly because of its shortage in organic matter and lime.

The subsurface, like the surface, varies from a gray or yellowish gray to a yellow silt loam sufficiently porous to permit slow percolation; its physical composition is such that capillary movement takes place very readily. In thickness it varies from 6 to about 16 inches.

The subsoil is a yellow or mottled grayish silt or clayey silt, somewhat compact but pervious. The depth to the natural subsoil is quite variable, owing to the amount of erosion that has taken place, but it commonly varies from 10 to 20 inches. In places, both surface and subsurface have been removed, but this is unusual.

The growth of natural vegetation on this type has done very little toward adding organic matter. In fact, it is more likely true that the growth of forest trees has reduced the content of this constituent in the original soil. At any rate, this type is now deficient in organic matter, and one of the most important problems in its management is to increase this constituent. In order to do this, a rotation must be carefully planned, and all crop residues and legume crops, or their equivalents in manure, put back on the land. Deep-rooting crops, such as red, mammoth, or sweet clover, should be grown; but in order to grow these successfully, applications of ground limestone are necessary. If the soil is to be enriched and its productive power increased and maintained in any permanent way, phosphorus must also be applied, altho the application may well be delayed until, thru the use of limestone and the growth of clover, some organic matter can be turned under; or else kainit should be applied with the phosphorus. Very marked improvement can be made with limestone and the organic matter which it helps to produce.

Field experiments on yellow-gray silt loam in the lower Illinois glaciation were begun in 1910 in Saline county near Raleigh, where the people of the community have provided the University with a very suitable tract of this type of soil for a permanent soil experiment field. There, as an average of triplicate tests each year, the yield of corn on untreated land was 25.3 bushels per acre in 1910, 23.6 in 1911, and 22.0 in 1912, while on duplicate plots treated with six tons per acre of ground limestone and the limited amount of organic manures produced upon the land, the corresponding yields were 41.4 bushels in 1910, 41.3 in 1911, and 50.1 in 1912. These results show an average increase of 20.6 bushels, of which only 6.6 bushels are due to organic manures.

As an average of duplicate tests with each crop each year for three years, the ground limestone increased the yields by 14 bushels of corn, 10.55 bushels of oats, .85 ton of hay (clover or cowpea), and 4.45 bushels of wheat. The value of these increases at 35 cents for corn, 30 cents for oats, 70 cents for wheat, and $6 for hay, amounts to $16.28 and corresponds to the value of the increase produced by limestone on one acre during a four-year rotation. Thus the limestone paid about 200 percent interest on the investment, and the application of 6 tons per acre is sufficient for about fifteen years, altho in order to maintain a liberal amount of limestone in the soil it is well to apply about 2 tons per acre every four or five years after making the heavier initial application.

Owing to the low supply of active organic matter in the soil at Raleigh, phosphorus produced no benefit, as an average, during the first two years; but with the turning under of the crop residues and farm manure in proportion to the crops produced, the effect of phosphorus is seen to some extent in the crops of 1912 and 1913. The fourth series of plots will receive its first farm manure for the 1914 crops, so that trustworthy data as to the benefits of organic matter, or of phosphorus combined with organic matter, will not be secured before the second rotation period.

Where kainit has been used at the rate of 200 pounds for each year, applied in connection with phosphate and in addition to the 6 tons of limestone, the average increase for the kainit during the first three years has been $2.90, or only about half its cost.

Yellow Silt Loam (335)

Yellow silt loam in Bond county includes the broken, very rolling, and hilly land along the streams and sometimes on the steep slopes of ridges. It is best to keep much of it forested, tho when properly treated it makes good pasture land. It is so steeply sloping that little of it should ever be cultivated. When it is cultivated, the utmost care should be taken to prevent washing, which is the most serious danger to this type of soil. Already many fields have been ruined by gullying. This type of soil covers an area of 60.09 square miles (38,458 acres), or 16.15 percent of the county.

The surface soil is a friable yellow silt loam varying somewhat with topography. The less broken areas are a grayish yellow, while the steep slopes are reddish yellow, or brownish yellow where a little more organic matter remains. As a rule, the soil contains enough fine sand to give it a fairly good texture, but it is very deficient in organic matter, having only 2 percent, or 20 tons per acre. This condition contributes toward its excessive washing. "Clay points," or places where the top soil has been removed by washing, are quite common, and they are very unproductive.

The subsurface varies in thickness; where little or no washing has taken place it is from 6 to 14 inches thick. It consists usually of a friable, slightly loamy, yellow silt, mottled with gray or with reddish blotches of iron oxid.

The subsoil is usually a somewhat friable and quite pervious, yellow, clayey silt. Where much washing has occurred, the glacial drift frequently forms the subsoil.

Of most importance in the management of this type is the prevention of much loss by washing. Erosion occurs as sheet-washing and gullying. Ordinarily sheet-washing is not thought of as doing very much damage, but it is really the most injurious form of erosion. Gullying results in the absolute ruin of small areas, but sheet-washing reduces the productive capacity of large areas to such an extent that it prevents not only profitable cropping but even the growing of crops large enough to pay for their raising. Every means should be taken to prevent this loss.

The steep, gullied slopes probably never can be reclaimed with profit for cropping purposes at the present average prices for labor and farm produce. The forests that originally covered these lands should never have been entirely removed. The only thing that made these lands valuable in the first place was the forests, and to make them of any future value they should be reforested. This has been done in a few cases and has met with excellent success. The accompanying illustrations show such results. The black locust can be used most successfully for this purpose, as it is largely independent of the supply of nitrogenous organic matter in the soil, altho it is subject, of course, to insect injury which is sometimes fatal. Where not in forest, the steep land should be kept in pasture as much as possible; if cropped, it should be for only one or two years

PLATE 6.—YOUNG GROVE OF BLACK LOCUST TREES ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS (GROWN BY J. C. B. HEATON)

at a time and then the land should be reseeded for pasture. Live-stock is indispensable to general farming on this type of soil.

Sheet-washing on the moderate slopes may be prevented to a great extent by the following methods:

(1) By increasing the organic-matter content, thus binding together the soil particles and rendering the soil more porous. This can be done by applying farm manure and plowing under stubble, straw, corn stalks, and legume crops, such as clover and cowpeas.

(2) By deep plowing from seven to ten inches, in order to increase the absorption of water and diminish the run-off. Ten inches of loose soil will readily absorb two inches of rainfall without run-off.

(3) By contour plowing. When land is plowed up and down the slope, as is often done in this state, dead furrows are made which furnish excellent beginnings for gullies. Even the little depressions between furrows aid in washing. On land subject to serious washing, plowing should always be done across the slope, on the contour, so that water will stand in the furrow without running in either direction. Every furrow will then act as an obstruction to the movement of water down the slope, thus checking the velocity of the water

PLATE 7.—GROVE OF LOCUST TREES ABOUT TWENTY-FIVE YEARS OLD ON ROLLING HILL LAND IN JOHNSON COUNTY, ILLINOIS (GROWN BY J. C. B. HEATON)

and its power to wash, and also facilitating absorption and diminishing the amount of run-off.

(4) By using cover crops to hold the soil during the winter and spring. Rye is a fairly good cover crop to sow in the corn during the late summer or early fall. Wheat, especially when seeded late, is a poor crop to grow on rolling land because it does not usually make sufficient growth in the fall to afford a good protection to the soil during winter. Of course both rye and wheat invite the development of chinch bugs. A mixture of winter vetch and clover with a few cowpeas, seeded at the time of the last cultivation of the corn, gives good results in favorable seasons. (See Circular 119, "Washing of Soils and Methods of Prevention.")

This yellow silt loam is markedly acid. Where cropping is practiced, limestone should be used liberally, especially for the benefit of clover grown to provide nitrogen, in which this soil is very deficient, particularly where it has been long cultivated and thus exposed to surface washing. On such land nitrogen is the element which now first limits the growth of grain crops, as will be seen from Plates 8 and 9 and Tables 14 and 15.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 14.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed

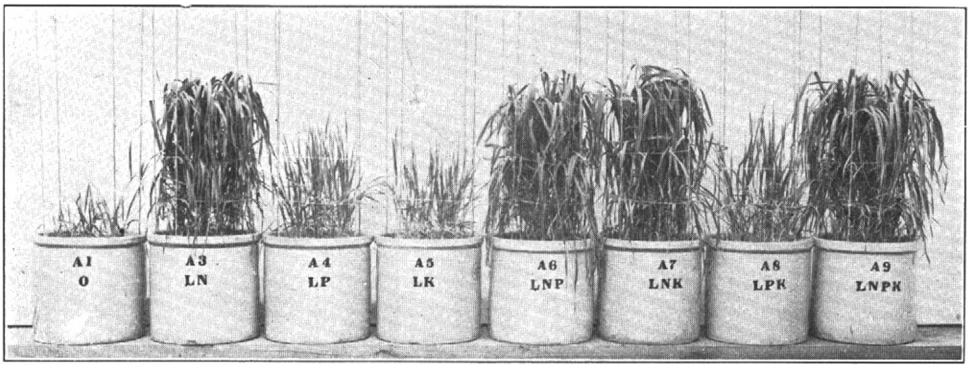

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 14)

TABLE 14.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND

(Grams per pot)

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

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

or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

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

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

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used for the wheat cultures described above. The results are reported in Table 15.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second catch crop of cowpeas had been turned under, the yield from Pot 2 exceeded

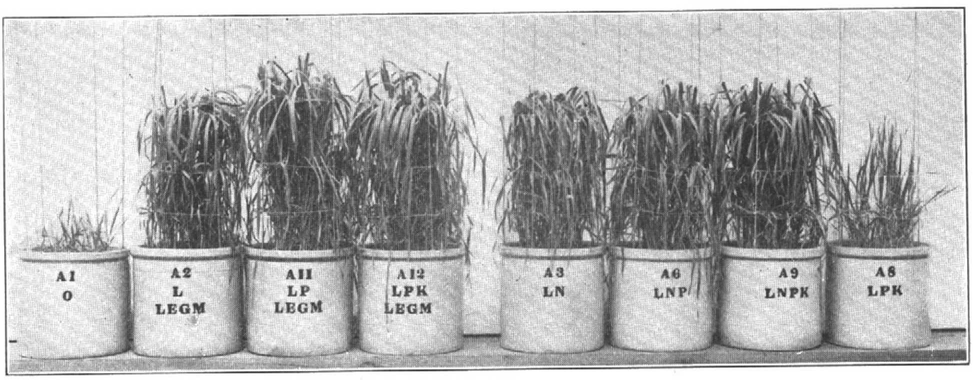

PLATE 9.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 15)

TABLE 15.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

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

that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 14, in showing the very great need of nitrogen for the improvement of this type of soil; and it also shows that nitrogen need not be purchased, but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if crops of legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

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

Field experiments covering nine years have been conducted on the yellow silt loam at Vienna, Johnson county. Here heavy applications of ground limestone paid nearly 200 percent on the investment, and about half the limestone applied still remained in the soil for the benefit of later crops. Neither phosphorus nor potassium produced sufficient increase to pay the cost. (The details of these investigations are reported in Soil Report No. 3, "Hardin County Soils.")

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

Light Gray Silt Loam on Tight Clay (332)

Light gray silt loam on tight clay occurs in old timbered regions where the land is so nearly level that there is no chance for rapid surface drainage. It is the most common level timber land of Bond county and occupies a total area of 16.45 square miles (10,528 acres), or 4.42 percent of the county. The type has two distinct phases: one phase is slightly better surface-drained, but lighter colored and less productive; the other is more swampy (water oaks commonly grow on this phase), with a darker surface and a greater porosity, so that better drainage is probably possible. The amount of this latter phase is small as compared with the former and is frequently confined to narrow strips too small to map.

"Scalds" are found on this type, but they are not so common as on the gray silt loam on tight clay (330) or the brown-gray silt loam on tight clay (328).

The surface soil of this type, 0 to 6⅔ inches, is a light gray to almost white silt loam containing 1.6 percent of organic matter, or 16 tons per acre. It is somewhat porous and incoherent, but contains sufficient clay to bake when puddled and dried. When the moisture content is at its optimum, the soil works very well, but because of the low organic-matter content it "runs together" badly with rains or with freezing and thawing when wet. The surface soil, as well as the subsurface and subsoil, contains large numbers of iron oxid concretions of various sizes up to one-fourth inch in diameter. Small pebbles of quartz are sometimes found, possibly having been brought to the surface from the underlying glacial till by burrowing animals during past centuries.

The subsurface varies from light gray silt loam to a white silt, compact but friable, from 2 to 20 inches in thickness. Water passes thru it slowly.

The subsoil consists of a compact yellowish gray clayey silt, or silty clay, only slowly pervious to water, but usually not quite so tight as the corresponding layer of the gray silt loam on tight clay (330). In places the type has a somewhat more friable subsoil which is not so nearly impervious as the subsurface. Where the tight clay occurs at the greater depths from the surface, it is less objectionable.

An invoice of plant food shows great need of nitrogen and phosphorus. With provision made for these, with a liberal use of limestone and organic matter, including legume residues or farm manure, and with proper surface drainage, the soil can be made highly productive.

White Silt Loam on Tight Clay (332.1)

White silt loam on tight clay is found on the level upland, and it is now or was formerly covered by a growth of stunted trees, principally the so-called post oak. The term post-oak flat or post-oak soil is commonly applied to this type, altho these terms are often used locally to designate the poorer phase of light gray silt loam on tight clay (332). The surface drainage is very poor and the subsoil is almost impervious. The total mapped area of this type in the county is only 435 acres, but there are many small areas that cannot be shown on the map. Much of the light-gray silt loam on tight clay (332) grades toward this related type (332.1).

Where land of this type has been cultivated, the surface soil, 0 to 6⅔ inches, is a white silt; in the timbered areas this characteristic white silt is sometimes overlain by an inch or two of dark gray silt loam. The organic-matter content of this layer is even lower in this type than in the light gray silt loam, containing only 1.25 percent, or 12.5 tons per acre. Because of this lack of organic matter and the high silt content, the soil "runs together" badly. Iron oxid concretions are always present.

The subsurface layer is a white silt with many iron oxid concretions. It varies from 4 to 16 inches in thickness and passes abruptly into the subsoil.

The subsoil is a light yellow, iron-stained, silty clay, very tough and plastic when wet and hard when dry, with an organic-matter content of only .30 percent. Both subsurface and subsoil are almost impervious.

The first need of this soil is ground limestone, the initial application of which may well be 4 to 6 tons per acre. The increase in organic matter should follow as rapidly as practicable. Legumes, such as cowpeas, clover, and sweet clover, should be grown and turned under with farm manure and crop residues, such as straw and corn stalks. For such flat, poorly drained land, alsike is usually a more satisfactory crop than red clover. Finally, phosphorus should be used liberally in connection with the organic matter in order to provide a permanent system of soil improvement.

(c) RIDGE SOILS

Yellow Silt Loam (235)

The morainal ridges of the lower Illinois glaciation have given a slight variation to the usual level topography of this region, their height varying from 20 to 100 feet or more. A fine covering of loess from 5 to 10 feet deep, together with excellent drainage, has resulted in the formation on these ridges of a soil known as yellow silt loam, very different from the surrounding prairie but somewhat resembling in texture the better phase of the yellow silt loam timber land (335) already described. The total area of this type in Bond county is 12.41 square miles (7,942 acres) or 3.33 percent of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish brown silt loam with a considerable amount of very fine sand. The color varies with the amount of erosion that has taken place. Where little washing has occurred, the color may be a yellowish brown, while with more washing it becomes yellow. The soil is loose, porous, and readily pervious to water. Its physical composition is such as to give it great water-retaining power and strong capillarity, so that it will resist drouth well if properly cultivated. The organic-matter content is about 1.8 percent, or 18 tons per acre.

The subsurface layer, extending from 6⅔ to about 20 inches below the surface, varies from a yellowish brown silt loam to a yellow silt or a slightly clayey silt. It becomes more compact with depth but still retains its perviousness and capillary power.

The upper part of the subsoil is somewhat compact and slightly clayey, but it passes into a friable silt containing some fine sand. It is yellow or reddish yellow in color. Below 24 inches it is sometimes slightly gray or marked with gray blotches, and when grading toward yellow-gray silt loam (334) it becomes decidedly gray in places. This soil, considered from a physical standpoint, is almost as good as could be desired. In respect to aeration, drainage, and ability to withstand drouth, it is one of the best upland types in the county.

The organic-matter content should be increased by growing clovers and cowpeas, and these should be turned under directly or as farm manure, together with crop residues, straw, and corn stalks. The maintenance of organic matter is made more difficult because of the rolling character of the land, which facilitates erosion and the removal of the best soil.

This ridge soil contains no limestone. As a rule the subsoil is markedly acid, but with a liberal use of limestone and thoro inoculation it becomes a very good soil for alfalfa, altho where badly worn manure may well be used in getting the alfalfa started. (See also discussion of yellow silt loam, No. 335.)

Gray-Red Silt Loam on Tight Clay (233)

Gray-red silt loam on tight clay occurs on some of the ridges, which are in part at least of preglacial origin, rising from 5 to 75 feet above the surrounding upland. As a rule, it is one of the poorest upland types in the state, but most of the areas in this county are a better phase of the type than ordinary. This type in Bond county occupies 922 acres. In some places it may suffer from erosion, but it is extremely doubtful whether tile-drainage would profitably benefit this soil,—at best, not until other methods of improvement have been put into practice.

The surface soil is a friable gray silt loam very similar to that of the gray silt loam on tight clay (330).

The subsurface layer also resembles the corresponding stratum in gray silt loam on tight clay both in texture and thickness, but it contains more of the higher oxid of iron, which gives it a reddish color. As a rule, the organic-matter content is low.

The subsoil lies from 7 to 20 inches below the surface and consists of a layer of very plastic, gummy, almost impervious red clay, varying from 4 to 12 inches in thickness and underlain by a less plastic and more silty stratum. When dry, the red clay becomes so hard that it is next to impossible to bore into it with an auger. Where this layer appears at the surface, as it does on some small eroded areas, the land is practically worthless.

This type of soil closely resembles the more extensive gray silt loam on tight clay (330). Methods for its improvement are the same, except on areas subject to considerable erosion, where the addition of phosphorus is not advised. This factor of erosion, together with the tighter texture, as a rule will make the improvement of this type less satisfactory than that of the gray silt loam.

Yellow Fine Sandy Silt Loam (245)

Yellow fine sandy silt loam occupies some of the highest glacial ridges, which have been covered with a deposit of loess varying from 10 to 20 feet in thickness and of slightly coarser grade than the surrounding deposits. The type has always been well drained and as a result is well oxidized. Practically all of it was originally forested. The total area in Bond county is almost 2 square miles (1,267 acres), or .53 percent of the county.

The surface soil, 0 to 6⅔ inches, is a brownish yellow to a yellowish brown silt loam containing from 25 to 35 percent of fine sand. It also contains much coarse silt. This mixture furnishes the basis for an ideal soil. It is easy to work, porous, and at the same time has great water-retaining power and strong capillarity, so that it will resist drouth well when properly cared for. The organic-matter content is about 2 percent, or 20 tons per acre.

The subsurface layer varies from a yellowish brown to a yellow silt loam, containing slightly more clay than the surface soil. It becomes somewhat more compact with depth, but still retains its perviousness and capillary power.

The upper part of the subsoil is a somewhat compact, clayey silt, but it passes into a very pervious friable silt containing considerable amounts of fine sand and coarse silt. It is yellow or reddish yellow in color and rarely contains the gray blotches which are so common in yellow silt loam (235).

From a physical standpoint this type is the best upland soil in the county. As a rule it is low in organic matter and slightly acid. The organic matter should of course be increased, altho the rolling character of the type renders this problem difficult.

Like most soils that are subject to much erosion, this type is poor in nitrogen and rich in potassium. The supply of phosphorus is low but it increases with depth, so that erosion enriches the soil in that constituent. For this reason and also because of the extensive feeding range afforded by the porous character of the soil, the addition of phosphorus is not advised.

Very marked and profitable improvement can be made with the use of limestone and legumes, and these means are sufficient to provide for permanent systems of moderately high production.

(d) BOTTOM-LAND SOILS

Deep Gray Silt Loam (1331)

Deep gray silt loam occurs along most of the streams of the lower Illinois glaciation. It is formed from the gray, yellow-gray, and yellow silt loams that have washed down from the upland and blended into a gray or yellowish gray soil. During floods these lands in most places still receive frequent or occasional deposits of new material. Aside from the difficulties from overflow and lack of drainage, this is the most valuable extensive soil type in Bond county.

This type occupies a total area of 26.22 square miles (16,781 acres), or 7.05 percent of the county. It lies so low that the drainage is generally poor, and there is often much difficulty in getting sufficient outlet for under-drainage or sometimes even for adequate surface drainage. Where a satisfactory outlet can be secured, tile drainage greatly benefits this soil.

The surface soil is a gray silt loam, varying from a gray to a drab in color and from a loam to a clayey silt loam in physical composition.

The subsurface and subsoil are about the same as the surface except that they are lighter in color and commonly a little more clayey with depth. In the smaller stream bottoms, the recent deposits are frequently yellow and slightly sandy, and consequently there is found in places a stratum of yellow on the gray, varying from a few inches to a foot or more in thickness.

In phosphorus content, this type exceeds the most common prairie soil of the corn belt. The porous subsoil affords such a deep feeding range that the application of that element is not likely to give profitable returns, except where overflow is not common and where the soil has been long cropped.

The soil of this type is acid. It is also rather poor in nitrogen, altho this deficiency is counterbalanced to a large extent by the great depth and porosity of the soil.

While the overflow and drainage problems are of first importance, where these are under sufficient control to permit of soil improvement the use of limestone and the addition of nitrogenous organic matter, such as clover or manure plowed under, will make this soil still more productive; and if the land is protected from the usual overflow deposits, the addition of phosphorus will ultimately be necessary; even now it is likely to be profitable for the highest improvement of the soil. To illustrate, it may be pointed out that on the University Farm at Urbana, land that has yielded 72.5 bushels of corn per acre as a six-year average, in a rotation of corn, oats, and clover, with limestone and organic manures provided, has with the addition of phosphorus made an average of 88.5 bushels during the same years. Thus there may be room for phosphorus "at the top," even where very satisfactory yields may be secured without its application and where other factors are of first importance.

Deep Brown Silt Loam (1326)

The basic material for the deep brown silt loam naturally belongs to the middle Illinois glaciation with its dark-colored upland soils, but this has been covered by loads of dark sediment brought down by Shoal creek and its tributaries and deposited over their flood plains. This sediment has been more or less mixed with material brought in by small streams from the light-colored upland soils, resulting in the formation of soils intermediate in character or lacking in uniformity. The bottoms along the streams vary in width from a few rods to more than a mile. The soil of the narrower bottoms has a tendency to be darker than that of the wider areas. This type occupies 13.74 square miles (8,794 acres), or 3.7 percent of the area of Bond county. In topography it is flat or with very slight undulations that represent old stream or overflow channels. Better drainage is needed in much of this area.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying in places, especially in the flat, poorly drained areas, to a gray silt loam. While the organic-matter content of this type is not high, yet it is more easily maintained here than in the upland because of the occasional overflow and the consequent deposition of material rich in organic matter. The physical composition of this soil varies from a heavy silt loam to a sandy loam, but the areas of these extreme types, especially the latter, are so small and so changeable that it would not mean much to show them on the map, as the next flood might change their boundaries.

The subsurface varies from a brown silt loam to a gray silt loam.

The subsoil varies in color from a brown to a yellowish drab, and in physical composition from a clayey silt to a sandy loam or sometimes even a sand in the lower subsoil.

Under the usual conditions it is very doubtful whether any materials can be applied to this soil with profit, but where feasible some legumes should be grown in the crop rotation.

APPENDIX

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

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

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 82, "Physical Improvement of Soils"
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, "Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"
Circular No. 167, "The Illinois System of Permanent Fertility"

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

SOIL SURVEY METHODS

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

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

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

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

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

Soil Characteristics

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

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

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sands	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

[1]25 millimeters equal 1 inch.

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. Some silt and a little clay may be present.

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

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

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

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

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

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

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

Sands—Soils with more than 75 percent of sand.

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

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

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

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

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

SUPPLY AND LIBERATION OF PLANT FOOD

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

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

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

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

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porus condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] 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.

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

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

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

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

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

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

Produce: Kind	Produce: Amount	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs	½ ton	2		2		
Oats, grain	100 bu.	66	11	16	4	2
Oat straw	2½ tons	31	5	52	7	15
Clover seed	4 bu.	7	2	3	1	1
Clover hay	4 tons	160	20	120	31	117
Total in grain and seed		244[1]	42	51	16	4
Total in four crops		510[1]	77	322	68	168

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

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

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

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

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

PERMANENT SOIL IMPROVEMENT

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

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

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

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

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

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

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

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

Good three-year rotations are:

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

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

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

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

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

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

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

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil

improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

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

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

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

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought.)

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

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

THE POTASSIUM PROBLEM

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

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

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

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

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

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

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

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

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

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

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

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

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

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

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

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

No. BULLETINS

76 Alfalfa on Illinois Soil, 1902 (5th edition, 1913).
*86 Climate of Illinois, 1903.
*88 Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois, 1903.
*93 Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils, 1904. (See No. 157.)
94 Nitrogen Bacteria and Legumes, 1904 (4th edition, 1912).
*99 Soil Treatment for the Lower Illinois Glaciation, 1905.
115 Soil Improvement for the Worn Hill Lands of Illinois, 1907.
123 The Fertility in Illinois Soils, 1908 (2d edition, 1911)
*125 Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois, 1908.
145 Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils, 1910 (2d edition, 1912).
157 Peaty Swamp Lands; Sand and "Alkali" Soils, 1912.

CIRCULARS

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

SOIL REPORTS

1 Clay County Soils, 1911.
2 Moultrie County Soils, 1911.
3 Hardin County Soils, 1912.
4 Sangamon County Soils, 1912.
5 La Salle County Soils, 1913.
6 Knox County Soils, 1913.
7 McDonough County Soils, 1913.
8 Bond County Soils, 1913.

*Out of print.

DATA FROM EIGHT YEARS' ACTUAL FIELD EXPERIMENTS

AS APPLIED TO AN AVERAGE 80-ACRE FARM IN SOUTHERN ILLINOIS

Crop Rotation: Corn, Cowpeas (or Soybeans), Wheat, and Clover

Fields of 20 acres in size	Where manure alone is used	With manure, limestone, and rock phosphate	Value of increase	Cost of limestone and phosphate
Value of Crops First Four Years				
Field No. 1.........	$492.60	$854.80	$362.20	$200
Field No. 2.........	360.40	455.40	95.00	200
Field No. 3.........	632.40	852.20	219.80	200
Field No. 4.........	547.40	867.40	320.00	200
Total for four years..	$2032.80	$3029.80	$997.00	$800
Value of Crops Second Four Years				
Field No. 1.........	$596.80	$1251.40	$654.60	$200
Field No. 2.........	549.20	1046.80	497.60	200
Field No. 3.........	508.20	1228.40	720.20	200
Field No. 4.........	707.00	1149.40	442.40	200
Total for four years..	$2361.20	$4676.00	$2314.80	$800

The fact that this system of soil improvement is profitable is very important, but of even greater importance is the fact that the system is permanent. It provides for positive soil enrichment in all essentials naturally deficient. In these eight years' experiments the soil has been changed from an acid to a "limestone soil," and the phosphorus content of the plowed soil has been increased from 750 to 1200 pounds per acre, an amount equal to that of the $200 cornbelt land. (For complete details of these investigations see Tables 5, 6, 7, and 8.)

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