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SOIL REPORT NO. 12

WINNEBAGO COUNTY SOILS

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INTRODUCTORY NOTE

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

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

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

WINNEBAGO COUNTY SOILS

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

Winnebago county is located on the northern boundary of Illinois, in the Iowan and pre-Iowan[1] glaciations, and is covered with a deposit of drift, loess, and alluvial material.

The topography of this county is quite variable, being extremely rolling in the northwestern part and gently rolling in the southwestern area, while the eastern and southeastern parts are of intermediate topography. The difference in topography is due largely to the irregular deposition of material during the Glacial period. However, in many local areas the broken character is due to stream erosion.

During the Glacial period accumulations of snow and ice in parts of Canada became so extensive that they pushed southward until a point was reached where the ice melted as rapidly as it advanced. In moving across the country from the north, the ice gathered up all sorts and sizes of material, including masses of rock, boulders, pebbles, and smaller material, which when deposited formed what is known as boulder clay, till, or glacial drift. Much of this was carried for hundreds of miles and the coarser materials 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 accumulated in a broad, undulating ridge, or moraine. When the ice melted away more rapidly than the glacier advanced, the terminus of the glacier receded and left the moraine, or glacial ridge, 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. Thinner and somewhat more uniform deposits were made over the intermorainal areas. Characteristic glacial ridges are found in many parts of the state, and, locally, hills of gravel and sand, known as "kames," and short ridges of the same material, called "eskers." Quite a number of these latter are found in Winnebago county, and are the source of much of the gravel that is being used as road material.

The depth of the deposit of drift varies widely in this county. In many places the bed rock is exposed, while in the area east of the Rock river, over which the drift is deepest, the depth is sometimes over 300 feet.

The pre-Iowan glaciation covers that part of the county north of the Pecatonica and west of the Sugar river; also the southwestern part of the county west of the Rock river and south of a line almost coincident with the diagonal wagon road extending from Rockford to Freeport. The drift is rather thin over this glaciation, except in the brown silt loam area in the southwestern part of the county. The Iowan glaciation covers the rest of the county.

[1]The pre-Iowan is regarded by Leverett as probably Illinoisan.

According to borings made in the old preglacial valley, the bed of the Rock river at one time was from 250 to 300 feet below the present stream bed. This valley was filled during the Wisconsin glaciations by the immense amount of material brought down by the drainage waters from the melting glacier. In the northern part of the county this material is much coarser than in the southern. The rapid filling of the Rock river valley produced peculiar conditions in the Pecatonica river valley. Since the silting up of the Pecatonica valley was not so rapid as the filling of the Rock, the former stream was ponded and this likely resulted in the formation of a lake in the valley, that extended even farther west than Winnebago county. In the waters of this shallow lake, fine sediments were deposited that now constitute the clay and silt terraces and which give rise to a number of peculiar soils. After the Rock river cut down thru the bed of deposited material, this old Pecatonica lake was drained, and now a new bottom land, from six to ten feet lower, has been formed by the Pecatonica river within the terrace.

The general effect of the ice sheet on the topography was to make it more nearly level by rubbing down the hills and filling the valley. In making wells evidences of former occasional valleys have been found that were over 75 feet in depth. These probably were preglacial tributary valleys of the Rock and Pecatonica rivers.

PHYSIOGRAPHY AND DRAINAGE

Winnebago county lies entirely in the drainage basin of the Rock river, which, with its two large tributaries, the Kishwaukee in the southeastern part and the Pecatonica in the northwestern, constitute the principal streams. The highest part is in the northeast, where an altitude of 990 feet is reached. The northwest part has nearly the same altitude. The lowest point, which is about 685 feet above sea level, is where the Rock river leaves the county. The following are the altitudes of some of the stations in the county: Argle, 878; Cherry Valley, 737; Durand, 774; Harlem, 775; Latham Park, 725; New Milford, 720; Pecatonica, 754; Rockford, 728; Rockton, 748; Roscoe, 740; Seward, 864; Shirland, 732; Winnebago, 861; Elida, 870; Kishwaukee, 730; Wempleton, 860.

The Rock river flows thru a broad valley from two to six miles in width, that represents the flood plain of the old stream, a kind of gravel outwash plain; while the new or later stream has cut a valley 30 to 60 feet deep in the terrace. The process of deepening is still going on. The Pecatonica valley varies from one to four miles in width and consists of a silt terrace in which a new bottom land has been developed, very irregular in width, thru which the Pecatonica meanders. The Sugar river and Coon creek, tributaries of the Pecatonica from Wisconsin, flow thru very poorly developed valleys of insufficient depth for good drainage.

The upland contains large numbers of poorly drained areas varying in size from two or three sections to only a few acres, which are not now usually under cultivation but are utilized for pasture or hay. Aside from these the upland is sufficiently rolling for fair surface drainage.

SOIL MATERIAL AND SOIL TYPES

The glaciers carried with them immense quantities of debris that was deposited irregularly over the surface of the county. This, however, does not constitute the soil over any large area. The pre-Iowan drift was covered by wind-blown, or loessial, material to a depth of five to seven feet, the upper part of which now constitutes the soil. The theory is advanced that this material, derived from Iowan drift, was deposited during the melting of this glacier. The commonly accepted belief is that during the melting of the Iowan glacier the water deposited large amounts of rock flour over the flood plains of streams draining from the glacier, and that this material, when dry, was picked up and carried over the land by the wind. There is also some loess over the Iowan glaciation, but it is very irregularly distributed. It frequently happens that one side of a hill will be covered with fine loessial material while the other will be made up largely of sand, and both deposits may have been due to the wind.

The terrace of the Rock river was formed largely from the deposition of gravel and sand, which has since been covered with a layer of finer material composed of sand and silt. The depth of this finer material varies from one foot to four or five feet. This terrace area is so porous that streams from the upland flowing out upon it sink into the porous gravel. Springs are abundant in the Rock river.

The Pecatonica terrace, as previously stated, was made from fine material deposited in a shallow lake that, when drained, left an area which was subsequently covered with loess and this loess now constitutes the soil. An area north of Shirland in Townships 46 and 29 North, Ranges 11 East of the 4th P. M. and 1 East of the 3d P. M., is composed largely of sand transported to its present position by the wind. The soils here are very sandy and many dunes occur.

The soils of Winnebago county are divided into the following five classes:

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

(b) Upland timber soils, including practically all of the upland that was formerly covered with forests.

(c) Residual soils, including stony loam and rock outcrop.

(d) Terrace soils, which include bench lands, or second bottom lands, that were formed by deposition from overloaded streams during the melting of the glaciers, as along the Rock and the Kishwaukee rivers, and in shallow lakes, as in the Pecatonica terrace.

(e) Late swamp and bottom-land soils, which include the overflow lands or present flood plains along the streams and other poorly drained lands.

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

TABLE 1.—SOIL TYPES OF WINNEBAGO COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 34)			
626 / 726	Brown silt loam	110.08	70 451	21.35
626.5 / 726.5	Brown silt loam on rock	.10	64	.03
620 / 720	Black clay loam	1.08	691	.21
628 / 728	Brown-gray silt loam on tight clay	1.19	762	.23
660 / 760	Brown sandy loam	98.50	63 040	19.10
760.5	Brown sandy loam on rock	7.10	4 544	1.38
781	Dune sand	3.05	1 952	.60
	(b) Upland Timber Soils (page 43)			
634 / 734	Yellow-gray silt loam	83.18	53 235	16.13
635 / 735	Yellow silt loam	25.39	16 250	4.92
635.5	Yellow silt loam on rock	4.21	2 694	.82
632	Light gray silt loam on tight clay	.31	198	.06
764	Yellow-gray sandy loam	23.91	15 303	4.63
764.5	Yellow-gray sandy loam on rock	1.94	1 242	.38
665 / 765	Yellow sandy loam	3.55	2 272	.69
765.5	Yellow sandy loam on rock	1.77	1 133	.34
690 / 790	Gravelly loam	6.16	3 942	1.19
	(c) Residual Soils (page 53)			
698 / 798	Stony loam	2.25	1 440	.44
799	Rock outcrop	.02	13	.003
	(d) Terrace Soils (page 54)			
1520	Black clay loam	2.08	1 331	.40
1526	Brown silt loam	4.75	3 040	.92
1527	Brown silt loam over gravel	5.88	3 763	1.14
1528	Brown-gray silt loam on tight clay	2.45	1 568	.48
1532	Light gray silt loam	6.58	4 211	1.28
1536	Yellow-gray silt loam over gravel	5.60	3 584	1.09
1560.3	Brown sandy loam on[1] gravel	18.15	11 616	3.52
1564	Yellow-gray sandy loam	2.16	1 383	.42
1566	Brown sandy loam over[1] gravel	34.43	22 035	6.68
1581	Dune sand	.73	467	.14
	(e) Late Swamp and Bottom-Land Soils (page 59)			
1401	Deep peat	2.23	1 428	.43
1402	Medium peat on clay	.43	275	.08
1402.2	Medium peat on sand	.27	173	.05
1403	Shallow peat on clay	.08	51	.02
1410.2	Peaty loam on sand	4.43	2 835	.86
1450	Black mixed loam	17.29	11 066	3.35
1454	Mixed loam (bottom land)	34.33	21 971	6.64
	Total	515.66	330 023	100.00

[1] "On" signifies that the gravel or rock is less than 30 inches below the surface; "over" that it is more than 30 inches.

THE INVOICE AND INCREASE OF FERTILITY IN WINNEBAGO 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.

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

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

TABLE 2.—FERTILITY IN THE SOILS OF WINNEBAGO COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
626, 726	Brown silt loam	52 030	4 400	1 220	35 260	8 360	9 710		110
626.5, 726.5	Brown silt loam on rock	43 620	3 960	980	32 940	7 560	6 580		120
620, 720	Black clay loam	120 380	10 840	1 940	28 800	14 920	29 020	8 520	
628, 728, 1528	Brown-gray silt loam on tight clay	57 510	5 530	1 300	33 780	7 720	9 140		150
660, 760	Brown sandy loam	33 100	2 910	790	28 830	5 450	5 220		140
760.5	Brown sandy loam on rock	48 250	4 170	1 210	24 890	7 560	8 180		60
781, 1581	Dune sand	10 430	730	600	13 570	1 950	2 060		360
	Upland Timber Soils								
634, 734	Yellow-gray silt loam	22 880	2 200	870	36 610	6 760	8 910		30
635, 735	Yellow silt loam	28 850	2 480	910	34 280	7 500	8 840		50
635.5	Yellow silt loam on rock	44 180	3 630	1 060	35 090	8 210	10 130		70
632	Light gray silt loam on tight clay	27 580	2 440	1 040	34 940	4 940	7 980		60
764	Yellow-gray sandy loam	19 320	1 530	530	23 560	3 420	4 410		40
764.5	Yellow-gray sandy loam on rock	19 720	1 640	500	21 700	4 500	3 720		20
665, 765	Yellow sandy loam	21 960	1 740	560	32 740	4 760	5 580		40
765.5	Yellow sandy loam on rock	11 340	1 080	460	17 240	3 780	2 400		20
690, 790	Gravelly loam	49 810	4 320	1 760	20 630	15 180	27 970	82 450	
	Residual Soils								
698, 798	Stony loam	15 820	1 660	740	33 400	11 640	7 660	13 680	
	Terrace Soils								
1520	Black clay loam	87 180	7 560	1 840	35 780	12 220	20 860		40
1526	Brown silt loam	93 580	7 160	2 180	31 440	10 820	17 300		100
1527	Brown silt loam over gravel	55 020	4 820	1 660	34 340	7 920	8 980		100
1528, 628, 728	Brown-gray silt loam on tight clay	57 510	5 530	1 300	33 780	7 720	9 140		150
1532	Light gray silt loam	28 180	2 440	1 140	38 800	7 040	8 400		100
1536	Yellow-gray silt loam over gravel	26 220	2 660	1 300	36 680	5 900	10 020		60
1560.3	Brown sandy loam on gravel	47 120	4 040	1 060	25 680	7 380	7 440		60
1564	Yellow-gray sandy loam	25 800	2 000	820	26 140	4 860	4 900		40
1566	Brown sandy loam over gravel	26 260	2 170	850	17 890	4 240	5 170		70
1581, 781	Dune sand	10 430	730	600	13 570	1 950	2 060		360
690, 790	Gravelly loam	49 810	4 320	1 760	20 630	15 180	27 970	82 450	

TABLE 2.—*Continued*

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1]	327 040	28 880	3 800	4 410	5 750	25 360		110
1402	Medium peat[1] on clay..	300 470	26 930	2 730	4 680	7 140	55 430	53 970	
1402.2	Medium peat[1] on sand.	174 020	15 030	1 220	9 520	4 040	15 710	4 820	
1403	Shallow peat[1] on clay..	203 900	16 930	2 280	10 130	5 510	19 390		60
1410.2	Peaty loam on sand...	152 440	16 280	2 180	16 600	6 540	37 180	42 340	
1450	Black mixed loam.....	99 060	11 300	2 480	26 160	28 560	101 360	240 460	
1454	Mixed loam (bottom land)	73 160	6 770	1 860	31 560	10 450	18 780		40

[1]Composition reported for 1 million pounds.

The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soil of Winnebago county (brown silt loam) does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for thirty-five years, while the upland timber soils contain, as an average, much less nitrogen than the prairie land.

With respect to phosphorus, the condition differs only in degree, the most extensive soil type of the county containing no more of that element than would be required for sixteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium is sufficient for 28 centuries if only the grain is sold, or for 440 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,000 and 500 years for magnesium, and about 10,000 and 730 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and, as explained in the Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil 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; and, with a population increasing by more than 20 percent each decade, the future needs of the people dependent upon the corn belt are likely to be far greater than the requirements of the past, and soil fertility and crop yields should not decrease but should increase.

The variation among the different types of soil in Winnebago county with respect to their content of important plant-food elements is very marked. The richest prairie land (black clay loam) contains five times as much nitrogen and twice as much phosphorus as the common upland timber soils; and the deep peat soil contains thirteen times as much nitrogen but only one-eighth as much potassium as the yellow-gray silt loam. The most significant facts revealed by the investigation of the Winnebago county soils are the lack of limestone and the low content of phosphorus, or nitrogen, or both, in the most common prairie and timber types. And yet these deficiences can be overcome at relatively small expense by the application of ground limestone and fine-ground raw rock phosphate, and, after these are provided, by the use of clover—which can then be grown with more certainty and in greater abundance, and nitrogen thus secured from the inexhaustible supply in the air. If the clover is 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, will in time double the yield of corn and other crops on most farms.

Fortunately, some definite field experiments have already been conducted on brown silt loam, the most extensive type of soil in the county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained on the Rockford soil experiment field, and also on some other experiment fields in different parts of Illinois, where definite systems of soil improvement have been tried out.

RESULTS OF EXPERIMENTS ON ROCKFORD FIELD

The Rockford soil experiment field is located on the farm of Mr. George F. Tullock, about three miles north of the city of Rockford. It occupies the northeast ten acres of the southwest forty and about three acres of the west part of the northwest ten of the southeast forty, of the southwest quarter of Section 34, Township 45 North, Range 1 East of the 3d P. M.

This field was established after a soil survey, directed by the United States Bureau of Soils, had been completed. This survey had classified the soil as "Winnebago sandy loam" (brown sandy loam), and it is so referred to in Bulletin 123 of the Illinois Experiment Station; but the subsequent more detailed survey conducted by the Station shows the field as brown silt loam. It should be noted, however, that the brown silt loam of both the Iowan and the pre-Iowan glaciations, the glaciations found in Winnebago county, contains a larger percentage of sand and is consequently somewhat more porous, in both top soil and subsoil, than the corresponding type in the middle Illinois, the upper Illinois, and the early Wisconsin glaciations. (The more porous subsoil affords a deeper feeding range for plant roots, which enables the crop to draw upon the mineral plant food to a greater extent than in more compact soils.) The average nitrogen content of this soil type is less in Winnebago county than in some other sections of the state, in part, perhaps, because of the more rolling topography—and the soil on the Rockford field was, at the beginning of the experiments, even poorer in nitrogen than the average for this type in the county.

Because of the above facts, the addition of organic manures, supplying nitrogen, is the first requisite for the improvement of this soil, at least for the lighter phase or where it is much worn. Enrichment in phosphorus probably ranks second in importance, altho on the heavier phase or where the previous farm practice has included liberal use of manures, phosphorus may be of first importance.

In Tables 3, 4, 5, and 6 are recorded the detailed results from eleven years' work on the Rockford field, which includes 80 tenth-acre plots arranged in four series of 20 plots each, the series being numbered 100 to 400 from north to south, and the plots 1 to 20 from west to east. The different kinds of soil treatment are shown by the tables. A four-year rotation is practiced, consisting of two crops of corn, followed by oats with clover seeding the third year and by clover the fourth year. When clover fails, soybeans are substituted in the fourth year, as they were in 1905, 1911, and 1912.

On the residue plots of Series 100, 200, and 300, legume cover crops were turned under in 1905, and on the corresponding plots of Series 400 the second-growth clover was turned under for the crop of 1909. In 1910 the complete residue (R) system was started on these plots, but it was not fully under way till 1913. This system includes returning to the soil the corn stalks, oat straw, and all legumes except the seed (whether clover or soybeans), and such cover crops (Cv) as may be grown, the latter being practically limited to some legume seeded in the first-year corn crop at the time of the last cultivation and plowed under for corn the next year. Under favorable conditions a satisfactory growth of red clover (common or mamoth), alsike, or sweet clover is usually secured; but in very dry seasons it is scarcely worth while to seed the cover crop.

Manure (M) was first applied to the plots indicated, on Series 300 for the 1906 crop, on Series 200 for 1907, Series 100 for 1908, and Series 400 for 1909, and subsequently in the same order. The initial applications were made at the rate of 8 tons per acre, but since 1909 the weight of manure applied has been equal to the weight of the crops produced. On Plots 4, 9, and 14 of each series some cover crops have also been grown, as shown by the tables.

Ground limestone (L) was applied to Plots 1 to 15 of all series for 1906 at the rate of 1,300 pounds per acre, and again for 1913 at the rate of 4 tons per acre. As yet no conclusions are justified concerning its effects.

Once every four years to part of the plots in each series phosphorus (P) has been applied in 1 ton per acre of rock phosphate, and potassium (kalium=K) in 400 pounds per acre of potassium sulfate, after beginning in 1904-5 with an application of three-fourths of these amounts on Series 300, full amounts on Series 200, five-fourths on Series 100, and six-fourths on Series 400.

In order to help settle the question whether commercial nitrogen could be used with profit, nitrogen (N) has been applied to Plot 19 at the rate of 25 pounds per acre per annum. Nearly the total amount for the first four years was applied in 1904, but since 1907 the applications have been made annually.

In Table 7 are shown the values of the increases produced from 1907 to 1914 by the different materials applied. It should be kept in mind that the full treatment on the manured plots dates from 1909, and that the residue system was not fully under way till 1913.

One method of computing the increase from a given treatment is to deduct from the total produce the computed yield of the same plot if it had not been so treated. For example, in 1914 the actual yield of corn on Plot 401 was 47.0

TABLE 3.—CROP YIELDS PER ACRE IN SOIL EXPERIMENTS, ROCKFORD FIELD: SERIES 100
BROWN SILT LOAM PRAIRIE; IOWAN GLACIATION

Plot	Soil treatment applied	Corn 1904	Corn 1905	Oats 1906	Clover 1907	Corn 1908	Corn 1909	Oats 1910	Soybeans 1911	Corn 1912	Corn 1913	Oats 1914	Value of 3 crops 1904-1906		Value of 4 crops 1907-1910		Value of 4 crops 1911-1914	
		Bushels or tons (clover) per acre											Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
101	L	64.7	65.1	53.7	1.95	63.4	47.0	67.5	17.3	49.4	41.0	52.8	$60.47	$86.38	$71.19	$101.70	$58.53	$ 83.62
102	RL	60.0	61.7	56.6	1.95	59.6	53.0	68.1	19.3	52.2	46.8	60.0	58.44	83.49	72.13	103.04	64.96	92.80
103	ML	72.2	60.5	51.9	1.94	72.8	59.4	72.5	17.2	78.0	48.8	57.8	60.98	87.11	80.15	114.50	72.60	103.72
104	CvML	67.5	61.9	51.6	1.96	70.0	58.4	73.8	16.8	78.0	46.2	47.5	59.74	85.34	79.32	113.32	68.53	97.90
105	L	65.6	63.9	48.7	1.86	60.6	52.0	67.5	20.2	59.4	36.8	40.6	58.96	84.23	71.33	101.90	59.18	84.54
106	LP	69.6	69.3	58.1	2.36	79.4	58.8	78.1	22.0	58.8	37.6	60.3	64.88	92.69	86.76	123.94	66.02	94.32
107	RLP	73.3	62.4	51.9	2.36	77.6	66.4	73.1	26.5	60.6	45.0	58.1	62.03	88.61	87.39	124.84	71.78	102.54
108	MLP	70.6	69.2	53.7	2.35	86.2	64.6	80.6	22.7	78.0	49.6	58.1	63.97	91.38	91.80	131.14	76.82	109.74
109	CvMLP	62.8	63.7	50.6	2.38	84.0	65.4	80.0	23.3	75.2	49.4	55.6	58.44	83.49	91.35	130.50	75.49	107.84
110	L	65.6	58.4	47.8	1.80	63.2	51.6	72.2	20.7	40.4	37.2	52.5	56.78	81.12	72.86	104.08	56.35	80.50
111	LPK	69.5	65.9	49.4	2.51	81.2	68.8	74.1	24.2	68.4	47.2	56.2	61.22	87.46	90.82	129.74	73.14	104.48
112	RLPK	68.0	62.9	50.3	2.46	76.2	71.4	74.7	25.0	63.2	52.2	60.9	59.90	85.57	89.80	128.28	74.94	107.06
113	MLPK	66.1	65.7	47.8	2.45	85.4	68.0	77.9	23.2	70.2	48.6	54.4	59.51	85.02	92.65	132.36	73.05	104.36
114	CvMLPK	65.4	62.8	53.7	2.55	82.2	69.2	84.4	22.2	70.8	47.8	55.6	59.90	85.58	94.47	134.96	72.62	103.74
115	L	65.5	61.3	45.0	2.06	65.2	51.8	68.4	21.3	45.6	37.4	47.5	56.98	81.40	74.52	106.46	57.26	81.80
116	R	65.5	64.3	49.4	2.25	57.2	65.2	78.4	24.2	51.0	46.0	53.1	59.26	84.66	80.54	115.06	65.76	93.94
117	RP	67.8	61.9	53.1	2.35	75.0	65.8	75.3	23.0	55.4	50.6	64.4	60.26	86.09	86.81	124.02	71.23	101.76
118	RPK	65.9	66.0	52.8	2.43	79.0	72.4	83.4	21.7	61.4	48.6	60.9	60.95	87.07	93.35	133.36	70.74	101.06
119	RLNPK	71.3	72.1	78.1	2.35	80.4	72.8	89.7	23.7	71.8	49.2	56.9	72.06	102.94	95.19	135.98	74.87	106.96
120	0	65.4	62.4	47.2	1.26	63.6	45.0	72.5	18.8	37.8	37.8	47.8	57.95	82.78	67.13	95.90	53.00	75.72

L=ground limestone; R=crop residues (corn stalks, oat straw, all legumes except the seed); M=manure; Cv=cover crops; P=phosphorus; K=potassium; N=nitrogen.

TABLE 4.—CROP YIELDS PER ACRE IN SOIL EXPERIMENTS, ROCKFORD FIELD: SERIES 200
BROWN SILT LOAM PRAIRIE; IOWAN GLACIATION

Plot	Soil treatment applied	Corn 1904	Oats 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Corn 1911	Corn 1912	Oats 1913	Clover 1914	Value of 3 crops 1904-1906		Value of 4 crops 1907-1910		Value of 4 crops 1911-1914	
		Bushels or tons per acre[1]											Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
201	L	62.9	82.5	1.09	67.8	55.2	85.3	1.60	64.2	61.0	43.8	1.85	$52.74	$75.35	$78.13	$111.62	$69.03	$98.62
202	RL	61.8	78.4	.84	67.3	51.2	90.3		68.8	65.8	49.1	(.33)	49.46	70.66	66.76	95.37	63.17	90.24
203	ML	69.2	75.3	.82	78.4	66.2	88.8	1.64	81.6	69.2	49.1	1.88	51.04	72.92	86.95	124.22	79.69	113.84
204	CvML	69.4	77.2	1.07	75.5	64.8	90.9	1.75	80.0	68.6	47.8	1.85	53.40	76.28	86.80	124.01	78.34	111.92
205	L	65.3	77.5	1.13	69.6	55.8	83.4	1.80	72.4	54.4	41.9	1.88	52.47	74.95	79.84	114.06	69.27	98.96
206	LP	62.4	78.4	1.40	72.9	61.6	95.6	2.13	74.0	62.6	51.2	1.72	53.59	76.56	88.75	126.79	74.19	105.98
207	RLP	61.2	70.9	1.25	71.9	63.6	84.7		78.6	71.6	52.8	(.17)	50.02	71.46	71.14	101.63	68.54	97.92
208	MLP	69.6	82.2	1.35	81.2	73.6	95.6	2.08	81.4	67.3	50.6	1.80	56.82	81.18	95.50	136.44	78.81	112.59
209	CvMLP	68.0	80.0	1.35	80.4	69.6	90.3	2.11	79.8	70.4	50.6	1.88	55.65	79.50	92.55	132.22	79.90	114.14
210	L	65.2	80.3	1.26	71.5	51.8	86.3	1.51	73.4	49.6	42.2	1.80	54.12	77.32	77.89	111.27	67.47	96.38
211	LPK	63.8	82.2	1.42	81.5	69.6	85.3	2.17	81.8	69.0	49.7	2.10	55.29	78.98	91.96	131.37	81.40	116.28
212	RLPK	64.7	77.2	1.33	78.7	68.4	84.7		79.8	75.0	50.0	(.17)	53.57	76.53	75.20	107.43	69.37	99.10
213	MLPK	66.8	73.1	1.26	83.3	80.0	80.3	2.26	84.2	73.6	50.0	2.05	52.69	75.24	95.46	136.37	83.58	119.40
214	CvMLPK	70.8	75.9	1.44	84.7	79.0	90.9	2.37	86.0	71.2	50.3	1.85	56.11	80.16	99.34	141.91	82.05	117.22
215	L	72.5	78.1	1.39	76.6	58.8	85.6	1.93	72.0	51.8	43.8	1.84[2]	56.97	81.39	84.87	121.24	68.47	97.82
216	R	66.1	75.9	1.34	69.4	59.0	84.4		78.4	68.4	47.5	(.50)	53.77	76.81	68.57	97.96	68.18	97.40
217	RP	65.2	73.4	1.33	74.9	67.2	81.9		78.0	67.4	52.5	(.83)	52.68	75.26	72.67	103.81	71.40	102.00
218	RPK	64.2	77.5	1.34	77.0	72.8	90.6		76.2	71.0	54.7	(.50)	53.55	76.50	77.80	111.14	70.33	100.48
219	RLNPK	70.1	83.4	1.62	76.1	70.2	86.6		78.4	75.2	59.4	(.50)	59.22	84.61	75.45	107.79	73.89	105.56
220	0	62.4	79.4	.99	63.5	53.0	83.4	1.17	68.8	49.2	49.7	1.65	51.00	72.86	72.31	103.31	66.77	95.38

[1]For clover the figures indicate tons of hay, except where in parentheses, in which case they indicate bushels of seed.
[2]Yield estimated.

TABLE 5.—CROP YIELDS PER ACRE IN SOIL EXPERIMENTS, ROCKFORD FIELD: SERIES 300
BROWN SILT LOAM PRAIRIE; IOWAN GLACIATION

Plot	Soil treatment applied	Oats 1904	Soybeans 1905	Corn 1906	Corn 1907	Oats 1908	Clover 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913	Corn 1914	Value of 3 crops 1904-1906		Value of 4 crops 1907-1910		Value of 4 crops 1911-1914	
		Bushels or tons per acre[1]											Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
301	L..........	59.7	1.99	84.4	49.4	40.3	1.35	55.0	52.0	57.8	2.95	69.2	$60.19	$85.98	$57.27	$81.82	$79.25	$113.22
302	RL.........	60.8	2.04	82.0	51.8	40.3	(1.66)	57.6	66.0	75.0	(2.33)	81.6	60.04	85.72	61.19	87.42	88.97	127.10
303	ML.........	60.6	2.07	93.7	55.6	41.6	1.76	67.6	64.8	67.5	3.48	92.8	64.25	91.79	67.09	95.84	98.42	140.60
304	CvML.......	58.1	1.81	83.5	52.9	38.1	1.98	69.4	60.0	76.9	3.53	92.0	58.16	83.09	67.33	96.19	99.44	142.06
305	L..........	55.6	1.62	77.5	44.7	33.1	1.46	56.0	47.2	61.9	3.12	73.6	54.03	77.19	54.73	78.19	81.45	116.36
306	LP.........	53.8	1.88	77.4	45.7	33.8	1.59	59.8	56.2	72.8	3.60	81.2	55.31	79.02	57.52	82.17	93.67	133.82
307	RLP........	57.0	1.88	78.4	48.4	35.0	(.48)	63.0	69.6	71.3	(1.83)	88.4	56.56	80.80	52.15	74.50	88.07	125.82
308	MLP........	55.8	1.87	88.6	52.5	35.0	2.07	67.0	68.0	77.8	3.91	95.2	59.72	85.32	66.11	94.45	106.27	151.82
309	CvMLP......	58.9	1.87	85.6	54.3	35.3	2.07	68.0	66.4	70.9	3.87	93.6	59.54	85.06	67.18	95.97	102.94	147.06
310	L..........	60.3	1.66	74.9	42.9	33.1	1.40	54.4	48.4	60.9	2.98	73.4	54.72	78.17	53.12	75.89	80.54	115.06
311	LPK........	58.8	1.84	84.9	46.4	35.9	2.09	66.8	69.8	69.7	3.97	94.4	59.06	84.37	64.30	91.86	104.78	149.68
312	RLPK.......	58.3	1.96	81.0	49.3	36.3	(.50)	69.0	72.4	75.0	(1.83)	99.6	58.39	83.42	55.07	78.67	94.01	134.30
313	MLPK.......	60.3	1.97	84.9	50.1	32.2	2.37	67.0	74.6	72.2	4.03	88.6	60.39	86.27	66.59	95.13	105.55	150.78
314	CvMLPK.....	61.2	2.09	85.2	53.2	33.8	2.52	69.0	70.2	74.4	4.20	88.0	61.59	87.98	69.87	99.82	105.60	150.86
315	L..........	58.6	1.96	81.9	46.7	31.6	1.70	62.4	53.6	65.0	(2.83)	72.4	58.79	83.99	58.93	84.19	82.11	117.30
316	R..........	59.6	2.00	82.0	53.3	33.1	(1.24)	65.0	68.0	75.0	(2.33)	87.4	59.39	84.84	59.35	84.79	91.70	131.00
317	RP.........	56.3	2.26	87.1	58.3	37.8	(1.83)	66.6	68.2	73.4	(2.17)	89.6	62.07	88.67	67.11	95.87	90.97	129.96
318	RPK........	57.5	2.32	93.5	60.6	36.9	(2.04)	69.4	68.4	77.2	(1.83)	89.4	65.07	92.95	70.11	100.16	89.66	128.08
319	RLNPK......	73.4	2.62	96.6	62.5	44.7	(1.60)	67.6	72.0	74.1	(2.00)	92.0	72.70	103.86	69.25	98.93	92.15	131.64
320	0..........	54.1	1.87	81.4	43.9	40.9	2.39	59.2	51.4	68.4	3.68	71.2	56.73	81.04	64.27	91.81	87.82	125.46

[1]For clover and soybeans the figures indicate tons of hay, except where in parentheses, in which case they indicate bushels of seed.

TABLE 6.—CROP YIELDS PER ACRE IN SOIL EXPERIMENTS, ROCKFORD FIELD: SERIES 400
BROWN SILT LOAM PRAIRIE; IOWAN GLACIATION

Plot	Soil treatment applied	Timothy 1904	Corn 1905	Corn 1906	Oats 1907	Clover 1908	Corn 1909	Corn 1910	Oats 1911	Soybeans 1912	Corn 1913	Corn 1914	Value of 3 crops 1904-1906		Value of 4 crops 1907-1910		Value of 4 crops 1911-1914	
		Bushels or tons per acre[1]											Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
401	L..........	1.65	67.3	60.8	34.4	2.06	60.6	38.6	60.0	(9.3)	36.2	47.0	$56.39	$80.55	$58.77	$83.96	$52.43	$74.90
402	RL.........	1.66	64.0	54.6	33.8	2.10	64.2	49.6	60.6	(10.5)	44.6	72.4	53.13	75.90	63.99	91.42	65.27	93.24
403	ML........	1.65	69.1	63.6	33.8	2.22	81.6	46.0	69.4	10.5	51.4	72.0	58.00	82.85	69.66	99.52	69.97	99.96
404	CvML......	1.59	60.8	61.0	33.8	2.13	78.0	46.6	58.8	10.7	49.2	72.6	53.76	76.80	67.98	97.12	66.58	95.12
405	L..........	1.59	70.3	65.2	33.1	2.09	66.0	49.0	60.6	(9.0)	41.2	47.8	58.56	83.65	64.15	91.64	54.42	77.74
406	LP.........	1.44	70.8	67.9	36.6	2.19	69.6	33.6	58.8	(11.3)	40.2	53.2	58.62	83.75	61.70	88.14	57.06	81.52
407	RLP.......	1.52	70.7	71.0	39.4	2.27	73.4	41.2	64.1	(10.7)	45.8	80.2	60.23	86.05	67.03	95.76	69.54	99.34
408	MLP.......	1.47	70.7	71.4	34.7	1.95	86.0	48.4	60.3	12.7	52.0	86.4	60.02	85.75	70.40	100.58	74.21	106.02
409	CvMLP.....	1.45	66.4	72.1	38.8	2.15	83.8	41.2	69.4	14.2	45.6	87.4	58.62	83.75	69.66	99.52	75.92	108.46
410	L..........	1.47	67.6	66.0	33.1	2.13	68.2	38.2	60.3	11.2	37.4	55.4	57.05	81.50	60.42	87.74	57.20	81.72
411	LPK.......	1.57	68.9	73.8	38.4	2.23	85.2	43.4	69.7	(12.2)	51.0	82.8	60.93	87.05	71.37	101.96	74.89	106.98
412	RLPK......	1.53	73.1	67.0	40.6	2.20	85.2	49.8	70.9	(9.5)	45.6	85.4	59.74	85.35	74.02	105.74	72.35	103.36
413	MLPK......	1.43	68.3	65.4	37.5	2.21	86.4	63.8	71.3	11.7	47.2	89.4	56.80	81.15	78.54	112.20	75.96	108.52
414	CvMLPK...	1.41	69.9	67.9	38.8	2.21	87.2	51.8	72.8	10.3	56.4	90.8	58.10	83.00	74.98	107.12	79.11	113.02
415	L..........	1.62	68.8	66.3	34.1	2.18	69.2	45.0	61.6	(11.0)	41.2	58.2	58.62	83.75	64.78	92.54	59.74	85.34
416	R..........	1.65	66.9	64.1	34.7	2.24	68.6	50.6	70.6	(12.7)	43.0	77.4	57.40	82.00	67.12	95.88	70.80	101.14
417	RP.........	1.62	65.3	71.0	40.3	2.26	75.2	49.0	70.3	(11.0)	47.6	73.6	59.04	84.35	70.57	100.82	69.66	99.52
418	RPK.......	1.45	63.2	66.3	38.8	2.04	83.6	49.8	71.3	(8.2)	47.4	83.2	55.48	79.25	71.83	102.62	71.41	102.02
419	RLNPK....	2.46	69.3	83.0	43.8	2.27	83.8	55.2	66.9	(7.3)	49.0	92.8	70.52	100.75	76.80	109.72	73.47	104.96
420	0...........	1.40	54.7	47.6	31.3	2.07	59.0	35.6	66.9	(13.0)	39.4	52.4	45.60	65.15	56.36	80.52	59.96	85.66

[1]For timothy and clover the figures indicate tons of hay. For soybeans they indicate tons of hay, except where in parentheses, in which case they indicate bushels of seed.

TABLE 7.—FINANCIAL STATEMENT: ROCKFORD FIELD

Additions	Groups	No. of tests	Average total increase 1907-1910				Average annual increase from 4 acres 1907-1910	Average for 1911-1914				Average annual increase from 4 acres 1911-1914	Average annual increase from 4 acres 1907-1914
			Series 100	Series 200	Series 300	Series 400		Series 100	Series 200	Series 300	Series 400		
Lower Prices													
Residues..........	No K..........	2	$ .59	-$14.51	-$ .24	$1.30	-$3.22	$6.29	-$ 5.60	$ 1.88	$12.13	$ 3.68	$ .23
Residues..........	With K.........	1	-1.32	-18.16	-10.40	1.97	- 6.98	1.62	- 12.23	-11.08	-3.04	-6.18	-6.58
Manure..........	No K..........	2	6.64	7.75	10.16	5.46	7.50	12.84	7.94	15.52	16.30	13.15	10.32
Manure..........	With K.........	1	1.22	.71	-.03	5.82	1.93	-.45	1.78	.14	.06	.39	1.16
Phosphorus.......	All.............	5	11.40	6.61	1.48	5.03	6.13	7.00	3.49	4.10	2.16	4.19	5.16
Potassium........	With R or M....	4	2.06	1.43	.14	4.73	2.09	-.55	1.76	1.20	.40	.70	1.40
Potassium........	No R or M......	1	2.42	3.37	6.91	11.19	5.97	9.20	8.45	11.51	15.09	11.06	8.52
Nitrogen.........	....	1	5.39	.25	14.18	2.79	5.65	-.07	4.52	-1.86	1.12	.92	3.29
Higher Prices													
Residues..........	No K..........	2	$ .84	-20.73	-$ .35	$1.86	-$4.60	$8.99	-$8.00	$ 2.68	$17.33	$5.25	$ .32
Residues..........	With K.........	1	-1.89	-25.94	-14.85	2.82	- 9.97	2.32	-17.47	-15.83	-4.35	-8.83	-9.40
Manure..........	No K..........	2	9.48	11.07	14.52	7.80	10.72	18.34	11.34	22.17	23.28	18.78	14.75
Manure..........	With K.........	1	1.75	1.01	-.05	8.32	2.76	-.64	2.54	.20	.09	.55	1.66
Phosphorus.......	All.............	5	16.29	9.44	2.11	7.18	8.76	10.00	4.98	5.85	3.09	5.98	7.37
Potassium........	With R or M....	4	2.94	2.04	.20	6.76	2.99	-.79	2.51	1.72	.57	1.00	2.00
Potassium........	No R or M......	1	3.46	4.82	9.87	15.98	8.53	13.14	12.07	16.45	21.56	15.80	12.17
Nitrogen.........	....	1	7.70	.36	20.26	3.98	8.08	-.10	6.46	-2.66	1.60	1.32	4.70

bushels, and on Plot 405, 47.8 bushels. The increase in yields for the organic manures on Plots 402, 403, and 404, lying between these two check plots, may therefore be based on the assumption that with no organic manures the yields would have been 47.2, 47.4, and 47.6 bushels, respectively. The increase for phosphorus may be computed by the same method, or it may be computed by deducting the yield secured without phosphorus from the yield secured where phosphorus has been applied on comparable plots, or the increase without phosphorus from the increase with phosphorus.

The crop values given in Tables 3, 4, 5, and 6 serve as the basis for computing the value of the increases summarized in Table 7. The average increase of five trials with phosphorus, for example, is based upon the results from Plots 6, 7, 8, 9, and 17 of each series, and is found by comparing the return from Plot 6 with the computed return had no phosphorus been applied, the increases from Plots 7, 8, and 9, based on computed yields, with the increases from Plots 2, 3, and 4, respectively, and the returns from Plot 17 with those from Plot 16.

While the cumulative effects of permanent systems of soil improvement are already becoming very marked, final conclusions cannot be drawn as to the relative or absolute value of the several materials used, except that, as a rule, organic manures are evidently of first importance. Thus, in 1914 corn after corn on Series 400 varied in yield from 52.1 bushels per acre, as an average of four plots receiving limestone with no manure or crop residues, to 72.3 where organic matter is added (average of Plots 402, 403, and 404), to 84.7 where phosphorus is also applied (average of Plots 407, 408, and 409), and to 88.5 where potassium is used as a further addition (average of Plots 412, 413, and 414); while 92.8 bushels per acre were produced on Plot 419, receiving crop residues, limestone, phosphorus, potassium, and commercial nitrogen. The photographic illustrations of the 1915 clover crop (Plates 1 and 2) also suggest the cumulative effect of soil improvement. The yields reported are tons per acre of field-cured clover hay.

The crop values from all plots in all series are given in Tables 3, 4, 5, and 6 for the first three-year period and for the two succeeding four-year periods. The increases in values for the two full rotations, 1907 to 1914, resulting from the various applications, are summarized in Table 7. The "lower prices" used are 35 cents a bushel for corn, 28 cents for oats, 70 cents for soybeans, $7 for clover seed, and $7 a ton for hay; the "higher prices" are 50 cents a bushel for corn, 40 cents for oats, $1 for soybeans, $10 for clover seed, and $10 a ton for hay. The crop yields are all recorded, and one may compute the values at any other prices if he desires. It should be kept in mind that increases in crop yields resulting from soil treatment should be valued by the farm operator at reasonable prices for the crops standing in the field ready for harvest; while the landowner whose farm is operated by a tenant and who usually receives his share of the produce delivered at the market or placed in storage, may safely base his returns upon a higher valuation.

In Bulletin 123 and in the Appendix of this and other Soil Reports, attention is called to the fact that potassium produces little or no effect on normal Illinois soils when applied in connection with plenty of decaying organic matter; but if no adequate provision is made for organic matter, then potassium becomes effective, probably in large part because of its stimulating action, other soluble salts having a similar action. (See "The Potassium Problem" in the Appendix.) The averages by groups in Table 7 reveal in a very striking manner this action of potassium. They also indicate that the organic matter not only supplies nitrogen but also produces the same effect as potassium.

A permanent system of maintaining soil fertility is of course impossible without the restoration of nitrogen; but without a knowledge of the scientific facts involved one might easily be misled for some years into believing that potash salts would take the place of organic manures, when used in addition to limestone and phosphorus. Thus, from the eight-year average shown in Table 7 it will be seen that at the lower prices the annual increase from potassium without organic manures was $8.52 from four acres, but only $1.40 where applied in addition to manures; at the higher prices, the increases were worth $12.17 and $2, respectively. At $50 per ton for potassium sulfate, the cost of the 400 pounds applied to the four acres was $10. Thus while at the higher prices for produce potassium more than paid its cost when used without manures, it paid only one-fifth its cost when added to a rational system of soil improvement.

Furthermore, where farm manure was used without potassium, it produced on four acres an annual increase of $10.32 in crop values, but where applied in addition to potassium it produced an increase of only $1.16. Only the known facts concerning the composition of the soil and the requirements of the crops, and the knowledge afforded by other long-continued field investigations, can protect us from drawing erroneous conclusions from such data as these. The results with crop residues only confirm those with manure: residues without potassium produced sufficient increase to counterbalance the extra crops harvested from the check plots, but when used in addition to potassium they failed by $6.58 to overcome the loss from plowing under crops that would otherwise have been made into hay.

PLATE 1.—CLOVER IN 1915 ON ROCKFORD FIELD
ON LEFT: NO TREATMENT—YIELD, 1.44 TONS
ON RIGHT: MANURE, LIMESTONE, AND PHOSPHORUS—YIELD, 2.90 TONS

In 1914 the acre-yield of corn on Plot 406 (LP) was 53.2 bushels, and on Plot 411 (LPK) 82.8 bushels; while on Plot 407 (RLP) 80.2 bushels were grown, and on Plot 408 (MLP) 86.4 bushels. On Series 300 the corresponding acre-yields were 81.2 bushels (LP), 94.4 bushels (LPK), 88.4 bushels (RLP), and 95.2 bushels (MLP). The averages of these data from the eleventh year of the experiment show 1 bushel more corn per acre where potassium was applied than where organic manures were used. However, in experiments covering thirty years at Pennsylvania State College, the crop values from four acres, as an average of the first five years, were only 22 cents higher with farm manure than with soluble phosphate and potash salts, and as an average of the first fifteen years only $2.11 higher; whereas during the second fifteen years the average return was $16.04 larger with farm manure.

Phosphorus, as an average, has barely paid its cost, even at the higher prices for produce, but at least 600 pounds per acre of the applications still remains in the soil, which is now 50 percent richer in phosphorus than at the beginning, so that on the basis of investment the use of phosphorus might be considered profitable. In general, wheat and clover respond more markedly to phosphorus treatment than corn, oats, or soybeans, but no wheat is grown on the Rockford field and soybeans have sometimes been substituted for clover. Normally the effect of increasing the total supply of phosphorus becomes more and more pronounced on each succeeding crop yield, but in these experiments the effect during the last four years has been less than that for the preceding rotation. Perhaps this may be accounted for by seasonal variations. The future yearly cost of phosphorus will be reduced to about one-third the annual investment thus far, for in the final system of soil maintenance not more than one-

PLATE 2.—CLOVER IN 1915 ON ROCKFORD FIELD
ON LEFT: LIMESTONE—YIELD, 1.54 TONS
ON RIGHT: LIMESTONE AND PHOSPHORUS—YIELD, 2.55 TONS

third as much phosphorus need be applied for each rotation as that used in the preliminary system of soil enrichment.

Men pay more than $200 an acre for land because its productive power is high and durable, altho other land could be purchased for less than $50 which, if heavily fertilized, would produce as large crops. The difference of $150 or more per acre is invested in durability; and we may apply the same principle to investments in systems of substantial soil enrichment.

The application of potassium does not enrich the soil as does the application of phosphorus, for the plowed soil of an acre already contains 35,000 pounds of potassium, which is nearly a thousand times the average yearly application of 42 pounds made at Rockford.

Commercial nitrogen, at 15 cents a pound, has not paid its cost, as an average of the eleven years. The average return for the last four years, even at the higher prices, is about one-third the cost.

Farm manure applied without potash salts at the average rate of 12.4 tons per acre per rotation was worth in increased yields, as an average, 83 cents per ton at the lower prices for produce, or $1.19 at the higher prices. Without doubt the manure will have a cumulative effect. When comparing the rotations reported in Table 7, one should remember that the rate of application of manure was only 8 tons per acre for the years 1906 to 1909, and about 15 tons per acre, as an average, for the years 1910 to 1914, the proper plots on one series only being manured each year before the first corn crop in the rotation.

RESULTS OF EXPERIMENTS ON MT. MORRIS FIELD

The Mt. Morris experiment field, located on the brown silt loam prairie in Ogle county, was started in the spring of 1910, but no soil treatment was begun until the fall of that year. Series 200 (the results from which are recorded in Table 8) was the first series to receive full soil treatment. While the limestone was not applied till after the crop season of 1912, the other treatments indicated were under way on that series from 1912 to 1915. It may be noted, however, that the first full crop of clover was in 1914, and where this was plowed under its effect on corn and oats will not be secured till 1916 and 1917. Corn has not yet been grown on this series where the stalks from a previous corn crop have been plowed under in the residue system. On series 100 manure was first applied for 1915, and wheat will not be grown on manured land on that series till 1918.

Thus, the first six or seven years must be regarded as a preliminary period in establishing permanent systems of soil enrichment in a four-crop rotation, where crops must be grown at least for one year before the proper rate of application for manure can be determined, as must be the case in farm practice, or where crop residues are depended upon for the maintenance of nitrogen.

The data reported in Table 8 are far too meager to justify conclusions as to the ultimate results to be secured from these systems, but they are of some interest and value when considered in connection with the results from the Rockford field. Organic manures seem to be of first importance, while phosphorus (applied as at Rockford, page 9), has already nearly paid its total cost even tho from two-thirds to three-fourths of the applications remains for positive soil enrichment.

TABLE 8.—CROP YIELDS PER ACRE IN SOIL EXPERIMENTS, MT. MORRIS FIELD
BROWN SILT LOAM PRAIRIE

Plot	Soil treatment applied[1]	Corn 1912	Oats 1913	Clover[2] 1914	Wheat 1915	Value of 4 crops		Value of each addition		
	Bushels or tons per acre					Lower prices	Higher prices		Lower prices	Higher prices
201	0..........	48.6	52.8	1.85	31.7	$66.93	$95.62			
202	M..........	56.8	63.0	2.74	35.9	81.83	116.90	M	$14.90	$21.28
203	ML........	57.4	50.3	3.44	40.1	86.32	123.32	L	4.49	6.42
204	MLP.......	58.7	61.7	3.52	44.0	93.26	133.23	P	6.94	9.91
205	0..........	49.6	48.8	1.74	30.8	64.76	92.52			
206	R..........	45.8	62.5	(1.00)	37.7	66.92	95.60	R	2.16	3.08
207	RL.........	48.8	63.3	(1.25)	42.1	73.02	104.32	L	6.10	8.72
208	RLP.......	53.0	69.2	(1.00)	47.1	78.60	112.28	P	5.58	7.96
209	RLPK......	62.1	63.1	(1.67)	48.2	84.83	121.19	K	6.23	8.91
210	0..........	51.1	48.0	(1.50)	42.9	71.86	102.65			

[1]The limestone was not applied till after the crop season of 1912.
[2]The figures in parentheses indicate bushels of seed; the others tons of hay.

In this connection it is of interest to note that in the long-continued Pennsylvania experiments, as reported by Director Hunt in an address before the Illinois State Farmers' Institute at Centralia in 1912 (pages 31 to 47) and in Bulletin 90 of the Pennsylvania Agricultural Experiment Station, phosphorus applied in soluble acid phosphate at a cost of $3.84 per acre for each four-year rotation [corn, oats, wheat, and hay (mixed clover and timothy)] paid back only $3.61 during the first ten years, or a little more than one-third of its total cost, $9.60, but during the second ten years it paid $23.93, or more than double its cost, and during the third ten-year period, $33.32, or more than three times its cost. While Illinois prices or methods of interpretation would change these figures, a markedly increasing effect would still be shown from the use of phosphorus. Director Thorne of the Ohio Experiment Station has often called attention to the fact that phosphorus applied in acid phosphate on the Wooster and Strongsville experiment fields produced much more marked effects in later years than at the beginning of the experiments. (See also the records of the experiments on the South Farm at Urbana, pages 20 to 28.)

Ground limestone was applied to part of the plots in each series on the Mt. Morris field, for 1913, at the rate of 4 tons per acre. Table 8 indicates that it has already produced distinct benefit both to the clover and to the wheat following clover. Potassium is applied at the yearly rate of 20 pounds in 200 pounds of kainit, instead of 42 pounds in 100 pounds of potassium sulfate, as at Rockford. The results thus far secured suggest that the effects are better correlated with total salts than with their potassium content, and that the action is, in part at least, that of a stimulant.

The increase in crop values from $66.93 to $93.26, because of the use of ground limestone, fine-ground natural rock phosphate, and "home-grown" manure, in permanent soil improvement, is significant and encouraging.

In another rotation at Mt Morris, which was started in 1913, potatoes are grown. The applications per acre to the respective plots are 4 tons of limestone and 2 tons of rock phosphate for an eight-year rotation (two crops of potatoes and six of alfalfa), and 15 tons of manure for each potato crop. In Table 9 are given the results secured thus far. The value of manure is plainly shown,

TABLE 9.—YIELD OF POTATOES ON MT. MORRIS FIELD
BROWN SILT LOAM PRAIRIE

Plot	Soil treatment applied	1913 Bushels per acre	1914 Bushels per acre	Value of 2 crops	
				Lower price (35 cents)	Higher price (50 cents)
501	0	112	78	$66.50	$95.00
502	M	163	158	112.35	160.50
503	ML	184	174	125.30	179.00
504	MLP	208	175	134.05	191.50

and the effect of limestone and phosphorus suggests that both may be used to advantage in permanent systems. The total enrichment has more than doubled the crop values.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901. From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed. The average yields are recorded in Table 10.

A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields of clover in 1903 were taken by carefully weighing the yields from small representative areas; but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 10 in computing yields and values.) The average yields of hay shown in the table represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Le), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

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

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

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

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

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

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the various plots were treated the same as the corresponding plots in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation, wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then to be brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 11.)

From 1911 to 1914 soybeans were substituted three years because of clover failure; accordingly three-fourths of the soybeans and one-fourth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912 the field was plowed and reseeded. The average yield reported for alfalfa in Table 11 is one-fourth of the combined crops of 1912, 1913, and 1914.

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

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

TABLE 10.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

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

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

TABLE 11.—YIELDS PER ACRE, FOUR-YEAR AVERAGES, 1911-1914: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans–3, tons (bu.)	Clover–1, tons (bu.)	Alfalfa, tons	Value of 5 crops	
								Lower prices	Higher prices
1	0........	18.3	50.8	39.8	1.60	1.70	1.70	$65.00	$92.87
2	R.......	19.7	53.8	40.6	(20.1)	(.74)	1.27	64.72	92.47
3	M.......	20.3	59.3	48.8	1.60	1.43	1.13	67.44	96.35
4	RL......	22.3	55.7	42.8	(19.0)	(1.03)	1.19	67.20	96.00
5	ML......	24.9	58.6	51.6	1.66	1.94	1.67	76.19	108.84
6	RLP....	37.4	62.2	58.7	(21.0)	(2.48)	2.69	98.58	140.83
7	MLP....	36.6	63.8	60.9	1.88	2.90	2.63	98.36	140.51
8	RLPK...	36.1	58.9	59.1	(22.2)	(1.41)	2.58	94.61	135.16
9	MLPK..	35.3	59.6	65.1	2.09	2.72	2.66	98.15	140.22
10	MxLPx..	43.5	55.7	67.2	2.14	2.94	2.84	105.02	150.03

pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

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

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

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

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

As a general average, the plots receiving limestone have produced $1.22 an acre a year more than those without limestone, and this corresponds to more

TABLE 12.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 100
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1903	Corn 1904	Oats 1905	Wheat 1906	Clover 1907	Corn 1908	Oats 1909	Clover 1910	Wheat[2] 1911	Corn 1912	Oats 1913	Soybeans 1914	Value 1st four years		Value 2d four years		Value 3d four years	
		Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
163	RP.....	45.1	54.1	57.5	39.8	(.83)	72.0	45.4	(.60)	46.85	74.9	26.8	(16.6)	$78.68	$112.40	$47.92	$68.46	$78.13	$111.62
166	RP.....	43.8	49.3	60.9	36.5	(1.00)	74.9	40.8	(1.30)	53.40	79.5	24.6	(17.5)	75.19	107.41	53.74	76.77	84.34	120.49
169	R.......	42.7	39.5	49.3	28.4	(.90)	65.0	39.9	(1.70)	36.71	67.9	19.1	(15.3)	62.45	89.22	52.12	74.46	65.52	93.60
170	M......	41.8	38.7	52.2	26.2	2.56	69.6	40.1	2.87	35.85	76.7	22.5	1.09	61.13	87.33	73.60	105.14	65.87	94.10
173	MP.....	35.4	53.3	54.6	32.8	3.65	78.4	39.8	4.23	52.65	83.7	29.6	1.45	69.29	98.99	93.74	133.92	84.59	120.84
176	MP.....	39.3	58.1	61.9	38.8	3.74	79.5	40.0	4.23	51.03	85.6	32.1	1.52	78.58	112.26	94.81	135.45	85.30	121.87
163	RLP....	....	....	....	....	....	....	....	....	49.9	87.0	28.2	(18.1)	....	....	....	....	85.94	122.78
166	RLP....	....	....	....	....	....	....	....	....	53.6	81.4	26.8	(18.0)	....	....	....	....	86.11	123.02
169	R.......	....	....	....	....	....	....	....	....	33.8	62.7	17.0	(15.2)	....	....	....	....	61.00	87.15
170	M......	....	....	....	....	....	....	....	....	32.4	74.4	22.0	1.09	....	....	....	....	62.51	89.30
173	MLP...	....	....	....	....	....	....	....	....	51.3	85.7	28.0	1.37	....	....	....	....	83.33	119.05
176	MLP...	....	....	....	....	....	....	....	....	51.0	85.6	30.9	1.47	....	....	....	....	84.60	120.86

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1911 the acre-yields are based on half-plots, limestone having been applied to one half of each of the plots indicated.

TABLE 13.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SERIES 200
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Oats 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat[2] 1910	Corn 1911	Oats 1912	Soybeans 1913	Wheat 1914	Value 1st four years		Value 2d four years		Value 3d four years	
		Bushels or tons per acre[1]												Lower prices	Higher prices	Lower prices	Higher prices	Lower prices	Higher prices
263	RP.....	24.7	25.7	32.1	.82	65.3	31.3	42.5	43.7	52.3	72.9	(13.7)	30.61	$42.32	$60.46	$91.96	$131.37	$69.73	$99.62
266	RP.....	23.1	24.5	29.3	.80	59.7	26.7	40.7	32.3	50.2	75.7	(12.3)	33.86	39.43	56.34	79.47	113.53	71.08	101.54
269	R.......	26.8	22.5	26.8	.86	57.9	31.5	39.4	25.3	35.5	61.9	(10.7)	16.11	38.58	55.12	74.38	106.25	48.52	69.32
270	M......	22.0	21.5	24.0	.82	55.3	30.0	37.1	28.7	43.1	67.8	.84	17.40	34.72	49.60	73.81	105.45	52.12	74.47
273	MP.....	23.9	25.0	27.8	.77	62.5	29.5	43.4	43.7	38.6	69.4	1.17	37.16	38.54	55.06	91.10	130.15	67.14	95.92
276	MP.....	16.1	25.3	30.7	.68	58.0	27.9	44.1	38.2	48.0	68.6	1.34	41.98	37.84	54.06	85.72	122.46	74.77	106.82
263	RLP....	....	....	....	....	....	....	....	49.0	50.3	78.9	(13.2)	40.36	....	....	....	....	77.19	110.27
266	RLP....	....	....	....	....	....	....	....	45.2	47.1	78.7	(10.3)	36.01	....	....	....	....	70.93	101.34
269	R.......	....	....	....	....	....	....	....	35.3	45.3	68.4	(10.5)	20.71	....	....	....	....	56.85	81.22
270	M......	....	....	....	....	....	....	....	33.3	45.2	73.2	1.12	20.06	....	....	....	....	58.20	83.14
273	MLP...	....	....	....	....	....	....	....	46.2	53.7	69.0	1.27	46.23	....	....	....	....	79.37	113.38
279	MLP...	....	....	....	....	....	....	....	39.5	50.6	69.5	1.24	48.98	....	....	....	....	80.13	114.48

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1910 the acre-yields are based on half-plots, limestone having been applied to one half of each of the plots indicated.

than $6 a ton for all of the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, these increases varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.75 on five acres (Plot 5) as an average of the last four years. The need of limestone for best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in bone meal produced increases valued at $1.92 per acre per annum for the first three years and at $4.67 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $5.12 for the third rotation and $5.36 for the last four years, 1911 to 1914. The annual expense per acre for phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for rock phosphate at $7 a ton.

Potassium, applied at an estimated cost of $2.50 an acre a year, seemed to produce slight increases, as an average, during the first and second rotations; but subsequently those increases have been slightly more than lost in reduced

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

average yields, the net result to date being an average loss of $2.53 per acre per annum, including the cost of the potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as an average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,200 pounds of phosphorus and more than 36,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last four years is $65. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value exceeds $98. Thus 200 acres of the properly treated land would produce as much in crops and in value as 300 acres of the untreated land.

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

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

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

	Lower prices	Higher prices
First rotation, 1903 to 1906	$ 8.26	$11.80
Second rotation, 1907 to 1910	11.33	16.19
Third rotation, 1911 to 1914	18.88	26.97

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

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

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

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

	Residue System		Live-Stock System	
	Lower prices	Higher prices	Lower prices	Higher prices
Gain for phosphate	$18.80	$26.86	$18.96	$27.09
Gain for limestone	2.31	3.30	2.55	3.64

Detailed records of these investigations are given in Tables 12 and 13, the data being reported by half-plots after 1910-1911. (Series 300 and 400, which are also used in this rotation, are located in part upon black clay loam and a heavy phase of brown silt loam.)

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

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 14 and 15, giving all the results thus far obtained from the Bloomington soil experiment field, which is located on the typical brown silt loam prairie soil of the Illinois corn belt.

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 14 are considered reliable.

Nitrogen was applied to the residue plots of this field (except Plot 110), in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover, except the seed, was plowed under on the five residue plots. Straw and corn stalks have been returned to these plots, beginning with 1908. The effect of returning these residues to the soil has been appreciable since 1908 (an average increase on Plots 106 and 109 of 5.5 bushels of oats, 4.5 bushels of wheat, and 5.4 bushels of corn) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the thirteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil, for the roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

The addition of the element phosphorus has produced very marked increases, the average yearly increase being worth $7.68 an acre. This is $5.18 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied.

From the soil of the best treated plots on the Bloomington field, 180 pounds per acre of phosphorus, as an average, has been removed in the thirteen crops. This is equal to 15 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as now constitutes the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 120 pounds of phosphorus in the thirteen years, which is equivalent to only 10 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1914, as an average of all plots where it has been used, has amounted to 325 pounds per acre and has cost $32.50.[1] This has paid back $97.20, as an average

[1]This is based on $25 a ton for steamed bone meal, but in recent years the price has been advanced, as a rule, to nearly $30.

TABLE 14.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914
		Bushels or tons per acre[1]												
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	55.2	32.4	29.8
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6	1.09	22.5	47.9	30.0	40.6
103	Lime, crop residues[2]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4	(.83)	25.6	62.5	37.5	30.8
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8	4.21	57.6	74.5	44.1	45.0
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3	1.26	21.7	57.8	32.1	35.8
106	Lime, residues,[2] phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5	(1.67)	60.2	86.1	50.4	62.3
107	Lime, residues,[2] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1	(.33)	27.3	58.9	34.5	34.5
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5	3.27	54.0	79.2	49.4	63.1
109	Lime, residues,[2] phosphorus, potassium	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2	(.42)	60.4	83.4	49.0	54.4
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3	(.60)	61.0	78.3	33.8	44.8
	Increase: Bushels or Tons per Acre													
For residues		-1.9	-.8	9.0	1.7	-.12	1.2	1.6	-4.2		3.1	14.6	7.5	-9.8
For phosphorus		4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2	3.12	35.1	26.6	14.1	4.4
For potassium		.7	-3.9	1.7	4.4	-.07	1.0	.9	-8.3	.15	-.8	9.9	2.1	-4.8
For residues, phosphorus over phosphorus		2.2	4.6	12.6	11.7	-1.65	-3.2	-1.7	8.7		2.6	11.6	6.3	17.3
For phosphorus, residues over residues		8.8	18.1	15.5	20.4	-.46	14.6	8.9	23.1	(.84)	34.6	23.6	12.9	31.5
For potassium, residues, phosphorus, over res., phos.		8.8	3.3	5.2	1.0	.00	9.5	12.3	-8.3	(-1.25)	.2	-2.7	-1.4	-7.9

[1]For clover the figures indicate tons per acre, except where in parentheses, in which case they indicate bushels of seed.
[2]Commercial nitrogen was used from 1902 to 1905.
[3]Clover smothered by previous wheat crop.

TABLE 15.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, BLOOMINGTON FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices	Higher prices
101	None	$186.83	$266.90
102	Lime	186.76	266.80
103	Lime, residues	193.83	276.90
104	Lime, phosphorus	286.61	409.45
105	Lime, potassium	190.53	272.19
106	Lime, residues, phosphorus	285.03	407.19
107	Lime, residues, potassium	191.10	273.00
108	Lime, phosphorus, potassium	294.91	421.31
109	Lime, residues, phosphorus, potassium	284.47	406.39
110	Residues, phosphorus, potassium	259.10	370.15

Value of Increase per Acre in Thirteen Years

For residues	$ 7.07	$ 10.10
For phosphorus	99.85	142.65
For *residues* and phosphorus over phosphorus	–1.58	–2.26
For *phosphorus* and residues over residues	91.20	130.29
For *potassium*, residues, and phosphorus over residues and phosphorus	–.56	–.80

of four trials, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $2.20 per acre in the thirteen years, or less than 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops?

THE SUBSURFACE AND SUBSOIL

In Tables 16 and 17 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Winnebago county, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the most common upland soils are from slightly to strongly acid in the subsurface, and often more strongly acid in the subsoil. This fact emphasizes the

TABLE 16.—FERTILITY IN THE SOILS OF WINNEBAGO COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface (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								
626, 726	Brown silt loam	51 560	4 720	1 980	72 500	21 380	17 430		450
626.5, 726.5	Brown silt loam on rock	46 920	4 720	1 560	65 520	17 880	13 000		240
620, 720	Black clay loam	76 360	5 640	2 720	65 760	33 800	41 720	3 000	
628, 728, 1528	Brown-gray silt loam on tight clay	27 220	2 960	1 340	70 600	22 120	17 400		1 180
660, 760	Brown sandy loam	45 960	4 020	1 360	63 040	13 090	10 500		850
760.5	Brown sandy loam on rock	70 750	6 510	2 190	51 230	17 520	16 570	Rarely	Often
781, 1581	Dune sand	15 920	980	1 180	23 940	2 780	3 520		600

TABLE 16.—*Continued*

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Timber Soils								
634 / 734	Yellow-gray silt loam.	16 230	2 220	1 820	74 150	20 420	16 030		990
635 / 735	Yellow silt loam.....	30 000	2 980	2 180	70 420	22 900	16 700		1 000
635.5	Yellow silt loam on rock	44 840	4 510	2 190	70 960	25 150	20 350	Rarely	Often
632	Light gray silt loam on tight clay......	18 240	2 440	1 760	73 200	14 480	12 720		1 360
764	Yellow-gray sandy loam	13 530	1 300	980	50 300	10 210	8 570		160
764.5	Yellow-gray sandy loam on rock......	26 120	2 520	1 200	48 000	27 160	31 800	117 520	
665 / 765	Yellow sandy loam...	19 560	1 720	1 120	71 880	14 520	12 640		80
765.5	Yellow sandy loam on rock	15 640	1 360	1 040	44 000	16 600	11 160	22 640	
690 / 790	Gravelly loam	46 440	4 000	2 760	55 600	50 720	80 360	265 560	
	Terrace Soils								
1520	Black clay loam......	118 960	9 880	3 280	68 640	24 520	37 120		40
1526	Brown silt loam.....	85 920	6 800	2 680	64 560	24 160	25 640		520
1527	Brown silt loam over gravel	58 720	5 120	2 880	71 880	17 520	14 160		240
1528 / 628 / 728	Brown-gray silt loam on tight clay......	27 220	2 960	1 340	70 600	22 120	17 400		1 180
1532	Light gray silt loam..	15 920	1 720	1 920	76 400	22 280	18 720		2 800
1536	Yellow-gray silt loam over gravel	12 840	2 040	1 920	76 040	17 280	20 120		160
1560.3	Brown sandy loam on gravel	52 840	4 720	1 800	52 960	15 880	12 360		160
1564	Yellow-gray sandy loam	16 880	1 600	1 400	48 640	11 720	9 960		240
1566	Brown sandy loam over gravel	28 330	2 390	1 400	36 920	8 880	9 440		150
1581 / 781	Dune sand	15 920	980	1 180	23 940	2 780	3 520		600
690 / 790	Gravelly loam	46 440	4 000	2 760	55 600	50 720	80 360	265 560	
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1]	806 440	64 140	2 900	7 880	13 040	51 320		220
1402	Medium peat[1] on clay.	528 900	43 840	5 100	11 580	14 780	85 220	43 460	
1402.2	Medium peat[1] on sand	230 960	19 020	1 540	23 140	6 560	26 840	2 360	
1403	Shallow peat on clay.	493 280	39 520	4 640	49 000	27 240	63 880		160
1410.2	Peaty loam on sand..	38 280	3 800	1 440	41 400	13 120	16 800	4 920	
1450	Black mixed loam....	70 320	8 040	3 320	62 360	49 800	107 960	276 720	
1454	Mixed loam (bottom land)	70 000	6 920	2 600	64 520	22 200	31 600		80

[1]Composition reported for 2 million pounds.

importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during times of partial drouth, which are critical periods in the life of such plants as clover. While the common brown silt loam prairie is usually slightly acid, the upland timber soils are, as a rule, more distinctly in need of limestone, and as shown in Table 2, they are also more deficient in organic matter and nitrogen than the prairie soils, and therefore more in need of growing clover.

TABLE 17.—FERTILITY IN THE SOILS OF WINNEBAGO COUNTY, ILLINOIS

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

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
626, 726	Brown silt loam.....	30 470	3 050	3 020	105 310	47 750	40 600	Rarely	Often
620, 720	Black clay loam.....	43 260	3 300	4 380	110 100	71 340	95 040	198 000	
628, 728, 1528	Brown-gray silt loam on tight clay......	21 540	2 910	3 060	106 650	43 200	36 630		180
660, 760	Brown sandy loam...	31 070	3 140	1 950	91 740	30 810	28 070	Often	Often
760.5	Brown sandy loam on rock	47 580	5 370	3 300	65 460	37 560	32 160	Often	Often
781, 1581	Dune sand..........	17 910	1 020	1 410	35 910	4 860	6 540		1 230
	Upland Timber Soils								
634, 734	Yellow-gray silt loam.	14 160	2 290	3 580	103 250	40 870	28 120		4 780
635, 735	Yellow silt loam.....	23 670	3 030	5 850	105 240	58 740	67 590	172 290	
632	Light gray silt loam on tight clay......	15 000	2 400	3 660	105 900	33 180	23 040		7 380
764	Yellow-gray sandy loam	13 190	1 430	1 640	79 910	19 740	15 690	Rarely	Often
665, 765	Yellow sandy loam...	19 260	2 160	1 980	101 040	127 260	233 400	922 080	
	Terrace Soils								
1520	Black clay loam.....	67 260	5 100	3 900	107 520	39 360	52 620		60
1526	Brown silt loam.....	40 140	3 180	2 340	83 100	26 400	24 780		300
1527	Brown silt loam over gravel	26 100	2 640	3 720	92 640	29 460	19 200		960
1528, 628, 728	Brown-gray silt loam on tight clay......	21 540	2 910	3 060	106 650	43 200	36 630		180
1532	Light gray silt loam.	14 400	2 040	3 900	110 820	35 640	34 020		15 600
1536	Yellow-gray silt loam over gravel	9 060	2 280	4 860	110 280	33 120	31 560		1 320
1560.3	Brown sandy loam on gravel	44 400	4 020	1 980	73 200	24 420	16 860		300
1564	Yellow-gray sandy loam	14 040	1 380	1 740	58 440	20 160	13 620		1 380
1566	Brown sandy loam over gravel	19 160	1 700	1 600	53 940	14 760	12 500		320
1581, 781	Dune sand..........	17 910	1 020	1 410	35 910	4 860	6 540		1 230
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1]	149 850	11 910	1 590	38 700	26 280	32 190		30
1402	Medium peat on clay.	57 540	3 840	3 360	98 280	52 800	71 340	7 800	
1402.2	Medium peat on sand	12 480	2 520	1 380	69 420	94 020	156 480	676 800	
1403	Shallow peat on clay.	42 720	3 960	3 420	98 160	41 700	52 680		60
1410.2	Peaty loam on sand..	14 520	1 200	2 040	72 540	102 000	171 120	694 980	
1450	Black mixed loam....	26 220	3 060	3 900	96 660	94 020	148 380	502 020	
1454	Mixed loam (bottom land)............	65 130	6 480	3 900	103 650	39 660	48 750	Often	Often

[1]Composition reported for 3 million pounds.

INDIVIDUAL SOIL TYPES

(a) UPLAND PRAIRIE SOILS

The upland prairie soils of Winnebago county comprize 221.10 square miles, or 42.9 percent of the area of the county. They are usually quite dark in color owing to their large organic-matter content, which has been derived from the roots of prairie grasses that once covered these areas. The complete decay of these roots was prevented by the moisture of the soil, so that this partially decayed organic matter accumulated in sufficient quantities to give the soil its peculiar brown color.

The soils of the more rolling areas are lighter in color, because of their lower organic-matter content, due to the less luxuriant growth of vegetation and the more favorable conditions for oxidation; while the soils occupying the less rolling and comparatively level areas are darker, owing to the more favorable conditions that existed there for the growth and preservation of organic matter.

Brown Silt Loam (626 *and* 726)

Brown silt loam is the most extensive soil type in Winnebago county. It covers an area of 110.08 square miles (70,451 acres), or 21.35 percent of the area of the county. It is found thruout the county, but the largest area is located in the southwest part of the pre-Iowan glaciation. The other area in this glaciation, in the northwest part of the county, is made up of many small and irregular tracts, a great deal of which is rolling and quite shallow, and some of which shows evidence of former forests. In the Iowan glaciation are included many irregular areas somewhat broken by depositions of sand or the invasion of forests. The largest area in the Iowan glaciation, altho not continuous, occurs east of Rockford and north of Cherry Valley.

The topography of the brown silt loam varies quite widely. Comparatively few level areas exist in the county. The area north of the Pecatonica river is generally very rolling, approaching hilly; while the large area in the southwestern part of the county is undulating, except at the heads of many of the streams, where the type assumes a very rolling character. The areas east of the Rock river and those north and northwest of Rockford partake of this same rolling topography. In many instances care must be taken to prevent serious washing. This type generally possesses very fair surface drainage, so that no large amount of it is tile-drained.

In physical composition this type in Winnebago county differs from the corresponding type in other glaciations in its larger sand content. Nearly all the type in this county contains a very perceptible amount of sand (from 25 to 40 percent), either medium or fine, so that it approaches closely to a sandy silt loam. It normally contains from 50 to 70 percent of the different grades of silt and from 10 to 15 percent of clay. It sometimes grades imperceptibly into a fine sandy loam, and the fact that the sand varies so much in fineness makes extremely difficult a satisfactory separation of the brown silt loam and the brown sandy loam. A further variation in many areas is caused by the spread of timber over that part bordering the forests. White oak and hickory rarely ever grow on this type, but bur oak, wild cherry, elm, and black walnut, which are the first to invade the prairie, are quite common. Their growth gradually modifies the soil by lowering the organic-matter content, thus causing the type to pass into yellow-gray silt loam.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying in color from a brownish yellow on the more rolling areas to a dark brown or almost black on the more nearly level and poorly drained tracts. The amount of organic matter varies from 3.5 to 5.4 percent, with an average of 4.3 percent or 43 tons per acre. Where the type passes into yellow-gray silt loam (634 and 734), the organic-matter content becomes reduced, and where it passes into black clay loam (620) or black mixed loam (1450), it increases. In the Iowan glaciation, especially, and to some extent in the pre-Iowan, small areas of gravelly or sandy loam exist that are too small to be mapped. Small areas of yellow-gray silt loam that have been produced either by the presence of trees or by the removal by erosion of part of the surface soil are common in some areas of brown silt loam.

The subsurface varies from 4 to 10 inches in thickness, owing to changing topography, the stratum being thinner on the more rolling areas and thicker on the level areas. In physical composition it varies in the same way as the surface soil, but it usually contains a slightly larger percentage of clay and about one-half the percentage of organic matter. In the latter constituent it varies from 1.9 to 3.1 percent, with an average of 2.2 percent, or 44 tons per acre.

The natural subsoil begins 12 to 18 inches beneath the surface and extends to an indefinite depth but is sampled between 20 and 40 inches. It varies from a yellow to a drabbish yellow, slightly clayey silt, with the deeper subsoil more silty in the pre-Iowan glaciation. It contains a variable amount of sand. The drabbish colored subsoil is found only in the lower, poorly drained areas. In some cases the boulder clay, or drift, constitutes part of the sample. This is especially true in the Iowan glaciation. In the large area in the southwestern part of the county, drift is rarely encountered above 40 inches, and the subsoil consists of a yellow mealy silt containing a considerable percentage of very fine sand.

The subsoil is usually pervious to water, permitting good under-drainage, but where this type grades toward brown-gray silt loam on tight clay (628 or 728), a phase is found that is somewhat difficult to drain.

While this type is in fair physical condition, yet over-cropping to corn and oats and the removal of the stalks and straw, without clover being grown very often, is likely to destroy the tilth. The soil becomes more difficult to work, it runs together more, and aeration, granulation, and absorption of moisture do not take place as readily as formerly. This condition of poor tilth may become one of the limiting factors in crop yields if such methods of management continue.

For the improvement of this soil, organic manures are of first importance. These may be either animal manures or legume crops and crop residues, or some combination of these. As neither the surface nor the subsurface contains limestone, and usually the subsoil also is sour, liberal use of ground limestone is a necessary part of permanent soil improvement. Because of the relatively high content of sand, and the consequent porosity of the soil and the deep feeding range afforded plant roots, the addition of phosphorus is of much less immediate importance on this type of brown silt loam than on the brown silt loam of other areas, tho it will ultimately need to be applied and already produces appreciable increases in crop yields. (See Tables 3, 4, 5, 6, and 8 for results of field experiments on this soil type.)

Brown Silt Loam on Rock (626.5)

Brown silt loam on rock covers only a very small area, in the upper Illinoisan glaciation. The total area is only .1 of a square mile, or 64 acres.

The surface soil, 0 to 6⅔ inches, is a brown silt loam differing but little from the ordinary type (626). It contains 3.76 percent of organic matter, or 37 tons per acre.

The subsurface is of a lighter brownish color, becoming yellow at about 12 inches.

The natural subsoil extends to rock, which occurs at a depth of 16 to 30 inches. It is of a yellowish color with some reddish clay resting on the rock.

The supply of nitrogen and phosphorus in this type of brown silt loam is somewhat less than in the ordinary type. The same methods for improvement are recommended. Crops suffer more from drouth when the bed rock is firm and near the surface.

Black Clay Loam (620 *and* 720)

Black clay loam represents, in part, the originally swampy and poorly drained land of Winnebago county. It is frequently called "gumbo" because of its sticky character. Its formation in the low areas is due to the large accumulation of organic matter and to the washing in of clay and fine silt from the higher adjoining lands. This type covers only 1.08 square miles (691.2 acres), or .21 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black, plastic, very granular, clay loam, containing about 10 percent of organic matter, or 100 tons per acre. The more luxuriant growth of prairie grasses that once covered the swampy black clay loam areas, and the partial preservation of their roots by the wet condition of the soil, has resulted in a greater accumulation of organic matter in this type than in the other types of the upland prairie soils. Some sand and gravel is usually present.

The surface soil is naturally quite granular. This property of granulation is important to all soils, but especially so to heavy ones, for by it the soil is kept in good tilth and rendered pervious to air and water. If the granules are destroyed by puddling, as they may be if the soil is worked or stock are allowed to trample on it while it is wet, they may be formed again by temperature changes (freezing and thawing) or by moisture changes (wetting and drying). These natural agencies produce "slaking," as the process is usually termed. If, however, the organic-matter or the lime content becomes low, this tendency to granulate grows less and the soil becomes more difficult to work, as well as less pervious to air and water.

The subsurface extends to a depth of 11 to 18 inches. It differs from the surface in color, becoming lighter with depth, the lower part passing into a drab or yellowish drab clayey silt. It is quite pervious to water owing to the jointing or checking produced in times of drouth. The organic-matter content is 3.3 percent, or 66 tons per acre.

The subsoil is usually a drab or yellowish drab clayey silt and frequently contains limestone pebbles. Because of poor drainage, the iron in the subsoil is not highly oxidized as a rule. This stratum is also readily permeable to water and air because of the jointing produced by shrinkage.

Black clay loam, while covering only a small area, presents a number of variations that cause it to grade toward other types. With an increase of organic matter, it grades toward muck and peat, small patches of which are found in areas of black clay loam. Sandy spots are found that give a sandy phase of the type or even change the type to a black sandy loam. Besides these variations, alkali spots are common whose presence is indicated by an abundance of fragments of shells, a whitish crust on the surface of the soil, or the yellowish or brownish color of the growing corn, which may be damaged or destroyed by too much alkali.

Drainage is the first requirement of this type, and if the outlet is sufficient, tile drainage is most satisfactory because of the perviousness of the soil. One of the essentials in the management of the type is to keep it in good physical condition, and thoro drainage is a very important factor in this. In the production of granulation, wetting and drying is one of the most important factors. If the soil is saturated most of the time, but little effect is produced. Freezing and thawing do very little in effecting granulation in a saturated soil.

After drainage, the maintenance of organic matter is the principal problem in the management of this type. This may be easily accomplished by turning under crop residues with other forms of organic matter that may be applied to the land. The shrinkage of heavy soils rich in organic matter frequently becomes a very serious problem. Cracks two or three inches in width are formed which allow the soil strata to dry out rapidly, and as a result the crop may be injured thru lack of moisture. These cracks may also do considerable damage by severing the roots of growing crops. While cracking may not be prevented entirely, yet good tilth, which enables the production of a soil mulch, will do much toward that end.

Black clay loam is rich in all important elements of plant food and also contains limestone. With thoro drainage and a good rotation of crops, it is a very productive soil. The phosphorus content, however, is no higher than necessary for the best results, and with continued farming provision should be made to at least maintain the present supply of phosphorus and to insure an adequate supply of active organic matter.

Brown-Gray Silt Loam on Tight Clay (628 *and* 728)

Brown-gray silt loam on tight clay is found principally in the western part of Winnebago county in the pre-Iowan glaciation. It comprizes 1.19 square miles (762 acres), or .23 percent of the total area of the county. It occurs principally at the foot of slopes, where there is apparently some seepage that has been instrumental in producing the type.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying in color from a light to a dark brown. It contains some fine sand, which gives it an excellent texture. The organic-matter content is 4.3 percent, or 43 tons per acre.

The subsurface soil is represented by a stratum 4 to 8 inches in thickness. It varies with depth from a brown to a light gray, and contains 1.3 percent of organic matter. The rapid decrease in organic matter with depth is characteristic of this type.

The natural subsoil begins at a depth of 10 to 14 inches as a yellowish or grayish yellow, compact, plastic, clayey silt or silty clay, containing iron blotches and a few iron concretions. Below 36 inches the subsoil becomes much less compact and more previous.

This type is flat, and much of it needs drainage. Owing to the less pervious character of the subsoil, it is in greater need of tile drainage than the brown silt loam, and the lines of tile should be placed nearer to each other than is usual with most soil types. For effective drainage, they should not be over five rods apart, and four rods is better.

For the improvement of this soil, ground limestone should be used liberally to neutralize existing acidity and provide for crop requirements and loss by leaching. Deep-rooting legume crops, such as red, mammoth, or sweet clover, should be grown in order to loosen up in a measure the tight clay subsoil and promote drainage and aeration, and also to secure nitrogen and help maintain the supply of organic matter. Phosphorus is also required for best results, and, because of the more compact nature of the soil, it is likely to produce more marked benefit on this type than on the brown silt loam.

Brown Sandy Loam (660 *and* 760)

Brown sandy loam is next to brown silt loam in area in Winnebago county. It covers 98.5 square miles (63,040 acres), or 19.1 percent of the area of the county. It occurs almost entirely in the Iowan glaciation. In topography it varies from slightly undulating to rolling, but it is not sufficiently rolling to erode badly.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam varying in color from dark or almost black to a brownish yellow, in texture from a fine to a coarse sandy loam, and in amount of sand from a loam to a light sandy loam. The gradation between this type and the brown silt loam (726) makes the separation of the two rather difficult. The organic-matter content varies from 2.4 to 3.4 percent, with an average of 2.8 percent or 28 tons per acre.

The subsurface is a brown sandy loam changing to a yellowish silty sand or sandy silt at a depth of about 14 to 16 inches. The sand content varies; it is less, as a rule, on the more rolling areas and greater on the undulating or more level areas. This stratum contains 2 percent of organic matter, or 40 tons per acre.

The subsoil varies almost indefinitely. In many places it consists of a medium to coarse sand, in others a sandy silt, while in still others glacial drift is found at a depth of 20 to 30 inches. This stratum, especially when composed of drift, may contain considerable amounts of reddish or brownish red clay, very plastic and possibly derived from the residue left after the limestone of the drift had been dissolved and washed away. An attempt was made to divide this type on the basis of the subsoil, but its great variation made this impossible.

In the treatment of brown sandy loam, the organic-matter content should be maintained in every practical way. The sandier phase of the type is likely to suffer from blowing by dry winds, and for that reason fall plowing is objectionable. Some areas require drainage, as in the case of brown silt loam. The pervious character of the subsoil makes it a type that drains very easily.

Ground limestone and organic manures are of the greatest importance for the improvement of this soil. While the total supply of phosphorus is much less than in the brown silt loam, the porous character of the subsurface and subsoil and the deep feeding range afforded plant roots are likely to more than counterbalance this lack, so that the addition of phosphorus is not advised except where other limitations have been removed by the means suggested above.

Brown Sandy Loam on Rock (760.5)

Brown sandy loam on rock comprizes 7.10 square miles (4,544 acres), or 1.38 percent of the total area of Winnebago county. It occurs in comparatively small areas, but is found principally on the south side of the Pecatonica river. These areas are dotted with small patches of gravelly and stony loam too small to be represented on the map. In topography this type varies from slightly undulating to rather rolling, and with this variation occurs quite a variation in the character of the soil, due principally to the varying depth of the rock beneath the surface. Where the rock comes within 20 inches of the surface, the producing power of the type becomes quite low, but fortunately in most of the type the rock is deeper than this, and in many cases instead of being solid rock it consists of small boulders a few inches in diameter.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam containing 4.1 percent of organic matter, or 41 tons per acre. It varies in physical composition from an ordinary loam to a very sandy loam. In many places gravel occurs in the surface stratum, and many small areas of gravelly loam and even stony loam occur, some of which are indicated on the map by small circles. Small areas of rock outcrop are also quite common. Fine wash from the higher land frequently has produced small areas of brown silt loam that are sometimes too small to map.

The subsurface is a brown sandy loam containing 3.5 percent of organic matter. The same variations occur in the subsurface as are found in the surface stratum. The thickness of the subsoil varies with the depth to rock. In some cases, just above the rock, a stratum of dolomitic sand is found which has resulted from the disintegration of the underlying limestone. In other cases a plastic, reddish clay containing gravel occurs.

This type of soil does not, as a rule, resist drouth very well because of the nearness of the rock to the surface. During seasons favored with a large number of showers while the crops are growing, fair yields are produced. The same methods for improvement should be followed as are recommended for the normal phase of brown sandy loam.

Dune Sand (781)

Dune sand occurs very largely in the northern part of Winnebago county west of the Rock river and east of the Sugar river. The part east of Coon creek is terrace, while that west of the creek is upland of the Iowan glaciation. Another area of upland sand dunes occurs in the southern part of the county in Sections 20, 29, and 30, Township 43 North, Range 1 East. A few small isolated areas are found in other parts. The topography is typical of sand dunes, varying from slightly undulating to rolling. The latter is the most abundant. The total area of this type is 3.05 square miles (1,952 acres), or .6 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, consists of a slightly loamy sand varying somewhat in composition, principally in the fineness of the sand. The organic-matter content is about 1.1 percent.

The subsurface is a yellow sand varying from medium to coarse in texture.

The subsoil consists of a rather uniform yellow sand of medium texture.

In the management of this type, three things are necessary: first, the prevention of blowing; second, the correction of acidity; and third, the increase of nitrogen and organic matter. To prevent the movement of the soil by wind action, some special means should be employed, especially on the more sandy areas. Otherwise, ruin of the land will ultimately result. To hold the soil an application of some form of organic matter should be made. The common crop grown on sand soil is rye. This does not sufficiently cover the soil to protect it from blowing. Furthermore, it is a common practice to sell the straw as well as the grain, and this leaves very little organic matter to be turned back into the soil. A practice that could be followed to good advantage in favorable seasons would be to sow cowpeas after the rye, following the binder with the drill, and then later drilling the rye in the cowpeas without cutting them or turning them under. This would serve to protect the soil from blowing, as well as furnish a supply of nitrogen and organic matter to the soil, and would undoubtedly result in the improvement of this type. If care is taken, alfalfa may be grown without a great deal of difficulty after it is once started. In order to secure a good stand it would be necessary to apply limestone as well as a moderate amount of manure, or to turn under a legume crop, such as cowpeas. The fact that roots have such a deep feeding range in this type makes it generally unnecessary to supply phosphorus, which is largely accessible to the plants.

When potash salts can be secured at reasonable cost, their use is likely to produce profitable results, at least temporarily, in getting under way systems of permanent improvement. This applies more especially to the level areas that were originally sandy swamps. While the type contains a fair amount of potassium, much of this is locked up in sand grains, and where long exposed to leaching, as in swampy areas, the potassium still remaining in the sand is almost inaccessible to plant roots.

For six years experiments were conducted on sand ridge soil on the experiment field near Green Valley, Tazewell county. The soil varies from a very sandy loam to a slightly loamy sand that is easily drifted by the wind when not protected by vegetation. This field was broken out of pasture in 1902. In Table 18 are reported all results secured in the six years from that part of the Green Valley field where nitrogen as well as other elements were supplied in commercial form.

Plot 1, especially, and also Plot 2, in this series, were naturally more productive than the other plots, and were therefore selected as the check plots, in

TABLE 18.—CROP YIELDS IN SOIL EXPERIMENTS, GREEN VALLEY FIELD

Sand ridge soil		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Value of 6 crops	
Plot	Soil treatment applied	Bushels per acre						Lower prices	Higher prices
401	None	68.7	56.3	49.7	18.3	32.9	35.3	$94.35	$134.78
402	Lime	68.2	42.0	35.9	19.0	17.8	29.5	78.48	112.11
403	Lime, nitrogen	68.6	65.4	44.4	23.5	62.9	58.9	127.74	182.48
404	Lime, phosphorus	30.3	24.9	20.3	16.7	10.4	13.1	44.92	64.17
405	Lime, potassium	23.1	20.1	16.9	16.5	8.4	12.8	38.82	55.46
406	Lime, nitrogen, phosphorus	57.4	69.8	51.9	26.8	70.8	64.7	125.34	178.91
407	Lime, nitrogen, potassium	70.0	72.9	54.7	36.5	74.8	73.6	142.82	204.03
408	Lime, phosphorus, potassium	49.8	39.6	36.9	13.7	18.3	27.7	67.31	96.16
409	Lime, nitrogen, phosphorus, potassium	69.5	69.8	47.8	36.2	66.4	73.6	136.47	194.97
410	Nitrogen, phosphorus, potassium	57.2	66.1	50.0	26.5	66.0	71.9	123.97	177.10
Average gain for nitrogen		23.5	37.8	22.3	14.3	55.0	46.9	73.37	104.82
Average gain for potassium over nitrogen		6.8	3.8	3.1	11.2	3.8	11.8	17.88	25.54
Average gain for phosphorus over nitrogen		- 5.9	.7	.3	1.5	-.3	2.9	.22	.32

accordance with the regular custom of the Experiment Station to use the most productive land for the untreated check plots if any differences are apparent when the field is established, as was the case in this instance. Plot 1 serves only as a check against the lime treatment; the average of Plots 2, 4, 5, and 8 gives a more reliable basis of comparison for ascertaining the effect of nitrogen. A four-year rotation of corn, corn, oats, and wheat was practiced.

To facilitate summarizing the results of the six years, the total value of the six crops from each plot is shown in the last column, and at the bottom of the table are shown the average increases in yield for each year and the total value of the six years' increase: (1) for nitrogen under the four conditions; (2) for phosphorus in addition to nitrogen (two tests each year); and (3) for potassium in addition to nitrogen (two tests each year). Nitrogen is so clearly the limiting element that the only question regarding phosphorus and potassium is, Will either of them effect a further increase after nitrogen has been applied?

As an average of four tests covering six years, the addition of nitrogen to this sand soil produced increases valued, at the lower prices, at $73.37 an acre, or an average of $12.23 a year. The nitrogen cost $15 a year for 100 pounds of the element in dried blood. In one instance the increase produced actually exceeded in value the cost of the nitrogen applied, if the cost and effect of the potassium be disregarded. Thus, the total value of the six crops from Plot 5, treated with lime and potassium, was $38.82, while $142.82 was the corresponding value of Plot 7, which differed from Plot 5 only by the addition of nitrogen. Under these conditions 600 pounds of nitrogen costing only $90 produced an increase of $104 per acre in six years.

So far as we have discovered, this is the only instance where the use of commercial nitrogen has paid its cost in the production of ordinary farm crops in Illinois, and even here we must not overlook the fact that $15 worth of potassium was associated with $90 worth of nitrogen where this enormous increase was produced. While potassium without nitrogen produces no benefit on this sand soil, when applied with nitrogen potassium costing $15 produced an average increase valued at $13.10 per acre in six years, but in this case the influence and cost of the associated nitrogen must not be ignored. In no case did the total increase pay for the combined cost of the elements involved when nitrogen was one of them.

Potassium is evidently the second limiting element in this soil where decaying organic matter is not provided, but the limit of potassium is very far above the nitrogen limit.

During the six years Plot 7, receiving nitrogen and potassium, produced a total of 291.3 bushels of corn (an average of 72.5 bushels a year), 54.7 bushels of oats, and 36.5 bushels of wheat, per acre. To produce the increase of Plot 7 over Plot 5 would require about 75 percent of the total nitrogen applied. Thus, there was a loss of 25 percent of the nitrogen applied, which is a smaller loss than usually occurs where commercial nitrogen is used. Without doubt larger yields would have been produced, especially of corn, if 150 or 200 pounds of nitrogen per acre per annum had been used, which would have increased the cost of nitrogen to $22.50 or $30 per acre each year.

It need scarcely be mentioned that commercial nitrogen is used in these and other experiments in Illinois only to help discover what elements are limiting the crop yields. It should never be purchased for use in general farming, but, if needed, should be secured from the atmosphere by growing legume crops and returning them to the soil directly or in manure. It is interesting to note that on the sand soil the six years' increase from $15 worth of phosphorus (even when applied with nitrogen) is valued at only 22 cents.

On three other series of plots on the Green Valley soil experiment field a three-year rotation of corn, oats, and cowpeas was practiced, every crop being represented every year. On plots receiving lime and phosphorus, and legume crops as green manure, the yield of corn was 45.6 bushels in 1906 and 67.8 bushels in 1907, as compared with a yield of 70.8 bushels and 64.7 bushels on Plot 6 of Series 400 receiving lime, phosphorus, and nitrogen (see Table 18), and with 10.4 bushels and 13.1 bushels on Plot 4 of the same series, to which no nitrogen was applied. On other plots receiving comparable treatment, where lime, phosphorus, and potassium were used with nitrogen-gathering legume crops as green manure, the corn yields in the three-year rotation were 54.6 bushels in 1906 and 51.5 bushels in 1907, as compared with 66.4 bushels and 73.6 bushels on Plot 9 of Series 400, to which nitrogen was applied, and with 18.3 bushels and 27.7 bushels on Plot 8, which received no nitrogen.

The use of limestone and farm manure, and the growing of legume crops are the only recommendations made for the improvement of these well-drained sand soils, altho, until more organic matter is supplied, further tests may show profit from potassium. Cowpeas and soybeans are well adapted to such soil, and they produce very large yields of excellent hay or of grain very valuable for feed and also for seed.

Under the best conditions and with good preparation, sweet clover can be grown in good seasons with proper soil treatment and moderate manuring. Alfalfa can also be grown, more than five tons of alfalfa hay per acre in one year having been produced on part of the Green Valley field. Soybeans, sweet clover, and alfalfa should be inoculated with the proper nitrogen-fixing bacteria.

(b) UPLAND TIMBER SOILS

When the glaciers receded from Winnebago county, no forests existed there. It was all prairie land. Gradually the forests began to invade the prairie, and the invasion has continued to the present day, altho man has destroyed much of the forests in the process of clearing land for cultivation. Where cleared of timber, the upland virgin soils did not contain such large amounts of organic matter matter as did the prairie land. Originally they were the same. The effect on upland of long periods of foresting is to reduce the organic-matter content, for the roots of grasses are principally responsible for the high organic content of prairie soils, and forest soils contain practically none of these. What roots there are, are large and undergo complete decay. Leaves and twigs that fall upon the surface of forested areas either undergo almost complete decay or are burned by forest fires, and there is very little chance for them to become incorporated with the soil. The result is that the organic-matter content of the upland timber soils has been lowered until it averages less than half that of the prairie soils. The average organic-matter content of the upland prairie soils in Winnebago county is 4.76 percent in the surface and 2.36 percent in the subsurface, while in the upland timber soils the corresponding percentages are 2.28 and 1.15.

Yellow-Gray Silt Loam (634 *and* 734)

Yellow-gray silt loam is one of the very extensive types in Winnebago county, occuring very largely over the northwestern and southeastern parts of the county in very irregular areas along with brown silt loam, brown sandy loam, and other less extensive types. It occupies a total of 83.18 square miles (53,235 acres), or 16.13 percent of the area of the county. The topography varies from flat to slightly rolling, being generally sufficiently sloping for good surface drainage. This type, up to the time of settlement, was usually timbered, tho much of it is now cleared. There are areas of the type in the southwestern and northwestern parts of the county that have been produced by the removal, by erosion, of a large part of the surface soil from the lighter phase of brown silt loam.

The surface soil, 0 to 6⅔ inches, is a yellowish gray silt loam varying to brownish yellow, incoherent and mealy but not granular. The amount of organic matter contained in it varies from 1.6 to 3.7 percent, with an average of 2.3 percent, or 23 tons per acre, the content increasing where the type grades into brown silt loam (626 and 726) and brown-gray silt loam on tight clay (628), and decreasing where it passes into yellow silt loam (635) and light gray silt loam on tight clay (632). In places, erosion has reduced the amount of organic matter.

The subsurface stratum varies from 4 to 11 inches in thickness and is a brownish or grayish yellow silt loam, becoming slightly heavier with depth and containing about 1 percent of organic matter. At a depth of 10 to 17 inches it passes into the yellow or grayish yellow subsoil.

The subsoil is a clayey silt or silty clay, is friable when moist, but plastic when wet. Till is frequently encountered at a depth of 36 to 38 inches. Usually a slight amount of gravel is found in the lower depths of the subsoil, which is

TABLE 19.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Plot	Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Clover 1913[2]	Wheat 1914
		Bushels or tons per acre												
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2	34.4	21.3	.50	30.8
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0	24.6	17.5	.60	30.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4	10.4	24.4	([3])	40.8
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8	37.4	49.1	1.32	54.2
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6	20.4	18.8	.72	34.0
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0	37.0	46.9	([3])	41.3
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6	7.0	16.9	([3])	43.2
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2	42.2	35.9	1.60	46.0
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0	44.2	31.9	([3])	41.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0	49.0	38.1	([3])	37.8
	Increase: Bushels or Tons per Acre													
	For nitrogen	1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6	-14.2	6.9		10.8
	For phosphorus	5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8	12.8	31.6	.72	24.2
	For potassium	3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6	-4.2	1.3	.12	4.0
	For nitrogen, phosphorus over phosphorus	6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8	-.4	2.2		-12.9
	For phosphorus, nitrogen over nitrogen	10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6	26.6	22.5		.5
	For potassium, nitrogen, phosphorus over nitrogen, phosphorus	4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0	7.2	-15.0		-.3

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.
[3]No seed produced: clover plowed under on these plots.

TABLE 20.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$135.12	$193.03
102	Lime	119.74	171.06
103	Lime, nitrogen	124.70	178.15
104	Lime, phosphorus	202.20	288.85
105	Lime, potassium	138.88	198.40
106	Lime, nitrogen, phosphorus	179.41	256.31
107	Lime, nitrogen, potassium	133.54	190.77
Lime 108	[redacted], phosphorus, potassium	201.35	287.65
109	Lime, nitrogen, phosphorus, potassium	191.22	273.18
110	Nitrogen, phosphorus, potassium	[redacted]	[redacted]
	Value of Increase per Acre in Thirteen years	$96.62	280.58
	For nitrogen	$ 4.96	$ 7.09
	For phosphorus	82.46	117.79
	For *nitrogen* and phosphorus over phosphorus	–22.79	–32.54
	For *phosphorus* and nitrogen over nitrogen	54.71	78.16
	For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.81	16.87

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

derived from the glacial material. This gravel in some cases amounts to over 1 percent.

In the management of yellow-gray silt loam, the most essential points are the use of limestone and phosphorus and the maintenance or increase of the organic matter. This type not only contains no limestone but it is distinctly sour in the subsurface and highly acid in the subsoil. It contains only two-thirds as much phosphorus as the brown silt loam, and only one-half as much nitrogen. It is also less porous and affords a less extended feeding range for plant roots than the brown silt loam.

Table 19 shows in detail thirteen years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted. (See report of Urbana field, page 20, for further explanation.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of 40 tests (4 each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.54 (Plot 104) at the lower crop valuations used in the tabular statement, while potassium applied in addition to phosphorus (Plot 108) produced no increase. Thus, while the detailed data show great variation, owing both to some irregularity of the soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase. Tho commercial nitrogen was used in these experiments, of course the atmosphere is the most economical source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement" and "Physical Improvement of Soils.")

Yellow Silt Loam (635 *and* 735)

Yellow silt loam occupies 25.39 square miles (16,250 acres), or 4.92 percent of the area of Winnebago county. It occurs as the hilly and badly-eroded timber upland and is most abundant in the northwestern part of the county in the Iowan glaciation. It is so badly broken and so steep that as a rule it should not be cultivated but should be left in pasture or meadow. Practically all of it has been in timber.

The surface soil, 0 to 6⅔ inches, is a light brown, brownish yellow, or yellow silt loam. It contains about 2.8 percent of organic matter, or 28 tons per acre. It varies a great deal because of erosion and the presence of varying amounts of gravel and stones. Many patches of gravel and stony loam exist that are too small to be shown separately on the map.

The natural subsoil usually begins at a depth of 9 to 12 inches and consists of a compact, yellow, clayey silt. Usually glacial material constitutes part of the subsoil, in which cases the subsoil is much heavier and contains limestone and a noticeable percentage of gravel. Rock, overlain with a heavy reddish clay, is often found within 40 inches of the surface.

In the management of yellow silt loam, the most important factor is the prevention of surface washing and gullying. If the land is cropped at all, a rotation should be practiced that will require a cultivated crop as little as possible and allow pasture and meadow most of the time. If tilled, the land should be plowed deep and contours should be followed as nearly as possible in plowing, planting, and cultivating. Furrows should not be made up and down the slopes. Every means should be employed to maintain and to increase the organic-matter content. This will help hold the soil and keep it in good physical condition so that it will absorb a large amount of water and thus diminish the run-off.

Additional treatment recommended for this yellow silt loam is the liberal use of limestone wherever cropping is practiced. This type is quite acid in the subsurface, and where cultivated it is usually very deficient in nitrogen;

and the limestone, by correcting the acidity of the soil, is especially beneficial to the clover grown to increase the supply of nitrogen. (Even where limestone is present in the subsoil, the upper strata may be sour.) Where it has been long cultivated and thus exposed to surface washing, this type is particularly deficient in nitrogen; indeed, on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 21 and 22 and shown photographically in Plates 5 and 6.

In one experiment, a large quantity of typical worn hill soil was collected from two different places. Each lot of soil was thoroly mixed and put in ten four-gallon jars. Wheat was planted in one series and oats in the other.[1] Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 21.

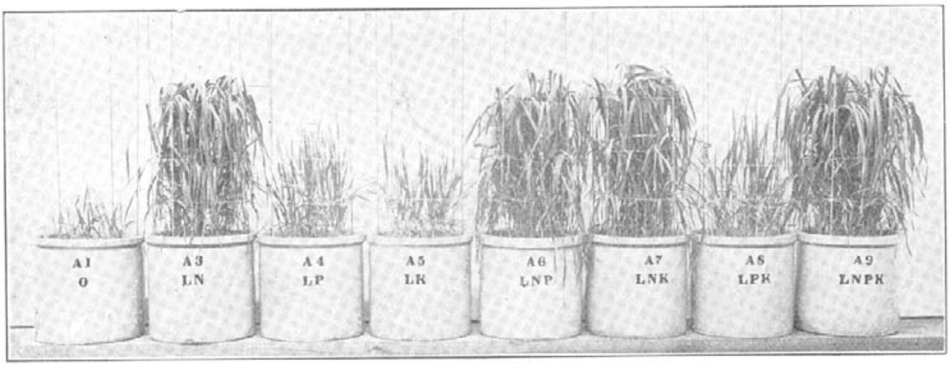

PLATE 5.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 21)

TABLE 21.—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.

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

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

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

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used for wheat in the former experiment. The results are reported in Table 22.

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.

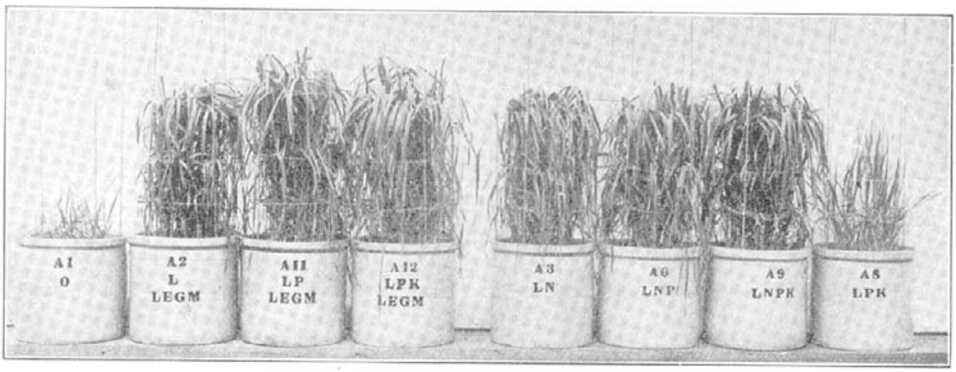

PLATE 6.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 22)

TABLE 22.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS

(Grams per pot)

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

In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 21 in showing the very great need of nitrogen for the improvement of this type of soil,—and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with erosion, which is sure to occur to some extent, the phosphorus supply will be renewed from the subsoil.

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

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

Yellow Silt Loam on Rock (635.5)

Yellow silt loam on rock occupies 4.21 square miles (2,694 acres), or .82 percent of the area of Winnebago county. It occurs almost entirely in the northwestern part of the county in the pre-Iowan glaciation. Many outcrops of gravel and rock are found that give rise to small patches of gravelly and stony loam too numerous even to indicate on the map. In topography this type is very broken, and in this respect is similar to the yellow silt loam.

The surface soil, 0 to 6⅔ inches, consists of a yellow or brownish yellow silt loam that in some cases is quite well supplied with organic matter. The average amount is 3.1 percent, or 31 tons per acre.

The subsurface varies in thickness from 0 to 10 inches and frequently rests directly upon limestone rock. In many cases, overlying the rock is a stratum of heavy red residual clay, containing some gravel, that is not readily pervious to water.

In the management of this type, the suggestions for yellow silt loam should be followed.

Light Gray Silt Loam on Tight Clay (632)

Light gray silt loam on tight clay comprizes only .31 square mile (198 acres), or .06 percent of the area of the county. The only areas in the upland are found in the southwestern and southern parts of the county west of the Rock river. The topography is so flat that drainage is difficult, altho the region is not swampy. The type was formerly covered with hickory and white oak.

The surface soil is a gray to yellowish gray, mealy silt loam, very low in organic matter, the amount present being 2.4 percent, or 24 tons per acre. Iron concretions are present which vary in size, the largest being about one-fourth inch in diameter.

The subsurface varies from a light gray to a yellowish gray silt loam and contains .8 percent of organic matter. It extends to a depth of 14 to 18 inches and becomes more clayey with depth.

The subsoil is a yellow or grayish yellow, tight, compact, clayey silt or silty clay.

Besides being very deficient in organic matter, this type contains no limestone; indeed it is one of the most acid types in Winnebago county, as will be seen by reference to Tables 16 and 17. Consequently it is in poor physical condition; it runs together badly and does not retain moisture well owing to the strong capillarity in the surface and subsurface strata caused by lack of organic matter.

For the improvement of this type ground limestone should be used liberally. Deep-rooting crops, such as red, mammoth, or sweet clover, should be grown in order to loosen the tight clay subsoil as well as to supply the top soil (surface and subsurface strata) with organic matter and nitrogen. Where this type is not well drained, alsike will grow better than red clover. Crop residues should be plowed under or plenty of farm manure supplied, and the content of organic matter increased in every practical way. Pasturing is one of the best uses that can be made of this land, and even when used for this purpose it may well be liberally supplied with limestone and organic matter. If used for grain crops and clovers in rotation, it should also be enriched in phosphorus.

Yellow-Gray Sandy Loam (764)

Yellow-gray sandy loam occupies 23.91 square miles (15,303 acres), or 4.63 percent of the area of Winnebago county. In topography it varies from undulating to slightly rolling. It occurs chiefly in the northern and eastern parts of the county.

The surface soil, 0 to 6⅔ inches, is a brownish yellow to a grayish yellow sandy loam varying in amount and coarseness of sand. The organic-matter content is quite low, ranging from 1.1 to 2.1 percent, with an average of 1.7 percent, or 17 tons per acre. Some gravel is usually present, but it constitutes no significant part of the soil. The type is very sandy in some areas, more particularly north of Shirland, where it varies a great deal, much of it being a loamy sand but in such irregular areas that they cannot be shown on the map.

The subsurface stratum, which ranges from 5 to 10 inches in thickness, varies much more in physical composition than the surface. The organic-matter content is only .6 percent, or about one-third that of the surface. The average amount of gravel varies from 1 to 3 percent, except in patches where it may be very abundant.

The subsoil varies widely in physical composition, being frequently less sandy than the surface stratum and in many cases very heavy, with considerable amounts of gravel, indicating derivation from glacial material. In one sample of subsoil 8.6 percent of gravel was found. A reddish residual clay sometimes constitutes part or all of the subsoil. This is sometimes brought to the surface thru erosion.

In the management of yellow-gray sandy loam, the things primarily needed are limestone and organic matter. In these constituents, the type is one of the poorest in the county, with the exception of sand. (Note also the low amounts of nitrogen and calcium, as shown in Tables 2, 16, and 17.) Limestone should be applied, and every practicable means should be used for increasing the organic-matter content, such as turning under crop residues, legumes, and green crops, and applying manure. Limestone should be added in part to increase the growth of legumes. Sweet clover and alfalfa would do well on this soil if the conditions were made favorable. The phosphorus content is so low that the addition of that element may be necessary in order to obtain the best results, especially where the subsoil is compact. Where the porous sand stratum extends several feet in depth, potassium salts may prove profitable.

Yellow-Gray Sandy Loam on Rock (764.5)

Yellow-gray sandy loam on rock is confined largely to the Iowan glaciation north of the Pecatonica river, and consists of a number of irregular areas that total 1.94 square miles (1,242 acres), or .38 percent of the county. The topography varies from undulating to slightly rolling.

The surface soil, 0 to 6⅔ inches, consists of a yellowish gray or brownish yellow sandy loam, its rather high sand content giving it a loose, mealy texture. The organic-matter content varies with the amount and coarseness of the sand present, but averages 1.7 percent—about the same as the yellow-gray sandy loam (764). Small patches of gravelly or stony loam abound.

The subsurface, which is from 7 to 10 inches in thickness, is a variable sandy loam of a yellowish or grayish yellow color, containing some reddish brown residual material that is somewhat plastic. At a depth of 12 to 17 inches this passes into a reddish plastic clay of residual origin, frequently containing iron and lime concretions. Just before reaching rock, a layer one or two inches in thickness is found which consists of magnesian sand, probably derived from the disintegration of the limestone.

This type varies about the same as yellow-gray sandy loam (764), except that it usually contains plenty of limestone in the subsurface and subsoil. Where the limestone can be reached by deep plowing, it may well be brought up and incorporated with the surface soil. Otherwise the type requires the same treatment as the yellow-gray sandy loam. This soil does not withstand drouth well because of the presence of rock so near the surface.

Yellow Sandy Loam (665 *and* 765)

Yellow sandy loam occurs principally in the northeastern part of Winnebago county and constitutes 3.55 square miles (2,272 acres), or .69 percent of the area of the county. As the topography is quite rolling, great care must be taken to prevent washing.

The surface soil, 0 to 6⅔ inches, is a light brownish yellow to yellow sandy loam varying considerably both in organic matter and in the amount and fineness of sand present. The organic-matter content averages about 1.9 percent, or 19 tons per acre. Where the type grades into silt loam, the sand becomes fine; in other places the amount of medium sand increases to such an extent that the type approaches a sand soil. Patches of gravelly loam are common.

The subsurface stratum varies in thickness from 7 to 10 inches and consists of a variable yellow sandy loam with occasional gray mottlings. In the more silty phase of the type, iron concretions are common. There is .8 percent of organic matter present, or 16 tons per acre. The subsoil is yellow or reddish yellow, containing some gravel, which is derived from glacial drift.

This type should receive practically the same treatment as the yellow silt loam. Every means should be taken to prevent washing; and organic matter should be incorporated into the soil as rapidly as possible and limestone applied except where the subsoil contains limestone sufficiently near the surface to benefit legume crops.

Yellow Sandy Loam on Rock (765.5)

Yellow sandy loam on rock occurs in the Iowan glaciation north of the Pecatonica and east of the Sugar river, and is associated with the yellow-gray sandy loam on rock (764.5). It consists of an area of 1.77 square miles (1,133 acres), or .34 percent of the area of the county. The topography is rolling, so that erosion is very apt to occur.

The surface soil, 0 to 6⅔ inches, is a brownish yellow to yellow sandy loam varying in organic matter and the amount and character of the sand. The organic-matter content averages about 1 percent, or 10 tons per acre. The sand is mostly of medium fineness, tho in some places it is coarse and increases to such an amount that the soil grades into a sand.

The subsurface is a yellow sandy loam containing some reddish residual clay, which does not seem to be uniformly distributed. The organic-matter content is .7 percent, or 14 tons per acre.

Below 14 inches the subsoil is made up almost entirely of residual clay of a reddish or brownish red color. Sometimes this material contains gravel, which is probably derived from the glacial material. Limestone sand usually occurs over the rock, and in places it may be brought up and incorporated with the surface soil by deep plowing.

In phosphorus content this type is the poorest of all the types in the county, and the addition of that element will no doubt be required for the best results. Trials may also well be made with potassium salts because of the fact that that element is so largely locked up in the sand grains.

Gravelly Loam (690 *and* 790)

Gravelly loam occurs in Winnebago county in both the Iowan and the pre-Iowan glaciations. It occupies, as mapped, 6.16 square miles (3,942 acres), or 1.19 percent of the area of the county. The areas are most abundant south of Pecatonica and east of the Rock river near the edge of the upland. The type is very irregularly distributed, however, and frequently occurs in areas too small to map. Some of these small areas are indicated by small circles. The topography is quite rolling, with rounded knobs, this feature having been produced by glacial influence. In many areas of gravelly loam, stones are found, and some small areas could be classed as stony loam. A very narrow belt of gravelly loam or gravel occurs where the terrace breaks the present flood plain of the Rock river.

The surface soil consists of a mixture of gravel and coarse sand, and contains 4.4 percent of organic matter. The subsurface is usually more gravelly than the surface. In many cases samples of the subsurface are very difficult to obtain because of the presence of gravel so large as to prevent the use of the auger. The larger part of the coarser material of the gravelly loam is made up of fragments of limestone while the larger part of the finer material is silica or is made up of fragments of granite and related rocks.

This is a moderately rich type, especially in phosphorus and limestone. It ought to grow alfalfa and other legumes where the topography is suitable for cropping. With liberal use of legume crops or manure, potassium is the only addition likely to prove profitable, most of this element being locked up in the sand and gravel.

(c) RESIDUAL SOILS

The residual soils in Winnebago county are very poorly developed. The residual material is mixed with large amounts of transported material, so that pure residual soils are not to be found. The principal areas occur east of the Sugar river near the Wisconsin line and on the upland east of the Rock river terrace in the northern half of the county. In many places the limestone residue has been brought to the surface by erosion, but only in areas too small to be mapped.

Stony Loam (798 *and* 698)

There are 2.25 square miles of stony loam (1,440 acres) in Winnebago county. The stones present vary in size from an inch to a foot or more in diameter, and generally preclude the possibility of cultivation. The only value of the type is for pasture. The larger part of the stones are limestone, altho mixed with these may be found boulders of granite, syenite, diorite, etc. In the northeastern part of the county the latter constitute the major part. The soil may be either sandy or silty. Where the stones are of limestone, solid rock is usually encountered at a depth of less than a foot.

Rock Outcrop (799)

Rock outcrop occurs in very small areas aggregating a total of about 13 acres exclusive of those areas that have been worked as quarries. Almost innumerable outcrops occur that have been quarried to a small extent. The county is well supplied with limestone, which, with the increasing acidity of the soil, may be advantageously utilized for soil improvement. Many small areas of rock outcrop are found that are too small to be shown on the map.

(d) TERRACE SOILS

The terrace soils comprize 82.81 square miles, or 16.07 percent of the area of the county. They are divided into two distinct classes: the gravel terraces found along the Rock and Kishwaukee rivers, and the silt terraces occurring along the Pecatonica river. The former were produced from material deposited by overloaded streams that carried the flood water from the melting glacier. The material transported was coarse, consisting of small stones, gravel, and coarse sand. By deposition of this, the old valleys have been partly filled and terraces produced. The silt terraces were formed by deposition of fine material in ponded streams, resulting in the formation of shallow lakes and the partial filling of these by fine sediment.

These two kinds of terrace are quite different in soil formation, the gravel terraces being of the sandier type, while the silt terraces are made up largely of silt and clay. Conditions for the growth of timber have not been so favorable on the gravel terraces as on the silt, and as a result little timber is found on the former.

Black Clay Loam (1520)

Black clay loam is found principally on the Pecatonica and Sugar river terraces. It occupies 2.08 square miles (1,331 acres), or .4 percent of the area of the county. In topography it is very flat. It needs drainage above everything else.

The surface soil, 0 to 6⅔ inches, is a black, granular, somewhat plastic, clayey loam, containing 7.5 percent of organic matter, or 75 tons per acre. Locally a perceptible amount of sand may be present, sufficient in some cases to produce a sandy clay loam. These areas are irregular and too small to be indicated on the map.

The subsurface soil extends to a depth of 18 to 20 inches, and varies from a dark brown to brownish drab clay loam, passing into a drab or yellowish drab subsoil. It contains 5.1 percent of organic matter.

The subsoil varies to some extent, but generally consists of a clayey silt or silty clay, mostly the former. The color, drab or yellowish drab, indicates poor oxidation, the result of deficient drainage.

The principal requirements for the type are drainage and the maintenance of organic matter. After long cropping the addition of limestone and phosphorus will become necessary.

Brown Silt Loam (1526)

Brown silt loam occurs principally in the western part of Winnebago county along the Pecatonica river. It differs from the upland brown silt loam in having a tighter, more clayey subsoil; and it might be said that this is characteristic of practically all the silt terrace types. The total area of the type is 4.75 square miles (3,040 acres), or .92 percent of the area of the county. The topography is flat or very slightly undulating, the undulations being due to former stream channels, or bars, or irregular deposits of silty material. Drainage is generally poor, and the soil is so heavy that drainage and tillage are somewhat difficult.

The surface soil, 0 to 6⅔ inches, varies from a light brown to a dark brown or black silty loam containing some fine sand. The lighter colored phase is in the Pecatonica terrace, while the darker and heavier phase is along the Sugar river and Otter creek. The organic-matter content is higher than that of the upland brown silt loam; in the heavier phase it averages 8.1 percent, or 81 tons per acre, while in the Pecatonica phase it averages 7 percent, or 70 tons per acre.

The subsurface soil of the type found along Otter creek and Sugar river is a dark, brownish drab, heavy silt loam extending to a depth of 16 to 18 inches, while along the Pecatonica river it is light brown to yellowish brown and extends to a depth of 12 inches. It contains 3 percent of organic matter.

The subsoil is a heavy, plastic, drabbish, clayey silt or silty clay that verges toward the impervious in some places in the Pecatonica terrace. Some gravel and iron concretions are present.

This brown silt loam is one of the richest soils in the county, altho there is a slight tendency toward acidity in all strata. Limestone is the only material which is suggested for trial upon this land, aside from the use of legume crops in rotation and the return of residues or manure. With long-continued cropping, moderate use should be made of phosphorus so as to prevent the depletion of that element. On the more level areas drainage is very essential.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel is confined entirely to the gravel terraces along the Rock and Kishwaukee rivers. It covers a total area of 5.88 square miles (3,763 acres), or 1.14 percent of the area of the county. In topography it varies from flat to undulating. Natural drainage is usually good.

The surface soil, 0 to 6⅔ inches, consists of a brown silt loam varying in color from a light brown to black, and in composition from a silt loam containing perceptible amounts of sand to a slightly heavy phase of silt loam. It contains 4.7 percent of organic matter, or 47 tons per acre.

The subsurface soil is a brown silt loam extending to a depth of 16 to 20 inches and containing 2.5 percent of organic matter, or 50 tons per acre.

The subsoil consists of a yellowish, slightly clayey silt, becoming in some borings quite sandy and in places passing into gravel. The depth to gravel varies from 30 to 60 inches.

This type is one of the best of the terrace types. The depth of fine material is sufficient for retaining a good supply of moisture for crops, and as a consequence there is less suffering from drouth than there is on some of the other terrace types. Artificial drainage is not often necessary, altho in a few cases it would be desirable. Vertical drainage could be used to fair advantage in some areas.

In the improvement of brown silt loam over gravel, ground limestone should be applied, and all crop residues that are not used to good advantage on the farm for feeding purposes should be turned back into the soil. Manure should be applied and legume crops grown. The type contains a very fair supply of phosphorus, and with the rather porous character of the subsoil, it is doubtful whether the addition of phosphorus would prove profitable for some years to come.

Brown-Gray Silt Loam on Tight Clay (1528)

Brown-gray silt loam on tight clay is found principally in the western part of the county on the Pecatonica and Sugar creek terraces. It occupies an area of 2.45 square miles (1,568 acres), or .48 percent of the area of the county. The topography is generally level or very slightly sloping.

The surface soil, 0 to 6⅔ inches, is a brown silt loam containing 5.6 percent of organic matter, or 56 tons per acre.

The subsurface, extending from 15 to 17 inches in depth, is a brownish gray to light gray silt loam or loamy silt, becoming more compact and less pervious with depth. It contains 1.1 percent of organic matter and some iron concretions.

The upper part of the subsoil is a yellowish gray, compact, rather slowly pervious silt, with a varying amount of clay. This usually is underlain by a lighter, more sandy silt, which becomes less compact at a depth of 30 to 36 inches.

Since lack of drainage is what has produced the peculiar characteristics of this type, it follows that one of the first requirements is drainage. In the improvement of the type, ground limestone should be applied and deep-rooting crops, such as red, mammoth, and sweet clover should be grown to loosen the subsoil and render it more pervious. These should be turned under with crop residues, or should be used for feed and the manure returned to the soil. Phosphorus must also be applied in permanent systems of improvement, and it is likely to prove profitable if turned under with vegetable matter.

Light Gray Silt Loam (1532)

Light gray silt loam occupies 6.58 square miles (4,211 acres), or 1.28 percent of the area of Winnebago county. Practically all of it is found on the Pecatonica silt terrace, generally on the slightly higher part. In topography it is flat, with a few old stream channels. Iron concretions are found in all strata.

The surface soil, 0 to 6⅔ inches, consists of a light gray to yellowish gray silt loam, very mealy and pulverulent, usually containing some fine sand. The amount of organic matter present averages 2.43 percent, or 24 tons per acre.

The subsurface extends to a depth of 14 inches, and consists of a yellowish gray silt loam, very pulverulent, but with a close arrangement, so that water does not penetrate it very readily. It contains about .7 percent of organic matter.

The subsoil, beginning at about 14 inches, becomes more yellow and more compact with depth, and in the deeper subsoil sand becomes a prominent constituent.

This is the most acid soil type in the county; it is also deficient in organic matter and rather poor in phosphorus. In its improvement, ground limestone should be applied, and crop residues, manure, and legume crops should be turned under to maintain and to increase the supply of organic matter. The supply of phosphorus should also be increased. Deep-rooting crops aid materially in the loosening of the subsurface and the subsoil.

Yellow-Gray Silt Loam over Gravel (1536)

Yellow-gray silt loam over gravel is found on the terrace along the Pecatonica river, principally near the junction of that river and the Sugar river. The type covers 5.6 square miles (3,584 acres), or 1.09 percent of the area of the county. In topography it is flat to slightly undulating.

The surface soil, 0 to 6⅔ inches, is a light gray or yellowish gray silt loam, containing 2.25 percent of organic matter, or 22 tons per acre.

The subsurface, extending to a depth of 12 to 14 inches, is a light gray silt loam, compact and not very pervious. It contains .55 percent of organic matter, or only 11 tons per acre.

The subsoil is a yellow, slightly clayey silt, compact, and showing mottlings of iron. Gravel is found at a depth varying from 48 to 68 inches. The stratum of gravel, however, is not continuous or is clogged with finer material, so that drainage is somewhat hindered.

This type requires the same treatment as the preceding type, light gray silt loam.

Brown Sandy Loam on Gravel (1560.3)

Brown sandy loam on gravel occurs very extensively on the terrace of the Rock river. It comprizes 18.15 square miles (11,616 acres), or 3.52 percent of the area of the county. In topography this type varies from flat to slightly rolling, the differences being due to bars that were formed by strong currents of water when the area was flooded. It is closely associated with brown sandy loam over gravel, differing chiefly in its lesser depth to the gravel. The two types occupy almost the entire Rock river terrace.

The surface, 0 to 6⅔ inches, is a brown, coarse, sandy loam, varying quite widely in sand content. In many places, it contains a small percentage of fine gravel, but not sufficient to class it as a gravelly loam. Locally, however, especially near the newer or first bottom land, patches of gravel or gravelly loam occur, but these are not large enough to be shown on the map. The stratum contains 4.1 percent of organic matter, or 41 tons per acre.

The subsurface is a sandy loam, varying in thickness with the depth to gravel, and in color from brown to yellowish or reddish brown. It contains from 1 to 2 percent of gravel, and frequently sufficient clay to give it some plasticity. The organic-matter content averages 2.3 percent.

The subsoil varies a great deal in texture. In some places it is largely made up of fine gravel mixed with coarse and some medium sand, while in others it is composed of a coarser gravel. In the northern part of the county, especially, much of this layer is made up of small boulders from 2 to 6 inches in diameter. The sample collected contained 23 percent of gravel. The depth to the subsoil varies from 12 to 24 inches.

The value of this type of soil varies with the depth to the gravel. As a rule, the fine material is not of sufficient depth to give the soil great water-holding capacity. The water percolates thru the surface and subsurface soil and on to the subsoil, from which, because of the coarseness of the material, it cannot be brought up by capillary action. Crops that mature early may be grown to some advantage. In the management of this type the supply of organic matter must be maintained in order to give the soil the greatest possible water-holding capacity. Limestone should be used and legume crops should be prominent in the rotation.

Yellow-Gray Sandy Loam (1564)

Yellow-gray sandy loam occupies the sandy terrace that has been forested along the Rock river and Coon creek. It covers 2.16 square miles (1,383 acres), or .42 percent of the area of the county. The type in some places, particularly along the Rock river, is undulating and indicates dune topography. Along Coon creek it is more nearly flat and has more of the character of a sand plain.

The surface soil, 0 to 6⅔ inches, varies from a light brown to a brownish gray sandy loam and contains 1.6 percent of organic matter. The sand content varies somewhat, ranging from 50 to 70 percent.

The subsurface varies from light brown to yellowish gray in color, and contains an average of 1.13 percent of organic matter. The sand content varies a great deal; in some places the stratum is quite silty, while in others it contains 80 percent of sand. The subsoil in places runs still higher in sand content.

The principal lines of treatment in the management of this type are the use of limestone, legume crops, and organic manures.

Brown Sandy Loam over Gravel (1566)

Brown sandy loam over gravel occurs on all the terraces in the less undulating areas. It occupies 34.43 square miles (22,035 acres), or 6.68 percent of the area of the county. This type differs from brown sandy loam on gravel in that a thicker layer of fine material rests on the gravel bed. It also differs in topography, varying from flat to slightly undulating.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam with an average of about 55 percent of sand, mostly medium and coarse, and 2.2 percent of organic matter, or 22 tons per acre. A small amount of gravel is present in some places.

The subsurface is a brown sandy loam with a slightly higher sand content than the surface. The gravel content is also somewhat higher than in the surface stratum, altho it varies widely even in the same area. The thickness of this stratum varies considerably in some localities; usually it extends to a depth of 26 to 30 inches before the characteristic yellowish color of the subsoil appears.

The subsoil varies a great deal, in some places passing into a silty or clayey material and in others into a yellow sand. These variations are quite irregular, sometimes occurring within a few rods.

The brown sandy loam over gravel of the Pecatonica terrace varies somewhat from that of the Rock river terrace in that the Pecatonica sand is finer and is more apt to pass into a silty material before the gravel is reached. The surface soil is not so dark as that of the Rock river terrace. Along the Sugar river some of the brown sandy loam has a red, silty, sandy subsoil, while some has a pure gray sand.

In the management of this type ground limestone should be used and legume crops should be grown as much as possible for turning under and providing nitrogenous organic matter.

Dune Sand (1581)

The dune sand of the terraces is found largely west of the Rock river in the extreme northern part of the county. One small area is found on the east side of the Rock river in Township 43 North, Range 1 East. The type covers a total area of .73 square miles, or 467 acres. It differs very little from the upland dune sand except that less of it is covered with timber.

The surface soil, 0 to 6⅔ inches, is a slightly loamy sand varying toward a pure sand. It contains very little organic matter, the average being about .7 percent, or 7 tons per acre. The subsurface and the subsoil consist very largely of yellow sand. The former contains .5 percent of organic matter.

For the improvement of this type the same methods should be followed as with the upland dune sand.

(e) LATE SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat occurs in various parts of Winnebago county, occuping low, swampy areas that have a rather constant supply of moisture. It covers a total of 2.23 square miles (1,428 acres), or .43 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a brown to black peat, containing 56 percent of organic matter. The other strata differ but little from the surface, except that in some cases sand or silty material is to be found in the lower subsoil.

Drainage is of first importance with this type. This in many cases is rather difficult to secure because tile cannot be laid to good advantage in peat on account of irregular settling and open ditches must be resorted to.

This type is rich in all important elements of fertility except potassium. A thoro trial should be made with potassium salts unless the supply of farm manure is sufficient to provide enough potassium.

In Table 23 are given all results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which however, were cropped the same as the plots.

The results of the four years' tests, as given in Table 23, are in complete harmony with the information furnished by the chemical composition of peat soil. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one-third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

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

Applications of 2 tons per acre of ground limestone produced no increase

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

in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

TABLE 23.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL (Bushels per acre)

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

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

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

Medium Peat on Clay (1402)

Medium peat on clay occurs in areas similar in location to those of deep peat. It comprizes .43 square miles (275 acres), or .08 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, consists of a brown or black peat containing, as shown by a single sample, 52 percent of organic matter. The subsurface consists of almost identical material, with an organic-matter content of 46 percent. The subsoil is composed of a silty clay containing 1.6 percent of organic matter.

Drainage is the first requirement of this type, and the clayey subsoil is sufficiently near the surface to furnish a very satisfactory bed for tile. If sufficient potassium is not secured from this soil to meet the needs of large crops, that element should be added.

Medium Peat on Sand (1402.2)

Medium peat on sand occupies but a comparatively small area in the county, aggregating .27 square miles, or 173 acres. The surface and subsurface soils consist of a brown peaty material, while the subsoil is a drab or grayish sand. The same treatment is suggested as for the preceding type.

Shallow Peat on Clay (1403)

Shallow peat on clay occupies only 51 acres in the county. The surface soil contains 35.2 percent of organic matter, the subsurface 21.3 percent, and the subsoil 1.2 percent.

No limestone was found in this type. The addition of this material may prove helpful. Deep plowing may be resorted to if more potassium is needed in the surface soil. On a similar soil in Ford county deep plowing changed the yield of corn from about 20 bushels per acre to 60 (see Bulletin 157).

Peaty Loam on Sand (1410.2)

Peaty loam on sand is found principally in the low areas along the Sugar and Kishwaukee rivers and Coon creek. The total area is 4.43 square miles (2,835 acres), or .86 percent of the area of the county. The topography is flat and the areas are poorly drained. Alkali is abundant.

The surface soil, 0 to 6⅔ inches, consists of a sandy, peaty material containing 13 to 15 percent of organic matter. The composition, however, varies a great deal; in some localities it is distinctly a peat, while in others it runs toward black sandy loam or even black silt loam.

The subsurface soil is usually a brown sandy loam, in many cases containing a considerable percentage of silt. The organic-matter content averages 1.6 percent.

The subsoil is usually a drab or yellowish drab sand. It varies, however, containing in some places strata of more silty or clayey material.

The first requirement of this type is drainage. Farm manure, preferably quick-acting, such as horse, mule, or sheep manure, may be used to correct the alkali condition and to supply potassium, which, tho present in fair amount, may be largely inaccessible because locked up in sand grains. Potassium salts may well be tried if the supply of manure is insufficient.

Black Mixed Loam (1450)

Black mixed loam occurs in the low, swampy, and poorly drained areas in which a variety of soils have been formed and have become so badly mixed that it is impossible to separate them into distinct types. These areas usually occur in valleys occupied by streams which furnish poor drainage for the lowland. The term "slough" is generally applied to them. In topography they are flat, and in many of them swampy conditions still exist. The total area is 17.29 square miles (11,066 acres), or 3.35 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, contains about 8.5 percent of organic matter, or 85 tons per acre, but it varies in this as it does also in mineral constituents. Some areas are peaty, while others may be heavy or even sandy.

The subsurface soil varies in the same way as the surface. It contains about 3 percent of organic matter. It usually passes into a drabbish gravelly clay (apparently boulder clay), of which commonly the subsoil consists. Frequently the subsoil contains pebbles of limestone, and alkali is often found in this type.

The surface of this type presents a characteristic hummocky appearance, as shown in Plate 7, especially when in pasture. The tramping of stock produces this characteristic.

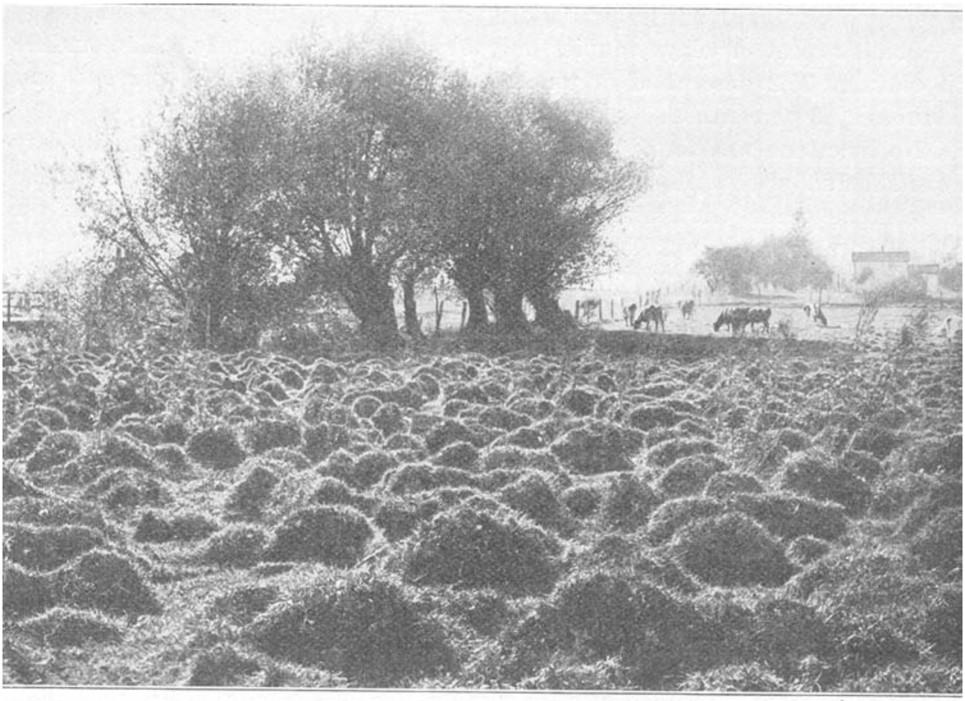

PLATE 7.—HUMMOCKS ON "BOG LAND"

Mixed Loam (Bottom Land) (1454)

Mixed loam is found in very irregular areas along the bottom lands of streams. It covers a total area of 34.33 square miles (21,971 acres), or 6.64 percent of the area of the county. A large area has been developed within the Pecatonica terrace, and more or less of the type is found in nearly all the other stream valleys. In topography it is flat to slightly undulating, the undulations being due to depositions and to washing by currents during flood periods. Some patches of peaty material occur, but are too small to map.

The surface soil, 0 to 6⅔ inches, is a brown mixed loam, varying from a silt loam to a sandy loam. This stratum contains an average of about 6.3 percent of organic matter, or 63 tons per acre, but the amount varies greatly.

The subsurface soil, extending to a depth of 16 to 24 inches, consists of a brown mixed loam, usually more variable, however, than the surface. The organic-matter content averages 3 percent.

The subsoil is quite variable, owing to the method of formation. In some borings a stratum of gravel is encountered, while in others sand, silt, or clay may predominate.

As leveeing has not been practiced in this county, much of this bottom land overflows. Corn and pasture are the most satisfactory crops grown. The soil is fairly rich in all important plant-food elements, but on the more sandy areas limestone and organic manures may prove helpful, especially where the land is not subject to overflow.

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 porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when 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.

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

[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."

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.)

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

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

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

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

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.

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

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 dolomite limestone.

PHYSICAL IMPROVEMENT OF SOILS

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

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

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus.

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

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result.

Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. This is well shown by the results of an experiment conducted by the Maryland Experiment Station, where 80 tons of manure were allowed to lie for a year in the farmyard and at the end of that time but 27 tons remained, entailing a loss of about 66 percent of the manure. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. Two tons of manure were exposed from April 29 to August 29, by the Canadian Experiment Station at Ottawa. During these four months the organic matter was reduced from 1,938 pounds to 655 pounds. To obtain the greatest value from the manure, it should be applied to the soil as soon as possible after it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is to be planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow, and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

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No.

76 Alfalfa on Illinois Soil, 1902 (5th edition, 1913).
*86 Climate of Illinois, 1903.
*88 Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois, 1903.
*93 Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils, 1904. (See No. 157).
94 Nitrogen Bacteria and Legumes, 1904 (4th edition, 1912).
*99 Soil Treatment for the Lower Illinois Glaciation, 1905.
*115 Soil Improvement for the Worn Hill Lands of Illinois, 1907.
123 The Fertility in Illinois Soils, 1908 (2d edition, 1911).
*125 Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois, 1908.
145 Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils, 1910 (2d edition, 1912.)
*157 Peaty Swamp Lands; Sand and "Alkali" Soils, 1912.
177 Radium as a Fertilizer, 1915.
181 Soil Moisture and Tillage for Corn, 1915.

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*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 (2nd 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.
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109 Improvement of Upland Timber Soils of Illinois, 1907.
110 Ground Limestone for Acid Soils, 1907 (3d edition, 1912).
*116 Phosphorus and Humus in Relation to Illinois Soils, 1908.
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*122 Seven Years' Soil Investigation in Southern Illinois, 1908.
123 The Status of Soil Fertility Investigations, 1908.
124 Chemical Principles of Soil Fertility, 1908.
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3d edition, 1912).
*129 The Use of Commercial Fertilizers, 1909.
130 A Phosphate Problem for Illinois Land Owners, 1909.
*141 Crop Rotation for Illinois Soils, 1910 (2d edition, 1913).
142 European Practice and American Theory Concerning Soil Fertility, 1910.
145 The Story of a King and Queen, 1910.
*149 Results of Scientific Soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois, 1911.
150 Collecting and Testing Soil Samples, 1911 (2d edition, 1912).
155 Plant Food in Relation to Soil Fertility, 1912.
*157 Soil Fertility: Illinois Conditions, Needs, and Future Prospects, 1912.
165 Shall we Use "Complete" Commercial Fertilizers in the Corn Belt? 1912 (4th edition, 1913.)
167 The Illinois System of Permanent Fertility, 1913.
168 Bread from Stones, 1913.
181 How Not to Treat Illinois Soils, 1915.

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1 Clay County Soils, 1911.
2 Moultrie County Soils, 1911.
3 Hardin County Soils, 1912.
4 Sangamon County Soils, 1912.
5 La Salle County Soils, 1913.
6 Knox County Soils, 1913.
7 McDonough County Soils, 1913.
8 Bond County Soils, 1913.
9 Lake County Soils, 1915.
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11 Pike County Soils, 1915.
12 Winnebago County Soils, 1916.

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