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Agricultural Experiment Station

SOIL REPORT NO. 11

PIKE COUNTY SOILS

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

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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.

PIKE COUNTY SOILS

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

Pike county is located in the southern part of the upper Illinois glaciation between the Mississippi and Illinois rivers. The southern and southwestern part of the county is in the unglaciated area that includes Calhoun county on the south. It is divided into two physiographic regions—the eastern, sloping to the Illinois river, and the western to the Mississippi.

The topography is due primarily to stream erosion, tho it is very likely that the glacier that covered the larger part of the county during the Glacial period did much toward producing the present topography, especially in the northern and northeastern parts of the county. This ice sheet, which covered half of North America, made several advances, the most extensive one in this part of the state being known as the Illinois glaciation.

The elevation of land to the north, in the vicinity of Labrador, Hudson Bay, and probably westward, changed the climate sufficiently so that snow and ice accumulated on this height of land to such an extent that vast ice sheets developed. These ice fields resembled that of Greenland at the present time, which covers an area of 500,000 square miles. There seemed to be three centers of accumulation, one in Labrador, another just west of Hudson Bay, and a third in the Rocky Mountains. From these centers the snow and ice pushed southward hundreds of miles until a point was reached where the ice melted as rapidly as it advanced.

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

The material transported by the glacier varied with the character of the rocks over which it passed. Granites, limestones, sandstones, shales, etc., were mixed and ground up together. This mixture of all kinds of boulders, gravel, sand, silt, and clay is called boulder clay, till, glacial drift, or simply drift. The grinding and denuding power of glaciers is enormous. A mass of ice 100 feet thick exerts a pressure of 40 pounds per square inch, and the ice sheets were probably thousands of feet in thickness. This enabled the glacier to change the surface over which it passed, rubbing down the hills and filling the valleys. With the exception of the morainal ridges, the deposit of drift in Pike county is comparatively shallow. In the morainal regions, however, it attains a thickness of 100 feet or more.

The ice made many advances, and with each advance a terminal moraine was formed. The three morainal ridges in Pike county indicate three glacial advances. These ridges have an elevation in some places of almost 900 feet above sea level. During one stage of this glaciation, Pike county was almost covered by the ice sheet, the south border of which extended from New Canton southeast to the vicinity of Pearl. North of this is found a series of drift ridges that are not very distinct because erosion has almost destroyed them in some places. One of these ridges enters Pike from Adams county near Baylis, and another is found between Hadley and Kiser creeks, swinging around to the northeast, then to the southeast, and uniting with the one mentioned above south of Pittsfield, and then continuing to just north of Bedford. The other ridge begins in the vicinity of Tempest and passes southeastward west of Griggsville, leaving the county between Milton and Florence. These ridges represent terminal moraines of the upper Illinois glaciation.

PHYSIOGRAPHY

About one-fourth of the upland of Pike county is within the drainage basin of the Illinois river and three-fourths within that of the Mississippi basin. The divide between these two basins is about three or four miles from the Illinois river as far north as Milton. From here it extends to the northwest, passing just west of Maysville and thence northwest thru Fish Hook. Blue creek and Middle Forks are the largest streams on the Illinois slope. Several streams flow into the Mississippi river, chief of which are Bay, Six Mile, Dutch, Kiser, and Hadley creeks. Besides these two upland regions there are approximately 160 square miles of bottom land. That along the Mississippi river varies from four to ten miles in width, but the only extensive bottom land along the Illinois river is in the northeastern part of the county, where it attains a width of about five miles.

Much of the upland of the county is badly eroded. Several small and irregular areas of prairie land are found however, principally in the eastern part of the county. The largest areas are around Milton and Griggsville. These are comparatively level.

The altitudes above sea level of some places in Pike county are as follows: Barry, 666 feet; Baylis, 864; Brewster, 466; Griggsville, 681; Hull, 467; Kinderhook, 464; Nebo, 484; New Salem, 774; Pearl, 451; Pittsfield, 760; Pleasant Hill. 459; Straut, 655; Bedford, 470; Chambersburg, 510; Detroit, 700; Fish Hook, 795; Milton, 695; Perry, 610. The altitude of low water on the Illinois river at Bedford is 413 feet, while on the Mississippi river at Louisiana, Missouri, it is 437 feet. The bluffs along the Mississippi are about 200 feet high, and consist of limestone.

SOIL MATERIALS AND SOIL TYPES

Altho the Illinois glacier covered the larger part of Pike county, yet the drift deposited by it does not constitute the material from which the soil has been made. The glacial drift, as well as the residual material on the unglaciated area, has been covered to a depth of ten to fifty feet or more by a wind-blown material, or loess, derived chiefly from the wide bottom lands of the Mississippi and Illinois rivers. During the periods of the greatest melting of the glaciers to the north, the bottom lands were flooded by streams at other times restricted to their ordinary channels. Finely ground material produced by the glacier was carried with the water and deposited upon the flood plains during the overflow. When this became dry, it was picked up by the wind and carried over the upland, where it formed the deposit of loess. Naturally this deposit would be deeper near the source of the material, and, since the prevailing winds were from the southwest, it would be deeper on the east slopes from the bottom lands than on the west, tho strong winds came also from the south or southeast and piled it to some depth on the west bluffs. So, in this case, the deposit is found quite thick on the east bluff of the Mississippi, gradually thinning out until within five or six miles of the Illinois bottom, where it begins to thicken, becoming quite thick for a mile or or two along the later bottom land.

Loess is a mixture of all sorts of materials that were finely ground by glaciers. As a consequence, it contained, when first deposited, much pulverized limestone, and this was largely responsible for the original fertility of loess soils. After the loess was deposited over the country, the surface stratum became mixed with more or less organic matter and was acted upon by organisms and thus gradually changed into soil. Subsequently the limestone has been removed by leaching.

TABLE 1.—SOIL TYPES OF PIKE COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 20)			
526	Brown silt loam	25.95	16 608	3.25
520	Black clay loam	.11	70	.01
530	Gray silt loam on tight clay	.82	525	.10
528	Brown-gray silt loam on tight clay	3.69	2 362	.46
		30.57	19 565	3.82
	(b) Upland Timber Soils (page 24)			
534	Yellow-gray silt loam	99.65	63 776	12.48
532	Light gray silt loam on tight clay	1.54	986	.19
535	Yellow silt loam	255.01	163 206	31.92
874	Yellow-gray fine sandy loam	27.66	17 702	3.46
875	Yellow fine sandy loam	126.77	81 133	15.87
599	Rock outcrop	3.62	2 317	.45
		514.25	329 120	64.37
	(c) Old Bottom-Land Soils (page 30)			
1330	Gray silt loam on tight clay	24.17	15 469	3.03
1354	Mixed loam	40.20	25 728	5.03
		64.37	41 197	8.06
	(d) Swamp and Late Bottom-Land Soils (page 31)			
1426	Deep brown silt loam	65.20	41 728	8.16
1426.2	Brown silt loam on sand	46.52	29 773	5.82
1415	Drab clay	38.12	24 397	4.77
1460	Brown sandy loam	17.29	11 066	2.17
1461	Mixed sandy loam	8.48	5 427	1.06
1480	River sand	.30	192	.04
		175.91	112 583	22.02
	Water	13.79	8 826	1.73
	Total	798.89	511 291	100.00

The soils of Pike county are divided into the following classes:

(a) Upland prairie soils, rich in organic matter.

(b) Upland timber soils, including those areas upon which forests have grown for a sufficient length of time to change the character of the soil.

(c) Swamp and bottom-land soils, including both the old (1300) and the new (1400) flood plains along streams.

Table 1 shows the area of each type of soil in Pike county and its percentage of the total area. It will be noted that the yellow silt loam hill land occupies nearly one-third of the county, while the three most extensive upland timber types cover 60 percent of the total area.

THE INVOICE AND INCREASE OF FERTILITY IN PIKE 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 Pike 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.

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

TABLE 2.—FERTILITY IN THE SOILS OF PIKE 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								
526	Brown silt loam........	41 060	3 200	900	36 440	8 500	7 360		60
520	Black clay loam........	52 580	3 840	1 000	34 220	10 400	13 120		120
530	Gray silt loam on tight clay	22 800	1 840	660	34 000	5 020	9 240		240
528	Brown-gray silt loam on tight clay	29 600	2 240	860	39 000	5 520	7 860		60
	Upland Timber Soils								
534	Yellow-gray silt loam...	26 100	2 120	780	36 890	6 290	7 900		140
532	Light gray silt loam on tight clay	22 940	1 800	840	37 440	5 920	8 780		20
535	Yellow silt loam........	17 170	1 590	730	36 790	6 400	8 680		70
874	Yellow-gray fine sandy loam	25 120	2 140	720	39 060	5 200	11 740		60
875	Yellow fine sandy loam..	18 430	1 760	730	38 260	5 430	8 350		50
	Old Bottom-Land Soils								
1330	Gray silt loam on tight clay	35 170	2 940	990	31 450	5 770	8 610		90
1354	Mixed loam	30 220	2 910	1 080	33 830	6 430	9 280		90
	Swamp and Late Bottom-Land Soils								
1426	Deep brown silt loam...	40 330	3 230	1 150	33 620	6 070	12 780		50
1426.2	Brown silt loam on sand.	36 900	3 230	1 360	33 170	10 040	13 060		70
1415	Drab clay	39 090	3 680	1 300	31 830	11 520	13 470		90
1460	Brown sandy loam......	27 540	2 610	1 810	27 550	7 380	12 490		110
1461	Mixed sandy loam......	27 860	2 400	1 360	31 380	8 280	13 540		60
1480	River sand	4 600	180	500	20 960	3 920	9 500		40

vigorous start from the rich surface soil, can draw upon the subsurface and the subsoil for a greater supply of plant food.

By easy computation it will be found that as an average the three most common upland soils of Pike county, aggregating 60 percent of the total area, do not contain in the plowed soil more than enough total nitrogen for the production of maximum crops for fifteen years; and the best soils in the county contain only about twice as much nitrogen.

With respect to phosphorus, the condition differs only in degree, the average upland of the county containing no more of that element than would be required for forty years 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 450 years even if the total crops should be removed and nothing returned. The corresponding figures are about 1,500 and 350 years for magnesium, and about 8,000 and 200 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium, and, as explained in the Appendix, with magnesium, and more especially calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the common upland 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 are likely to be far greater than were the requirements of the past.

As a rule, the variation among the different types of soil in Pike county with respect to their content of important plant-food elements is not very marked, altho the late bottom-land soils contain about twice as much nitrogen and phosphorus as the common upland timber soils. The most significant facts revealed by the investigation of the Pike county soils are the great abundance of potassium, the common lack of limestone, and the low content of nitrogen and phosphorus in the most extensive upland types, which combined cover about 60 percent of the entire county. And yet the deficiencies can be overcome at relatively small expense by the application of ground limestone and phosphorus, and by the production and proper use of clover, by means of which nitrogen can be secured from the inexhaustible supply in the air. If the clover is 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 largely increase the yield of corn and other crops. On the hilly lands (yellow silt loam and yellow fine sandy loam) where much erosion is likely to occur, the addition of phosphorus is not necessary or advisable, because the supply is renewed by the subsoil, which is gradually transformed into surface soil; but on the other upland types, which are less rolling or level, phosphorus must be supplied, as well as limestone and organic matter, if permanent systems of farming are to be adopted.

Fortunately, some definite experiments have already been conducted on soils representing some of the common types of Pike county, and before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out by pot cultures or field experiments.

RESULTS FROM POT-CULTURE EXPERIMENTS

The most extensive soil type in Pike county is the yellow silt loam. Where this soil has been long cultivated and thus exposed to surface washing, it 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 3 and 4, and shown photographically in Plates 1 and 2.

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 into ten four-gallon jars. Wheat was planted in one series and oats in the other.[1]

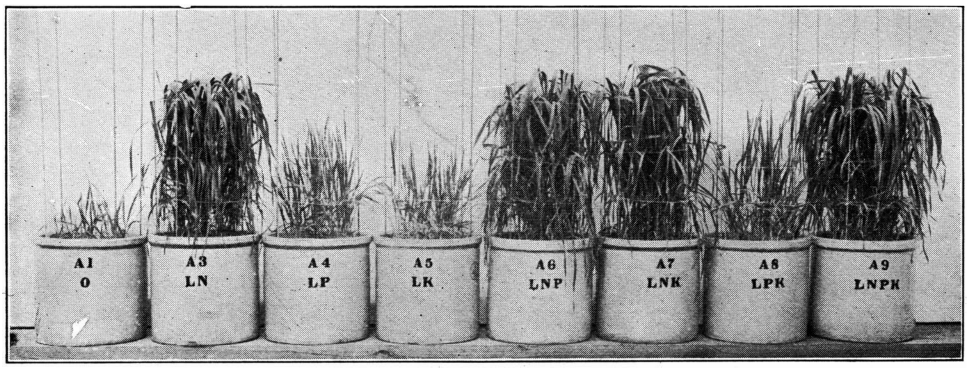

PLATE 1.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 3)

TABLE 3.—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.

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 3.

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 fertilizer would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

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 4.

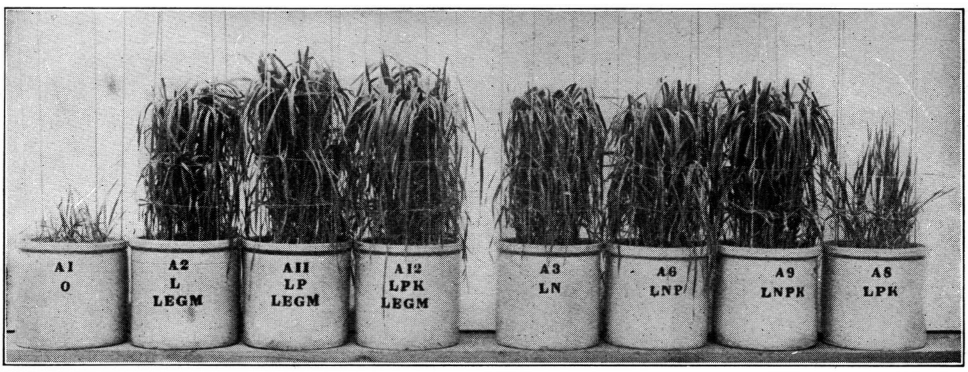

PLATE 2.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 4)

TABLE 4.—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

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 3, 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 sufficiently frequent crops of legumes are grown and if the farm manure produced is sufficiently abundant and is saved and applied with care.

RESULTS FROM FIELD EXPERIMENTS AT VIENNA

In 1902 a soil experiment field was established on the worn hill land of southern Illinois, near Vienna, in Johnson county. The results of nine years' experiments conducted there are reported in Table 5.

This field included three divisions, or series, with five plots in each series. A three-year rotation of wheat, corn, and cowpeas was begun, but because of local interest this was changed to corn, wheat, and clover. When the clover failed, which was frequent, cowpeas were substituted.

During the first three years the entire crop of cowpeas was plowed under, except on Plot 1 of each series, as indicated in Table 5. During the second three years all crops were removed; and during the third three-year period the pods of the cowpeas (small yields not threshed) and all grain were harvested and removed, while the pea vines or clover, and the wheat straw and corn stalks were returned to the land except on Plot 1, from which all crops were removed and nothing returned.

If the first three years required to get the rotation and soil treatment underway are passed over, there still remain the records of six years, during which time 6 crops of corn, 6 crops of wheat, and 1 crop of clover hay were harvested and weighed. A study of Table 5 will show that the land treated with ground limestone and some crop residues (Plot 3 of all series) produced, during the six years, 74 bushels more corn, 60 bushels more wheat, and 1¼ tons more hay than the untreated land. By comparing Plots 2 and 3, it will be found that the land receiving limestone and residues produced, during the same six years, 64 bushels more corn, 39 bushels more wheat, and 1.1 tons more harvested hay than the land receiving only residues.

In order to summarize the results of the nine years' experiments, the six grain crops from each series and the one crop of clover hay harvested from Series 200 (in 1907) are reduced to a money basis, in which corn is figured at 35 and 50 cents a bushel, oats at 28 and 40 cents, wheat at 70 cents and $1, and hay at $7 and $10 a ton. These dual prices are used in order to show the possible influence of prices upon farm practice. The lower prices are appreciably below the ten-year averages for Illinois, but it should be kept in mind that the increase produced by soil treatment is not delivered at the market by that treatment, but only ready for the harvest; and additional expense is required for harvesting, threshing, baling, and storing or marketing. For the farm operator the lower prices may be used, while the landlord, whose share is placed in storage, or sometimes delivered to the market by the tenant, may use the higher prices, if they seem fair. The yields are given, and anyone can compute the value of the increase at any other prices, if he so desires.

About 9 tons per acre of ground limestone were applied in 1902. The cost of this is figured at $1.25 per ton, which is about the average cost in Illinois, not including the expense of application, which is best estimated locally.

Phosphorus was supplied at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal (600 pounds every three years). With the bone meal figured at $25 per ton, the cost of the phosphorus is 10 cents a pound. However, the average cost of steamed bone meal is now somewhat higher; and where farm manure or green manure is available, and phosphorus is needed, the use of raw rock phosphate is advised in place of steamed bone, the raw phosphate being just as rich in phosphorus and costing in Illinois from $6.50 to $7.50 per ton in carload lots.

Potassium was applied at the rate of 42 pounds per acre per annum in 100 pounds of potassium sulfate. The potassium sulfate is figured at $50 per ton, or potassium at 6 cents a pound. As shown in Table 2, this common upland contains, as an average, more than 30,000 pounds of potassium in the plowed soil of an acre (6⅔ inches deep), and the subsurface and subsoil are still richer, so that the problem with respect to potassium is not one of addition but of liberation. If potassium salts are applied at all, or temporarily until more vegetable matter can be grown and plowed under, then the use of kainit in larger amounts and at less expense is recommended, rather than potassium sulfate, for reasons explained in the Appendix.

It should be understood that when these field experiments were begun, there was but very little information available concerning the composition or requirements of Illinois soils. Steamed bone meal and potassium sulfate were used to determine whether the soil needed phosphorus or potassium, for it was known that these materials furnish both phosphorus and potassium in good form. On many experiment fields established more recently, fine-ground rock phosphate is now being used with very good results, and in some cases trials with kainit are also being made. (See the Appendix and Circulars 149 and 165.)

Taking into account the entire period of nine years, it will be seen that, at most conservative prices, the ground limestone paid back nearly twice its actual cost, and the equivalent of about one-half of the limestone still remained in the soil for the benefit of subsequent crops.[1] It is possible, too, that half the quantity

[1]On the Edgewood experiment field in Effingham county, 10 tons per acre of ground limestone were applied in 1902. At the end of ten years the analysis of the soil showed that, as an average of eight plots, 8,370 pounds of limestone per acre still remained in the surface stratum, while in the surface stratum of eight untreated half-plots there was an acidity corresponding to 1,070 pounds of limestone required. The acidity of the subsurface of the treated plots averaged 2,270 pounds per acre less (in terms of limestone required to neutralize it) than that of the untreated plots. Thus the total difference at the end of ten years was equivalent to 6.1 tons of calcium carbonate, and the net loss was 3.9 tons of limestone, or 780 pounds per acre per annum. (These averages are based upon analyses involving twenty-four determinations, which were made by Mr. C. F. Ferris in 1912, as part of his work for the degree of master of science in agronomy.

of limestone applied at the beginning would have given nearly or quite as good results, but the information available as to the initial amount of limestone to apply for the most profitable results is not conclusive. In any case the initial

TABLE 5.—CROP YIELDS PER ACRE ON VIENNA EXPERIMENT FIELD: YELLOW SILT LOAM OF COMMON WORN HILL LAND, UNGLACIATED

Soil treatment		None (except rotation)	Crop res.	Crop res. Limestone	Crop res. Limestone Phosphorus	Crop res. Limestone Phosphorus Potassium
		Series 100				
Plot No.		101	102	103	104	105
1902	Corn, bu.	15.5	13.3	14.9	12.5	19.9
1903	Corn, bu.	9.3	5.0	8.3	7.4	11.6
1904	Cowpeas	Removed	Turned	Turned	Turned	Turned
1905	Wheat, bu.	1.3	10.8	18.2	25.6	30.0
1906	Cowpeas	Removed	Removed	Removed	Removed	Removed
1907	Corn, bu.	16.7	17.8	30.3	37.1	38.1
1908	Wheat, bu.	0	0	4.5	8.3	9.8
1909	Cowpeas	Removed	Turned	Turned	Turned	Turned
1910	Corn, bu.	33.5	35.4	44.7	46.6	58.3
Value of six crops	Lower prices	$27.16	$32.59	$50.26	$59.99	$72.62
	Higher prices	38.80	46.55	71.80	85.70	103.75
		Series 200				
Plot No.		201	202	203	204	205
1902	Oats, bu.	19.1	18.8	19.8	20.0	31.7
1903	Cowpeas	Removed	Turned	Turned	Turned	Turned
1904	Wheat, bu.	6.7	7.1	10.0	14.8	17.5
1905	Corn, bu.	37.5	42.9	61.9	57.2	56.5
1906	Wheat, bu.	3.8	5.4	17.9	11.3	15.0
1907	Clover, tons	.65	.81	1.92	2.56	2.23
1908	Corn, bu.	35.2	35.6	43.9	42.9	50.6
1909	Wheat, bu.	4.6	6.8	9.6	12.8	11.3
1910	Clover	Removed	Turned	Turned	Turned	Turned
Value of seven crops	Lower prices	$45.91	$51.92	$82.26	$85.79	$92.63
	Higher prices	65.59	74.17	117.52	122.55	132.33
		Series 300				
Plot No.		301	302	303	304	305
1902	Cowpeas	Removed	Turned	Turned	Turned	Turned
1903	Wheat, bu.	.4	.6	.7	8.0	11.0
1904	Corn, bu.	30.5	35.5	49.1	49.4	44.7
1905	Cowpeas	Removed	Removed	Removed	Removed	Removed
1906	Corn, bu.	41.2	40.6	48.9	40.9	40.9
1907	Wheat, bu.	4.3	6.1	13.0	13.6	15.6
1908	Cowpeas	Removed	Turned	Turned	Turned	Turned
1909	Corn, bu.	23.0	24.9	31.3	32.6	33.5
1910	Wheat, bu.	3.1	8.7	13.7	14.4	14.6
Value of six crops	Lower prices	$38.60	$46.13	$64.43	$68.21	$70.52
	Higher prices	55.15	65.90	92.05	97.45	100.75
Average of three series	Lower prices	$37.22	$43.54	$65.65	$ 71.33	$ 78.59
	Higher prices	53.18	62.20	93.79	101.90	112.28
Increase over Plot 2	Lower prices			$22.11	$ 27.79	$ 35.05
	Higher prices			31.59	39.70	50.08

application should be considered as an investment to be added to the value of the land, while the cost of subsequent necessary applications should be calculated in the annual expense.

On this rolling hill land, the addition of $22.50 worth of steamed bone meal increased the crop values by only $5.68 in nine years, at the lower prices used for the increase in yields; and the further addition of $22.50 in potassium sulfate produced only $7.26 increase. Whether a much larger use of organic manures will ultimately increase the nitrogen content of the soil to a point where phosphorus can be applied with profit on these hill lands, which are subject to rather serious surface washing, seems somewhat doubtful. Considering the fact that such an increase in decaying organic matter will largely increase the liberation of potassium from the enormous supply contained in the soil, it seems even more doubtful if the addition of potassium will ever be advisable in permanent systems of general farming.

Both the pot cultures and the field experiments agree in showing that on the yellow silt loam of worn hill land nitrogen is by far the most limiting element, and that this can be secured from the air by legume crops where liberal use is made of ground limestone to correct the acidity of the soil. The limestone, of course, also furnishes the element calcium, the supply of which in this soil is much less than the supply of potassium, while the combined loss by leaching and cropping is much greater with calcium than with potassium, as is more fully explained in the Appendix. As plant food, calcium is especially important for such crops as clover. (See Table A in the Appendix.)

RESULTS FROM FIELD EXPERIMENTS AT RALEIGH

The Raleigh experiment field, in Saline county, is located on the gently undulating timber land (yellow-gray silt loam), which is also an important upland soil type in Pike county.

Six tons per acre of ground limestone were applied to certain plots on the Raleigh field in the fall of 1909. As an average of two tests each year with wheat, corn, oats, and hay (cowpea or clover), the value of the increase per acre in five years (1910 to 1914) was $18.30 at the lower prices named (see page 9) or $26.14 at the higher prices; and the limestone applied to the soil is sufficient to last for more than ten years. These data strongly support those from the Vienna field in showing the positive value and need of limestone for these acid upland soils in the very beginning of improvement. (See Tables 8 and 9, pages 18 and 19, for acidity in subsurface and subsoil.)

The work at Raleigh has been carried on for only five years, with some severe drouths, and the organic manures thus far produced and returned to the soil are too meager to produce results from which trustworthy conclusions can be drawn concerning either phosphorus or potassium. The first step in the upbuilding of this soil is the liberal use of limestone in connection with clover or other legume crops grown in rotation with corn and other grains; and when the legume crops or farm manures are available to plow under in significant amount, then is the time to begin the application of phosphate, to be turned under in intimate contact with the decaying organic matter. Where raw phosphate has been used in this way on very similar land at the Ohio Agricultural Experiment Station, as an average of duplicate tests on three different series of plots during a period of eighteen years, every dollar invested in raw phosphate paid back $7.88, counting $7.50 per ton for the phosphate, 35 cents a bushel for corn, 70 cents for wheat, and $7 a ton for clover hay; while in a corresponding experiment every dollar invested in acid phosphate (at $15 per ton) paid back $3.97. (See Illinois Circulars 127, 130, and 181 for more details of these valuable Ohio experiments.)

Limestone has also produced marked benefit on the Ohio soil, which is naturally distinctly acid.

Results of Experiments on Antioch Field

On the Antioch experiment field, on the yellow-gray silt loam of Lake county, Illinois, 325 pounds of phosphorus, in 2,600 pounds of steamed bone meal applied at the rate of 200 pounds per acre a year, produced in thirteen years (1902 to 1914) increases of corn, oats, wheat, and clover aggregating a value of $82.46 per acre at the lower prices, or $117.79 at the higher prices, mentioned above. The subsoil of this type in Lake county contains plenty of limestone; otherwise it is very similar to the Pike county soil.

Results of Experiments on Bloomington Field

Space is taken to insert Tables 6 and 7, 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 6 are considered reliable.

Nitrogen was applied to this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover, except the seed, was plowed under on five plots (103, 106, 107, 109, and 110). 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. 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,

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

Plot	Brown silt loam prairie; early Wisconsin glaciation — Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909	Clover[2] 1910	Wheat 1911	Corn 1912	Corn 1913	Oats 1914
		Bushels or tons per acre												
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4	1.56	22.5	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[1]	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,[1] 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,[1] 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,[1] 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]Commercial nitrogen was used from 1902 to 1905.
[2]The figures in parentheses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

TABLE 7.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, BLOOMINGTON FIELD

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

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. The brown silt loam of Pike county is even more deficient in phosphorus than is that of McLean county.

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 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) that was 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. (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.) This amount, $32.50, has paid back $97.20 (average 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? (See Table 2, page 5, and also Table A in the Appendix.)

RESULTS OF FIELD EXPERIMENTS AT URBANA

On the University North Farm at Urbana on the common brown silt loam prairie, where a rotation of corn, oats, and clover was practiced for nine years (1902 to 1910), followed by a combination rotation involving corn, oats, clover,

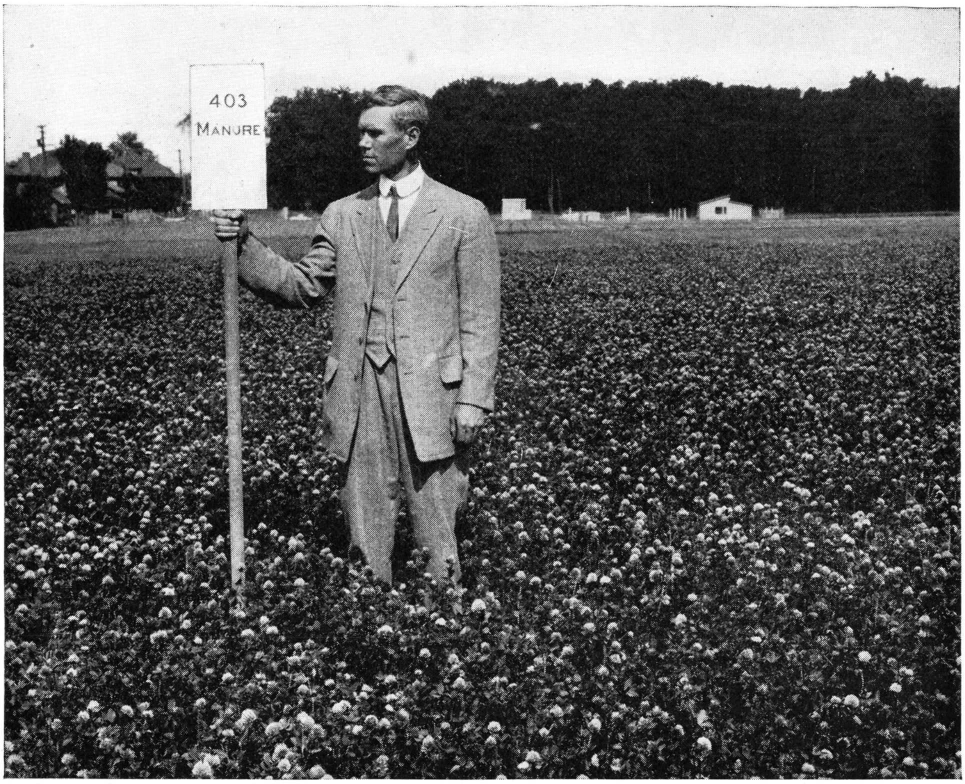

PLATE 3.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

wheat, and alfalfa,—phosphorus, applied at the yearly rate per acre of 25 pounds in 200 pounds of steamed bone meal, or of 75 pounds in 600 pounds of rock phosphate,[1] produced average increases per acre per annum valued at $1.92 for the first three years, at $4.67 for the next three, at $5.12 for the third three-year period, and at $5.36 for the last four years (1911-1914), the crops being valued at the "lower prices."

If we count $28 a ton for bone meal, and $7 for rock phosphate, the average annual expense per acre would be $2.80 for the first six years and $2.45 during the last seven years.

Thus, as an average, each dollar invested in phosphorus paid as follows:

	Lower prices	Higher prices
First rotation, 1902 to 1904	$ .69	$ .99
Second rotation, 1905 to 1907	1.67	2.39
Third rotation, 1908 to 1910	2.09	2.99
Fourth rotation, 1911 to 1914	2.19	3.13

Potassium, added at an annual cost of $2.50 per acre for the thirteen years, produced no benefit. In fact where it was applied the crops were slightly poorer,

[1]Phosphorus was applied only in bone meal from 1902 to 1907, after which rock phosphate was used on one half, and bone meal on the other half of the plots treated with phosphorus.

PLATE 4.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

as an average, than where none was applied, the net loss per acre per annum averaging $2.53, including the cost of the potassium.

On the University South Farm at Urbana, where one ton per acre of rock phosphate is applied every four years for a rotation of corn, oats, clover, and wheat, grown on typical brown silt loam prairie, applications of fine-ground rock phosphate have paid as follows in the value of the increase produced:

VALUE OF INCREASE FROM ROCK PHOSPHATE ON THE UNIVERSITY SOUTH FARM AT URBANA

Rotation	Years	Per ton of phosphate		Per $1 invested	
		Lower prices	Higher prices	Lower prices	Higher prices
First..........	1903 to 1906	$ 8.26	$11.80	$1.18	$1.69
Second........	1907 to 1910	11.33	16.19	1.62	2.31
Third..........	1911 to 1914	18.88	26.97	2.70	3.85

On both farms at the University organic matter is provided, either in farm manure or in crop residues (clover, straw, and corn stalks plowed under). More complete details of these investigations will be found in Soil Report No. 10 (McLean county), which will be sent, if requested, to those who may have special interest in the brown silt loam prairie of Pike county.

RESULTS OF FIELD EXPERIMENTS AT GALESBURG

On the University of Illinois soil experiment field near Galesburg, on the line between Knox and Warren counties, fine-ground rock phosphate is applied at the rate of 500 pounds an acre a year for a six-year rotation of corn, corn, oats, clover, wheat, and clover, on brown silt loam prairie soil of the upper Illinois glaciation. The field is divided into three different series of plots, and each series includes five different tests with phosphate, so that the average for each year is based upon fifteen trials. The results thus far secured are summarized as follows:

VALUE OF INCREASE FROM ROCK PHOSPHATE ON THE GALESBURG EXPERIMENT FIELD

Years averaged	Per ton of phosphate applied	
	Lower prices	Higher prices
1904 and 1905	$3.53	$ 5.04
1906 to 1908	7.73	11.04
1909 to 1911	8.60	12.29
1912 to 1914	12.93	18.49

Altho a part of the Galesburg field occupies a heavy phase of brown silt loam, the phosphate nevertheless more than paid its cost, as an average, after the first three years, while the results of the later years show returns of 200 to 300 percent on the investment,—and it should be remembered that more than two-thirds of the phosphorus applied remains in the soil for the benefit of future crops.

TABLE 8.—FERTILITY IN THE SOILS OF PIKE 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								
526	Brown silt loam	69 200	5 120	1 760	73 800	18 400	13 880		120
520	Black clay loam	75 040	5 320	1 480	68 600	21 080	23 960		280
530	Gray silt loam on tight clay	28 160	2 320	1 120	69 040	15 720	17 800		480
528	Brown-gray silt loam on tight clay	41 800	2 880	1 560	77 040	15 960	15 880		120
	Upland Timber Soils								
534	Yellow-gray silt loam	28 190	2 140	1 370	75 300	16 340	14 130		1 170
532	Light gray silt loam on tight clay	20 160	1 720	1 560	76 720	16 320	16 360		560
535	Yellow silt loam	14 650	1 600	1 560	72 650	18 920	14 670		2 840
874	Yellow-gray fine sandy loam	23 080	2 400	1 400	68 320	9 920	21 680		120
875	Yellow fine sandy loam	17 020	2 050	1 810	77 570	15 310	14 920		260
	Old Bottom-Land Soils								
1330	Gray silt loam on tight clay	28 640	2 600	1 300	61 980	9 960	15 100		660
1354	Mixed loam	50 020	4 580	2 480	68 800	11 960	17 100		260
	Swamp and Late Bottom-Land Soils								
1426	Deep brown silt loam	59 730	4 850	2 130	70 240	13 090	24 800		80
1426.2	Brown silt loam on sand	33 980	3 140	1 780	64 780	19 380	22 680		200
1415	Drab clay	38 840	3 700	1 760	65 180	23 900	26 400		100
1460	Brown sandy loam	26 040	2 350	1 640	54 450	14 710	20 000		490
1461	Mixed sandy loam	38 920	3 800	2 520	62 240	16 680	28 840		160
1480	River sand	6 480	320	960	42 240	7 240	20 120		40

Ultimately, the regular application (1½ tons per acre for each six-year rotation) will be reduced to perhaps one-half ton each six years, which will be sufficient to maintain the phosphorus content of the soil, even tho such crops are removed as are mentioned in Table A of the Appendix. For more complete details of experiments on the Galesburg field, see Soil Report No. 7 (McDonough county), which will be sent upon request.

THE SUBSURFACE AND SUBSOIL

In Tables 8 and 9 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Pike 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 timber soils are from slightly to strongly acid in the subsurface, and usually more strongly acid in the subsoil. This fact emphasizes the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during 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 9.—FERTILITY IN THE SOILS OF PIKE 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								
526	Brown silt loam	25 980	3 300	2 100	109 800	41 100	23 160		660
520	Black clay loam	43 560	3 480	2 160	104 100	43 140	34 020		420
530	Gray silt loam on tight clay	31 380	3 120	1 980	103 620	47 640	31 020		720
528	Brown-gray silt loam on tight clay	38 940	3 060	2 520	100 980	43 380	27 240		2 280
	Upland Timber Soils								
534	Yellow-gray silt loam	28 650	2 480	2 590	110 490	38 250	21 880		5 400
532	Light gray silt loam on tight clay	22 260	2 280	2 880	107 460	38 580	24 540		5 040
535	Yellow silt loam	13 640	1 920	2 940	110 640	36 420	24 460		8 720
874	Yellow-gray fine sandy loam	21 180	2 580	2 760	99 240	27 120	35 880		1 380
875	Yellow fine sandy loam	18 410	2 600	3 290	113 240	41 970	43 730	Seldom	1 040
	Old Bottom-Land Soils								
1330	Gray silt loam on tight clay	21 930	2 460	2 070	88 440	21 390	22 560		960
1354	Mixed loam	38 430	2 820	3 420	101 520	23 220	33 480		960
	Swamp and Late Bottom-Land Soils								
1426	Deep brown silt loam	46 300	3 820	2 620	104 740	22 940	33 160		160
1426.2	Brown silt loam on sand	32 640	2 790	2 760	98 610	29 190	34 710		600
1415	Drab clay	45 780	3 960	2 460	99 450	35 850	41 670		90
1460	Brown sandy loam	15 880	1 640	2 020	79 180	17 960	27 540		420
1461	Mixed sandy loam	27 960	2 400	2 880	87 000	19 740	41 460		180
1480	River sand	21 840	1 800	1 740	68 040	12 660	29 460		240

INDIVIDUAL SOIL TYPES

(A) UPLAND PRAIRIE SOILS

The upland prairie soils of Pike county comprize 30.57 square miles, or only 3.8 percent of the entire area of the county. These soils occupy rather small and irregular areas, chiefly in the eastern part of the county in the vicinity of Milton, Pittsfield, Griggsville, and Perry, tho small isolated areas occur in other sections.

Owing to their large organic-matter content the prairie soils are usually dark in color. This accumulation of organic matter is due to the growth of prairie grasses, the roots of which were protected from complete decay by the imperfect aeration afforded by the covering of fine soil material and the moisture it contained. From a sample of "blue stem" virgin sod it has been determined that the roots in an acre to a depth of 7 inches amounted to 13½ tons. On the native prairies, the tops of these grasses contributed little organic matter, as they were usually burned or became almost completely decayed.

Brown Silt Loam (526)

Brown silt loam is one of the best upland types in the county, but it is not very extensive, covering only 25.95 square miles (16,608 acres), or 3.25 percent of the area of the county. This type is sufficiently rolling for fair natural surface drainage. The poorly drained areas are small, altho there are a few exceptions, notably near Milton and Griggsville.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or almost black on the more nearly level and poorly drained areas. In physical composition it varies to some extent, but normally contains from 60 to 70 percent of the different grades of silt, with from 20 to 25 percent of very fine sand, and from 8 to 12 percent of clay. The amount of this last constituent increases as the type approaches black clay loam (520). The organic matter varies from 3.5 to 4.8 percent, but averages 3.5 percent, or 35 tons per acre. Where this type passes into brown-gray silt loam on tight clay (528) or yellow-gray silt loam (534), the amount of organic matter becomes lower.

Some of the brown silt loam may have been covered by recent forest growths, which, however, have effected very little or no change in the soil.[1] The first trees to invade the prairie are the black walnut, wild cherry, hackberry, ash, bur oak, and elm. The black-walnut soil is generally recognized by farmers as being one of the best timber soils. As a rule, it was prairie until recently and still contains a large amount of the organic matter that accumulated from the prairie grasses.

The natural subsurface is represented by a stratum varying from 5 to 12 inches in thickness. The variation is due to changing topography, the layer being thinner on the more rolling areas and thicker on the level. In physical composition this stratum varies the same as the surface soil, but it usually contains a slightly larger amount of clay and a much smaller amount of organic

[1]The effect of forest trees is ultimately to reduce the organic matter and change the brown prairie soil into yellow-gray silt loam.

matter. In some places it may become quite heavy, as where the type grades into black clay loam (520). In color it varies from a dark brown or almost black to a light brown or yellowish brown; as a rule it becomes lighter with depth and passes gradually into the yellow subsoil. The organic-matter content averages 3.4 percent.

The natural subsoil begins 12 to 20 inches beneath the surface and extends to an indefinite depth, but is sampled to 40 inches. It varies from a yellow to a drabbish yellow clayey silt or silty clay. On the more nearly level areas it is a mottled drab and yellow, while on the rolling areas, where better drainage has allowed greater oxidation of the iron to take place, it is yellow or reddish yellow. The upper part of the stratum usually contains more clay than the lower part. As a whole the subsoil is pervious to water, permitting good drainage, but where the type grades toward brown-gray silt loam on tight clay (528), a phase is found that is rather difficult to drain.

While this type is in fair physical condition, the continuous cropping to corn, oats, and wheat and the removal of the crop residues is destroying the tilth. This condition of poor tilth may become serious if the present most common systems are continued. The remedy is to increase the organic-matter content by plowing under manure or crop residues, such as corn stalks, straw, and clover, instead of selling them from the farm or burning them, as is sometimes practiced. Where corn follows corn, the stalks 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 either directly or as manure, instead of being sold as hay, except when manure can be brought back.

The addition of fresh organic matter is not only of great value in improving the physical condition of this type of soil, but it is of even greater importance because of its nitrogen content and because of its power, as it decays, to liberate potassium from the inexhaustible supply in the soil, and phosphorus from the phosphate contained in or applied to the soil. The turning under of crop residues in soil improvement increases the yield, as is shown by the results from the Bloomington field (page 14), where residues turned under on phosphorus plots (Nos. 106 and 109) gave an average increase of 6.7 bushels of oats in 1909, 4.5 bushels of wheat in 1911, 7.9 bushels of corn in 1912, 3 bushels of corn in 1913, and 4.3 bushels of oats in 1914.

For permanent profitable systems of farming on brown silt loam, phosphorus should be applied liberally, and sufficient organic matter should be provided to furnish the necessary amount of nitrogen. On the ordinary type, limestone is already becoming deficient. An application of two tons of limestone and one-half ton of fine-ground rock phosphate per acre every four years, with the return to the soil of all manure made from a rotation of corn, corn, oats, and clover, will maintain the fertility of this type, altho heavier applications of phosphate may well be made during the first two or three rotations. If grain farming is practiced, the rotation may be wheat, corn, oats, and clover, with an extra seeding of clover as a cover crop in the wheat, to be plowed under late in the fall or in the following spring for corn; and most of the crop residues, with all clover except the seed, should also be plowed under. In either system, alfalfa may be grown on a fifth field and moved every five years, the hay being fed or sold. In live-stock farming the regular rotation may be extended to five or six years by seeding both timothy and clover with the oats, and pasturing for one or two years. Alsike and sweet clover may well replace red clover at times, in order to avoid clover sickness. (For results of field experiments on the brown silt loam prairie, see pages 13 to 19.)

Black Clay Loam (520)

Black clay loam in Pike county occupies the naturally poorly drained prairie land. It is frequently called "gumbo," because of its sticky character. Its formation in the lower places is due to the more rapid accumulation of organic matter and to the washing in of clay and fine silt from the higher adjoining lands. This type covers only 70 acres. It occurs in several small patches located in areas of brown silt loam.

The surface stratum, 0 to 6⅔ inches, is a black, plastic, granular clay loam with an average organic-matter content of 4.4 percent, or 44 tons per acre. The more luxuriant growth of prairie grasses that once covered this black clay loam and the preservation of the roots by the moist condition of the soil has resulted in a larger amount of organic matter than on the more rolling areas. 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, rendered pervious to air and water, and made easier to work. If the granules are destroyed by working the soil when it is wet, it becomes puddled and very difficult to manage. Granulation will be restored by 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.

The subsurface soil is 10 to 15 inches in thickness. It differs from the surface in color, becoming lighter with depth, the lower part of the stratum passing into a drab or yellowish silty clay. It contains more clay than the surface but at the same time is quite pervious to water, owing to the jointing or checking produced in times of drouth. The amount of organic matter averages 6.4 percent.

The subsoil is usually a drab or dull yellow silty clay, but locally it may be a yellow clayey silt or even a silt. As a rule, the iron is not highly oxidized, because of poor drainage. The checking or jointing in the subsoil makes it readily permeable to water and consequently easy to drain.

Keeping the soil in good physical condition is very essential with this type of soil. The greatest help toward this end is thoro drainage, which is the first requirement of the type. As a further aid organic matter should be increased and lime added, for the organic matter present is naturally destroyed by cultivation and nitrification, and the lime is removed by cropping and leaching, so that the soil becomes poorer in physical condition and consequently more difficult to work. Both organic matter and lime tend naturally to develop a granular condition, but they are especially effective when aided by careful and well-timed cultivation. The organic matter should be maintained by turning under manure, clover, and crop residues, such as corn stalks and straw. Too often crop residues are burned. Straw is too frequently left in lots until the larger part of the organic matter is lost by fermentation and decay.

While black clay is one of the best soils, the clay and humus which it contains give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times. This shrinkage results in the formation of cracks, which break the roots of the crops and allow the soil strata to dry out rapidly. Good tilth with a soil mulch will go far toward preventing this.

This type is fairly well supplied with plant food, which is usually liberated with sufficient rapidity by a good rotation and by the addition of moderate amounts of organic matter. The amount of organic matter added must be increased, of course, with continued farming, until the nitrogen supplied is equal to that removed. Altho the addition of phosphorus is not expected to produce marked profit, it is likely to pay its cost in the second or third rotation, and even by maintaining the productive power of the land, the capital invested is protected.

At Urbana, on the South Farm of the University of Illinois, a series of plots devoted chiefly to variety tests and other crop-production experiments extends across an area of black clay loam. Where rock phosphate has been applied at the rate of 500 pounds an acre a year in connection with crop residues in a four-year rotation of wheat, corn, oats, and clover (or soybeans), the value of the increase produced per ton of phosphate applied, in three successive rotation periods, has been $2.13, $4.70, and $6.48, respectively, at the "lower prices," or $3.04, $6.71, and $9.26, respectively, at the "higher prices" for produce. In the livestock system, the phosphorus naturally supplied in the manure, supplemented by that liberated from this fertile soil, has thus far been nearly sufficient to meet the crop requirements, the increase in crop values per ton of phosphate applied having been, as an average for the twelve years, only $2.26 at the "lower prices," or $3.26 at the "higher prices" for produce. These returns are less than half the cost of the phosphorus applied, and some seasons no benefit appears.

However, the black clay loam in the Illinois glaciation contains less phosphorus than that in the Wisconsin glaciation, and consequently more marked benefits from the addition of that element are to be expected in Pike county than at Urbana. This type is rich in magnesium and calcium, but usually it does not contain carbonates. With continued cropping and leaching, applications of limestone will ultimately be needed, and may be found profitable very soon.

Brown-Gray Silt Loam on Tight Clay (528)

Brown-gray silt loam on tight clay occurs in isolated areas closely related to brown silt loam. It comprizes 3.69 square miles (2,362 acres), or .46 percent of the total area of the county. Some of this type may have been timbered; it usually occurs on the edge of the timbered areas and between these and the brown silt loam (526).

The surface soil, 0 to 6⅔ inches, is a brown or grayish brown, pulverulent silt loam containing some fine sand and coarse silt, which give it a very desirable texture. The organic-matter content varies somewhat according to the relation of the type to other types, being greater as it grades toward brown silt loam

(526) and less where it grades toward yellow-gray silt loam (534). The average is about 2.6 percent, or 26 tons per acre.

The subsurface is represented by a stratum 8 to 11 inches thick. In color it varies from a brown to a grayish brown or gray, the upper part of the stratum usually being brown and the lower part gray or a grayish brown. It differs from the surface stratum principally in the amount of organic matter it contains, which is 1.9 percent.

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

This type occupies rather flat areas and needs drainage in some cases. Because of the nearly impervious nature of the subsoil, it is somewhat more difficult to drain than the brown silt loam (526). Care should be taken to increase the amount of organic matter by the proper rotation of crops, by turning under crop residues, and by the application of farm manure. Deep-rooting 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.

From Table 2 it will be seen that the surface soil contains only 2,240 pounds of nitrogen and 860 pounds of phosphorus per acre. To increase these amounts, liberal applications of fine-ground rock phosphate should be made in connection with decaying organic matter, as on the brown silt loam. This soil is distinctly acid in surface, subsurface, and subsoil. Limestone should be applied at the rate of 2 to 3 tons per acre every four to six years. The initial application may well be 1 ton of phosphate and 4 tons of limestone.

Gray Silt Loam on Tight Clay (530)

Gray silt loam on tight clay occurs in a few small areas near Milton. It covers a total of 525 acres, or .1 percent of the area of the county. The topography is level to slightly undulating, with a few narrow and shallow erosion channels.

The surface soil is a light chocolate brown, mottled with darker iron stains. The amount of organic matter is 1.9 percent.

The subsurface consists of a brownish gray to gray silt loam, varying from 10 to 15 inches in thickness.

The subsoil consists of a tight clay extending from 18 to 20 inches below the surface to a depth of 30 to 34 inches. In some places it becomes quite compact, but it is always a clay and never of a stony nature. The type varies a great deal both in color and in the tightness of the subsoil.

In the management of this type one of the most important points is the maintaining or the increasing of the organic-matter content. The growth of deep-rooting crops, such as red, mammoth, or sweet clover, is very necessary, and in other respects, also, the soil should have the same treatment as the brown-gray silt loam on tight clay (528).

(b) UPLAND TIMBER SOILS

The upland timber soils are distinguished from the prairie soils primarily by their lower content of organic matter. The roots of prairie grasses have been responsible for the large amount in the prairie, but in the upland forests there is found no such quantity of roots. The vegetable material of forested areas consists of leaves and twigs which fall upon the surface and are either burned by forest fires or undergo almost complete decay, with very little chance to become mixed with the soil.

The invasion of the prairies by forests has been a slow process, while the changing of the soil by the growth of trees has been a much slower one. As a result of forestation, however, the organic-matter content of the upland prairie soils has been lowered until characteristic timber soils have been produced. The continuous growth of forests for long periods of time on level areas not subjected to erosion has produced soils of low productiveness, due largely to the extremely low content of organic matter.

Yellow-Gray Silt Loam (534)

The yellow-gray silt loam of Pike county covers 99.65 square miles (63,776 acres), or 12.48 percent of the entire county. In topography it is sufficiently rolling for good surface drainage, without much tendency to erode if proper care is taken. The largest areas of the type occur in the vicinity of Milton, Pittsfield, Griggsville, and Tempest. Innumerable small areas occupying the somewhat level tops of ridges are widely distributed over the county.

The surface soil, 0 to 6⅔ inches, is a gray to yellowish gray silt loam, coherent and mealy, but not granular. In physical composition it consists of 15 to 25 percent of fine sand, 6 to 10 percent of clay, and 65 to 70 percent or more of different grades of silt. A large amount of fine sand and coarse silt gives it a very desirable texture. The amount of organic matter contained in it varies normally from 1.7 to 2.9 percent, with an average of 2.2 percent, or 22 tons per acre. It also varies with the relation of the type to other types, diminishing as yellow silt loam (535) and light gray silt loam on tight clay (532) are approached, and increasing as the type grades into brown silt loam (526) and brown-gray silt loam on tight clay (528).

The subsurface stratum varies from 3 to 10 inches in thickness, being thinnest on the more undulating and rolling areas. In color it is a gray, grayish yellow, or yellow silt loam, somewhat pulverulent, but becoming more coherent and plastic with depth. It contains 1.2 percent of organic matter. The stratum becomes a lighter gray as the type grades into the light gray silt loam on tight clay (532).

The subsoil is a yellow or grayish yellow clayey silt or silty clay, pervious to water, somewhat plastic when wet but friable when only moist. The lower part of the stratum frequently consists of a pervious mealy silt.

In the management of yellow-gray silt loam, one of the most essential points is the maintaining or the increasing of the organic matter. This is necessary in order to supply nitrogen and liberate mineral plant food, to give better tilth, to prevent "running together," and, on some of the more rolling phases, to prevent washing. Definite rotations should be followed, and crop residues, as well as legumes, should be turned under to provide organic matter. Mammoth clover and sweet clover are probably the most desirable legumes to turn under, because of the greater amount of material they furnish. Another essential is that the acidity of the soil be neutralized by the application of ground limestone, so that clovers, alfalfa, and other legumes may be grown successfully. Phosphorus should be applied liberally with the increase of decaying organic matter. (Some field experiments on this general type of soil in the lower Illinois and late Wisconsin glaciations are reported on pages 12 to 15.)

Yellow Silt Loam (535)

In area, yellow silt loam exceeds all other types, covering 255 square miles (163,206 acres), or 31.92 percent of the county. It occurs as the hilly and badly eroded land. In topography it is very rolling and in most places so badly broken that it should not be cultivated, because of the danger of injury from washing.

The surface soil, 0 to 6⅔ inches, is a yellow, yellowish gray, brownish yellow, or light brown silt loam, pulverulent and mealy. It varies a great deal, owing to recent washing. In some places the natural subsoil is exposed as "clay points." The organic-matter content is about 1.7 percent.

The natural subsurface varies in thickness from 0 to 12 inches, the variation being due to the removal by erosion of all or part of this stratum as well as the surface. It consists of a yellow to a grayish yellow silt loam and contains .7 percent of organic matter.

The subsoil is a compact, yellow, clayey silt, varying in some places to a mealy silt mixed with a considerable percentage of fine sand.

In the management of yellow silt loam, the most important thing is to prevent general surface washing and gullying. Nothing will completely ruin land more quickly than erosion, especially gullying. In a single season, or even by a single rain, gullies may be produced that cannot be crossed with ordinary farm implements, and unless these gullies are promptly looked after, the land soon becomes worthless. Sheet washing does not ruin land so rapidly, but it causes the loss of the best soil and a consequent depreciation in productiveness that results in even greater loss than from gullying. Hence, every means should be employed to decrease the amount of surface run-off and to reduce to a minimum its destructive effect when it does occur. The injury resulting from run-off depends upon the velocity of the water. With the doubling of the velocity, the wearing, or abrading, power of the water is quadrupled, while its power to carry material varies as the sixth power of the velocity—which means that if the velocity is doubled, the carrying power will be increased sixty-four times. It then becomes necessary either that the soil be so firmly held by vegetation or that the velocity be so diminished that little injury can take place.

Certain practices may be followed on these rolling lands to prevent excessive losses by erosion:

(1) Cover crops should be kept on the land as much of the time as possible, in order to hold the soil. Blue grass, or any covering of that kind, is of material assistance for this purpose. Rye, cowpeas, and clover may be used in corn after it is laid by, for holding the soil during the winter and spring.

(2) The organic-matter content should be increased, for it makes the soil porous and gives it greater absorbing power, and also binds or cements the soil particles together so that they will not be carried off so readily.

(3) All operations on this land should be done as nearly as possible on the

contour. Plowing, planting, and cultivating should be done across the slope and not up and down, for a dead furrow up and down the slope is an excellent beginning for a gully. The plowing should be deep, so as to present a thick layer of loose soil for the absorption of water. Ten inches of loose soil will readily absorb two inches of rainfall. Incipient gullies should be stopped at once. For further suggestions in preventing washing, see Circular 119, "Washing of Soils and Methods of Prevention."

Additional treatment recommended for this yellow silt loam is the liberal use of limestone wherever cropping is practiced. This type is quite acid and 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.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for, with the erosion that 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 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. (For results of pot-culture and field experiments on yellow silt loam, see pages 7 to 12.)

Light Gray Silt Loam on Tight Clay (532)

Light gray silt loam on tight clay occurs in many small isolated areas occupying very flat tops of ridges. The largest area is found in Section 7, Township 3 South, Range 3 West. The total area is 1.54 square miles (986 acres), comprizing .19 percent of the area of the county. The topography is very flat, and the land has poor drainage, altho it is not swampy. It was formerly covered with hickory, white oak, and blackjack.

The surface soil, 0 to 6⅔ inches, is a white or very light gray silt loam, incoherent, friable, and porous. Small rounded iron concretions varying in size from a mustard seed to a pea are usually present. The organic-matter content is low, averaging only 1.9 percent, or 19 pounds per acre. This stratum varies somewhat with the relation of the type to other types; it is always surrounded by yellow-gray silt loam (534) or yellow silt loam (535), and where it grades into yellow-gray silt loam it possesses a larger organic-matter content.

The subsurface is a light gray silt loam, extending 16 to 18 inches below the surface. With depth it becomes more clayey and contains a perceptible amount of iron concretions. The organic-matter content is very low, being only .8 percent.

The subsoil is a tight, compact, clayey silt or silty clay of a drab or dull yellowish color, becoming slightly more porous and yellow with depth. This clay stratum is nearly impervious, both to air and to water.

Besides being very low in organic matter, this type of soil contains no limestone and consequently is in poor physical condition. It runs together badly and does not retain moisture well, owing to the strong capillarity in the surface and the subsurface strata caused by lack of organic matter.

In the management of this type, ground limestone should be used liberally and rock phosphate should be added with organic matter, the supply of which should be increased in every practical way. All crop residues should be turned under directly or in manure, and deep-rooting crops, such as red, mammoth, or sweet clover, should be sown. These tend to loosen the tight clay subsoil, as well as 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. All available farm manure should be put on the land as soon as possible after being produced. 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, organic matter, and phosphorus before being seeded down.

Yellow-Gray Fine Sandy Loam (874)

Yellow-gray fine sandy loam constitutes the less rolling land of the deep loess areas (designated by 800) and is confined to a belt from 3 to 6 miles wide over the uplands near the Mississippi valley, and from 1 to 3 miles wide adjoining the valley of the Illinois river. The origin of the loess from which this type of soil was formed is discussed on page 2.

The amount and coarseness of sand present varies with the distance of the type from the bluff—the greater the distance, the finer the material. The total area comprizes 27.66 square miles (17,702 acres), or 3.46 percent of the area of the county. The topography is sufficiently rolling for good surface drainage. Care must be taken, however, to prevent erosion. Gullies sometimes form in the more rolling areas which eat back into the level areas by what is called head erosion. In some parts of the county, especially near the east side, the loess is underlain by a deep stratum of incoherent sand, which is easily washed out, undermining the soil and causing it to cave in; in this way the gully works its way back into the less rolling upland.

The surface soil, 0 to 6⅔ inches, is a yellowish gray to yellow, fine sandy loam, incoherent and mealy, but not granular. It contains from 50 to 60 percent of very fine sand, with a considerable proportion of coarse silt. It has an ideal texture. The average amount of organic matter is 2.2 percent, or 22 tons per acre. This varies somewhat with the relation of the type to other types, being less as it approaches yellow silt loam (535) and yellow fine sandy loam (875), one or both of which always surround it.

The subsurface stratum varies from 4 to 10 inches in thickness. In color it is yellow. In physical composition it differs very little from the surface soil, except in the amount of organic matter it contains, which is only 1 percent.

The subsoil is a yellow clayey silt or silty clay, somewhat plastic when wet, passing into a fine sandy silt at a depth varying from 30 to 36 inches from the surface.

This type in all its strata is very pervious to water; and this condition, together with its undulating character, gives excellent drainage. Another fact of significance is the great capillary power which it possesses. It retains moisture well and brings it up from a considerable distance beneath the surface. In a tube filled with this type of soil, water rose to a height of about 10 feet. The pervious character enables the roots of plants to distribute themselves much more completely than in most soils.

In the management of yellow-gray fine sandy loam, the most essential thing is the maintaining or the increasing of the organic matter. This is necessary in order to supply nitrogen and liberate mineral plant food, as well as to give better tilth, to prevent "running together," to increase the power of the soil for retaining moisture, and, on some of the more rolling phases, to prevent washing. A systematic rotation should be practiced in which legumes are grown every two or three years, primarily for soil improvement. The legumes and crop residues should be turned under either directly or in manure.

This type contains no carbonates, but is slightly acid, and the acidity increases with depth, being very appreciable in the subsoil. While the supply of phosphorus in the surface soil is not large, the porosity of the soil and subsoil affords such an extensive feeding range for plant roots that the addition of phosphorus is not a matter of first importance, altho its use will probably be profitable after the organic matter and nitrogen have been sufficiently increased. The type is rich in potassium, but with much of this locked up in sand grains there is still greater need of more decaying organic matter in order to liberate it.

With liberal use of ground limestone, this type becomes one of the best soils in the state for the production of alfalfa. The Union Grove experiment field, in Whiteside county, is located on a very similar soil type, tho because it contains in the surface somewhat less sand and more organic matter, it is classed as brown silt loam over sand. In 1914 this field produced 4.1 tons per acre of well-cured alfalfa hay where 4 tons per acre of ground limestone had been applied. As an average of the results for four years (1911 to 1914), the yield of corn was increased 13 bushels per acre by crop residues and 16.5 bushels by farm manure, both materials having been applied during the previous rotation in proportion to what could be easily produced from the crops grown on the same land. Phosphorus further increased the yield only 4.6 bushels. In 1914 the yield of corn was increased from 40.8 bushels to 64.7 by crop residues, and to 67.2 by farm manure. When phosphate was added, the yields rose to 71.5 bushels with crop residues, and to 74.3 with farm manure, limestone having been applied in all cases mentioned. The effect of limestone is reported as very marked on the 1915 clover crop.

Yellow Fine Sandy Loam (875)

Yellow fine sandy loam occurs in the deep loess belt (800) and occupies the hilly and very rolling land which is so badly broken that it should be cultivated only with the utmost care because of the danger of injury from washing. The area is quite large, covering one-half as much of the county as the yellow silt loam (535). It comprizes 126.77 square miles (81,133 acres), or 15.87 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a yellow fine sandy loam, pulverulent, and of excellent texture. It varies a great deal because of recent washing; in some places, the natural subsoil is exposed. The organic-matter content varies from 1.2 to 2 percent, with an average of 1.6 percent, or 16 tons per acre. The content of fine sand varies from 40 to 60 percent.

The natural subsurface varies in thickness from 0 to 12 inches, the variation being due to the removal of all or part of this stratum as well as the surface. The organic-matter content varies, but averages .7 percent.

The subsoil varies widely in its composition. In some areas it is a compact, yellow, clayey silt, while in others it is made up entirely of a mealy, silty, fine sand containing large amounts of carbonate of lime. This latter is the unweathered loess and forms the subsoil because of the removal of the upper strata. The common subsoil is almost ideal in texture.

In the management of this type, the prevention of general surface washing and gullying is the most important point. 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. In general the methods of management and improvement should be the same as for yellow silt loam. See pages 6 and 26, and Circular 119, "Washing of Soils and Methods of Prevention."

(c) OLD BOTTOM-LAND SOILS

In the valleys of the streams of the older glaciations some parts of the flood plains of the larger streams bear distinct evidence of being an older deposit, while the small bottom lands are, without much doubt, of this character. This old soil is found in the flood plains of both the Mississippi and Illinois rivers and of some of the smaller streams. It is designated by the number 1300.

Gray Silt Loam on Tight Clay (1330)

Gray silt loam on tight clay occupies 24.17 square miles (15,469 acres), or 3.03 percent of the entire county. It is found in both the Mississippi and the Illinois bottoms. In topography it is flat, and by inspection of the map it will be seen that much of it is covered at times by overflows from the streams draining the upland. It is commonly spoken of as "ash" or "white ash" soil.

The surface soil, 0 to 6⅔ inches, consists of a gray to a light brown silt loam and contains from 2 to 3.5 percent of organic matter, with an average of a little less than 3 percent, or about 30 tons per acre. In physical composition it is a quite uniform silt loam with a considerable proportion of fine sand, which gives it a mealy texture.

The subsurface soil is a gray to dark gray silt loam, with an organic-matter content averaging about 1.2 percent.

The subsoil is usually a gray silt, with a compact, grayish yellow, silt or silty-clay layer that acts as a tight clay, retarding percolation.

Altho the topography of this type is quite flat, there are some small depressions in which under ordinary conditions in the Mississippi bottom one would expect the soil to be quite heavy and to contain drab clay or clay loam, but in these depressions the type has a dark surface and immediately under it a very light gray subsurface. The color of all the strata varies with the amount of organic matter present, but the surface shows the greatest variation. As brown silt loam is approached, the color of the surface and subsurface becomes darker, while that of the subsoil becomes more of a yellow or drab, somewhat similar to brown silt loam. Small round concretions are found in all the strata. While the topography of the type is not objectionable, the character of the subsurface and the subsoil renders it almost impervious to water and air, and hence it is a cold and somewhat poorly drained type.

In the management of this type, one of the first requirements is organic matter. This constituent is needed to give life to the soil,—or in other words, to stimulate bacterial action in order to increase moisture retention in times of drouth, and to increase porosity so that better aeration may take place. To increase the amount of nitrogen, all crop residues should be turned back into the soil and clover grown. In order to grow legumes successfully, it will be necessary to apply two or three tons of limestone per acre, as the soil is decidedly acid. Phosphorus is also needed for the maintaining and increasing of productive power.

Mixed Loam (1354)

Mixed loam is a mixture of types varying from sand to clay loam, forming the bottom land of the small streams. The areas are so small and irregular and the changes during floods so frequent that it is not practical to attempt to show the separate types; hence the name mixed loam is applied. This type covers 40.2 square miles (25,728 acres), or 5.03 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, contains, on an average, about 2.6 percent of organic matter, or 26 tons per acre. The subsurface varies fully as much as the surface, while the subsoil oftener passes into a sandy loam or a sand.

It is extremely difficult to do anything in the way of soil improvement with this type, but it is always a good plan to keep it supplied with organic matter. This can be done on these bottom lands easier than on the upland, because the soil of the bottom lands is in condition to grow soil-renovating crops to better advantage. Where the land is protected from overflow, limestone may be used to advantage, but the porous subsoil is likely to render the use of phosphorus unprofitable.

(d) SWAMP AND LATE BOTTOM-LAND SOILS

The swamp and late bottom-land soils have been formed in comparatively recent times and constitute the most fertile parts of the flood plains. They cover a total area of 175.9 square miles, or 22 percent of the total area of the county. Where not protected by levees, they are still receiving deposits at times of overflow.

Deep Brown Silt Loam (1426)

Deep brown silt loam comprizes 65.2 square miles (41,728 acres), or 8.16 percent of the entire area of the county. It is formed primarily from material washed from the nearby upland, both by the ordinary streams and by occasional torrential rains which produce general erosion. The streams occupy comparatively narrow valleys on the upland, but when they leave these valleys and enter the broad bottom lands of the Mississippi or Illinois rivers, they spread out, depositing in immense alluvial fans the loads they have carried. The streams thus build up their shores above the general level, then break over and form new channels and make new deposits. By this means, Pigeon, Craney, Hadley, Kiser, Dutch, Six Mile, and Bay creeks have built up large areas of alluvial material that now forms excellent soil. The chief objection to this soil is that these streams break into the cultivated areas and form new channels.

The surface soil, 0 to 6⅔ inches, consists of a brown silt loam containing from 25 to 35 percent of fine sand. The color depends somewhat upon the age of the deposit. Where the material has been deposited for some time, and vegetation allowed to grow, the organic matter has developed in sufficient amount to give the soil a deep brown color, whereas in the case of very recent deposits the soil is a light brown or even a yellow. Ten or fifteen years is sufficient to change the color very decidedly, and if overflow is prevented for that length of time, the soil is changed, by the organic matter produced, into a light-colored brown silt loam. The average amount of organic matter is 3.5 percent, or 35 tons per acre.

The subsurface soil consists of a brown or yellow fine sandy silt loam, the color again depending upon the age of the deposit. The amount of organic matter is 2.6 percent.

The subsoil, as a rule, does not differ very materially from the surface and the subsurface except in color, being as a general rule lighter than these two strata. However, where a rather shallow deposit of this type has been made over another type, the other type sometimes forms part of the subsoil. In these shallow alluvial deposits there may be a subsoil of gray silt loam, drab clay, or brown silt loam, according to the type that has been covered.

Deep brown silt loam is one of the most fertile soils in the county, and from the point of texture it is all that could be desired, especially in the darker areas. The sediment that is brought down from the upland may be acid, or if from deep gullies it may contain some limestone. As an average, however, the type is practically neutral and not markedly in need of limestone. Its porosity allows a sufficient liberation of phosphorus for good crops, altho where overflow does not occur, both limestone and phosphorus will ultimately need to be supplied. In the management of this type, is it well to maintain the supply of organic matter by plowing under legumes, crop residues, or farm manure.

Brown Silt Loam on Sand (1426.2)

Brown silt loam on sand covers 46.5 square miles (29,773 acres), or 5.82 percent of the area of the county. It generally occurs along the bayous and sloughs about halfway between the bluff and the river. The principal stream in this area is known as the Sny, but there are large numbers of small lakes and bayous that divide the bottom land into irregular areas, many of which are islands.

The surface soil is a brown silt loam. It varies, however, with the wavy or undulating character of the surface, being slightly sandy on the tops of the ridges, but somewhat heavy in the depressions between them. It contains 3.2 percent of organic matter.

The subsurface is a brown loam, becoming more sandy with depth.

The subsoil is a brown to yellowish sandy loam, passing into a sand at a variable depth of 20 to 40 inches, the sand being nearer the surface on the ridges than in the depressions. The organic-matter content is 1.5 percent.

This type is very pervious, permitting ready percolation of water and air. With drainage and good tillage, together with the incorporation of organic matter, very good crops may be produced. However, since overflow is being prevented, the use of limestone may soon be necessary in the best system of soil improvement.

Drab Clay (1415)

Drab clay covers 38.12 square miles (24,397 acres), or 4.77 percent of the area of the county. This type occupies the lower, back-water areas, where the finest material in suspension has settled. Much of the older deposit has without doubt been covered by more recent and lighter deposits.

The surface soil, 0 to 6⅔ inches, is a drab to dark drab, almost black, granular plastic clay, containing 3.4 percent of organic matter. Locally it contains large amounts of sand, but these areas are too irregular to be considered. The subsurface varies from a dark drab to a bluish drab clay. The subsoil differs but little from the lower subsurface, but sometimes rests upon sand within 40 inches of the surface. There is no doubt that sand underlies all of this type, but it is usually at considerable depth.

All of the strata of the drab-clay type in this county are pervious to water, owing to the checking or jointing produced by shrinkage and the action of crayfish and other animals which produce openings down to the sand and gravel underneath. The property of shrinkage is very highly developed and, in times of severe drouth, results in the formation of large cracks, which injure the crops by severing the roots. These cracks attain a width of 2 to 4 inches and extend to a depth sometimes of 2½ feet. The surface soil is granular, a characteristic that is produced by the property of shrinkage around many centers.

The soil is difficult to work because it puddles when too wet and is cloddy when too dry. The danger is increased by a low organic-matter content. In either case the natural agencies, such as freezing and thawing and wetting and drying, will ultimately restore good tilth.

The first requirement of this soil is thoro drainage. This aids in the production of good tilth, since a saturated condition tends to puddle not only this but most other types of soil. Deep-rooting crops will be of benefit in aiding aeration and percolation of water, and further improvement will result from additions of limestone and organic matter.

Brown Sandy Loam (1460)

Brown sandy loam occupies 17.29 square miles (11,066 acres), or 2.17 percent of the county. It is found only in the bottom land of the Mississippi, where it occupies the higher parts.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam, the sand varying in coarseness as well as in amount. On some of the higher parts the wind has evidently been a factor in increasing the amount, and here the content becomes so great that many small areas are mapped as sand.

The subsurface soil consists of a brown sandy loam, becoming somewhat more sandy with depth. At a depth of 12 to 18 inches the subsurface passes into the subsoil, the line being indicated by a change in color more than in texture. The amount of sand increases with depth until, 30 to 40 inches from the surface, it becomes a pure sand.

This type varies with its relation to other types. It is frequently surrounded by drab clay, usually with a belt of heavy sandy loam or sandy clay between the two. Where it grades into brown silt loam on sand (1426.2), the separation is more difficult to determine, since topography lends little or no assistance in this case. Many small areas of sandy loam that are not large enough to map occur on the shores of bayous. These areas usually consist of ridges from 4 to 10 rods wide, and in many cases they are quite sandy. They are probably the result of wind and wave action. Altho usually a dark brown in color, the type in some cases is a light brown. It is deficient in organic matter.

Liberal use of limestone and legume crops, to be turned under directly or in manure, will result in marked improvement. No other applications are likely to prove profitable.

Mixed Sandy Loam (1461)

Mixed sandy loam occupies 8.48 square miles (5,427 acres), and comprizes 1 percent of the area of the county. It lies almost entirely outside the levee, and for this reason is not of great importance, because of the danger from overflow.

The type varies from a clay to an almost pure sand, but the larger part is sandy loam. In Township 6 South, Range 6 West, an area of approximately a half-section lies within the levee, and near East Hannibal is a similar area. This type is almost entirely covered with timber.

River Sand (1480)

River sand comprizes an area of .30 square miles (192 acres). Its presence is due in every case to breaks in the levee and the consequent deposition of considerable amounts of sand, burying other types. Two areas occur, one in Section 16, Township 5 South, Range 7 West, and the other in Section 18, Township 7 South, Range 5 West. In places, this type may well be used for truck crops if heavily fertilized with farm manure.

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 dolomitic limestone.

Physical Improvement of Soils

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

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

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

The nitrogen in a ton of corn stalks is 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. BULLETINS

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

CIRCULARS

*64 Investigations of Illinois Soils, 1903.
*68 Methods of Maintaining the Productive Capacity of Illinois Soils, 1903 (2d edition, 1905).
*70 Infected Alfalfa Soil, 1903.
*72 Present Status of Soil Investigation, 1903 (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.
105 The Duty of Chemistry to Agriculture, 1906 (2d edition, 1913).
108 Illinois Soils in Relation to Systems of Permanent Agriculture, 1907.
109 Improvement of Upland Timber Soils of Illinois, 1907.
110 Ground Limestone for Acid Soils, 1907 (3d edition, 1912).
*116 Phosphorus and Humus in Relation to Illinois Soils, 1908.
*119 Washing of Soils and Methods of Prevention, 1908 (2d edition, 1912).
*122 Seven Years' Soil Investigation in Southern Illinois, 1908.
123 The Status of Soil Fertility Investigations, 1908.
124 Chemical Principles of Soil Fertility, 1908.
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3d edition, 1912).
*129 The Use of Commercial Fertilizers, 1909.
130 A Phosphate Problem for Illinois Land Owners, 1909.
*141 Crop Rotation for Illinois Soils, 1910 (2d edition, 1913).
142 European Practice and American Theory Concerning Soil Fertility, 1910.
145 The Story of a King and Queen, 1910.
149 Results of Scientific Soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois, 1911.
150 Collecting and Testing Soil Samples, 1911 (2d edition, 1912).
155 Plant Food in Relation to Soil Fertility, 1912.
157 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.

SOIL REPORTS

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

*Out of print.

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

Year	Crop grown	Yield without phosphorus	Yield with phosphorus	Increase for phosphorus	Value of increase per acre
1902	Corn, bu.	37.0	41.7	4.7	$ 1.64
1903	Corn, bu.	60.3	73.0	12.7	4.44
1904	Oats, bu.	60.8	72.7	11.9	3.33
1905	Wheat, bu.	28.8	39.2	10.4	7.28
1906	Clover, tons	.58	1.65	1.07	7.49
1907	Corn, bu.	63.1	82.1	19.0	6.65
1908	Corn, bu.	35.3	47.5	12.2	4.27
1909	Oats, bu.	53.6	63.8	10.2	2.86
1910	Clover, tons	1.09	4.21	3.12	21.85
1911	Wheat, bu.	22.5	57.6	35.1	24.58
1912	Corn, bu.	47.9	74.5	26.6	9.30
1913	Corn, bu.	30.0	44.1	14.1	4.93
1914	Oats, bu.	40.6	45.0	4.4	1.23

Total value of increase in thirteen years $99.85
Total cost of phosphorus in thirteen years 32.50

Net profit in thirteen years $67.35

After the first year the phosphorus began to more than pay its annual cost; and during the second five-year period the increase produced by the phosphorus was worth almost as much as the total crops produced on the land not receiving phosphorus. In later years the need of organic manures with phosphorus has become apparent. (See pages 13 to 15 for more complete details.)

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