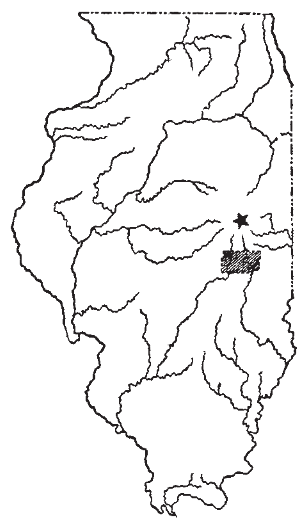
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT No. 43

DOUGLAS COUNTY SOILS

By R. S. SMITH, E. E. DeTURK, F. C. BAUER,
and L. H. SMITH



URBANA, ILLINOIS, JULY, 1929

The Soil Survey of Illinois was organized under the general supervision of Professor Cyril G. Hopkins, with Professor Jeremiah G. Mosier directly in charge of soil classification and mapping. After working in association on this undertaking for eighteen years, Professor Hopkins died and Professor Mosier followed two years later. The work of these two men enters so intimately into the whole project of the Illinois Soil Survey that it is impossible to disassociate their names from the individual county reports. Therefore recognition is hereby accorded Professors Hopkins and Mosier for their contribution to the work resulting in this publication.

[1] Engaged in Soils Extension as well as in Soil Experiment Fields.

INTRODUCTORY NOTE

It is a matter of common observation that soils vary tremendously in their productive power, depending upon their physical condition, their chemical composition, and their biological activities. For any comprehensive plan of soil improvement looking toward the permanent maintenance of our agricultural lands, a definite knowledge of the various existing kinds or types of soil is a first essential. It is the purpose of a soil survey to classify the various kinds of soil of a given area in such a manner as to permit definite characterization for description and for mapping. With the information that such a survey affords, every farmer or landowner of the surveyed area has at hand the basis for a rational system of improvement of his land. At the same time the Experiment Station is furnished an inventory of the soils of the state, upon which intelligently to base plans for those fundamental investigations so necessary for solving the problems of practical soil improvement.

This county soil report is one of a series reporting the results of the soil survey which, when completed, will cover the state of Illinois. Each county report is intended to be as nearly complete in itself as it is practicable to make it, even at the expense of some repetition. There is presented in the form of an Appendix a general discussion of the important principles of soil fertility, in order to help the farmer and landowner to understand the significance of the data furnished by the soil survey and to make intelligent application of the same in the maintenance and improvement of the land. In many cases it will be of advantage to study the Appendix in advance of the soil report proper.

Data from experiment fields representing the more extensive types of soil, and furnishing valuable information regarding effective practices in soil management, are embodied in the form of a Supplement. This Supplement should be referred to in connection with the descriptions of the respective soil types found in the body of the report.

While the authors must assume the responsibility for the presentation of this report, it should be understood that the material for the report represents the contribution of a considerable number of the present and former members of the Agronomy Department working in their respective lines of soil mapping, soil analysis, and experiment field investigation. In this connection special recognition is due the late Professor J. G. Mosier, under whose direction the soil survey of Douglas county was conducted, and Mr. F. A. Fisher, who, as leader of the field party, was in direct charge of the mapping.

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SUPPLEMENT

DOUGLAS COUNTY SOILS

By R. S. SMITH, E. E. DeTURK, F. C. BAUER and L. H. SMITH[1]

Douglas county is located in the east-central part of Illinois. It lies well toward the southern end of the most recently glaciated area—that of the early Wisconsin. The major portion, 87 percent, of the county is covered with productive, dark-colored prairie soils. The agriculture is typically that of the cornbelt region. Douglas is a relatively small county, having an area of only a little more than 400 square miles.

The climate of Douglas county is typical of central Illinois. It is characterized by a wide range between the extremes of winter and summer and by an abundant, well-distributed rainfall. Since there is no Weather Bureau station in Douglas county, data taken from Urbana in the adjoining county of Champaign are of interest. The greatest range in temperature at Urbana for any one year during the period from 1903 to 1927 was 122 degrees in 1905 and again in 1918. The highest temperature recorded is 103° in 1913; the lowest, 25° below zero in 1905. The average date of the last killing frost in spring is April 26; the earliest in the fall, October 16. The average length of the growing season is 173 days.

The average annual rainfall, as recorded for this 24-year period at Urbana, was 34.50 inches. The average rainfall by months for this period was as follows: January, 2.11 inches; February, 1.82; March, 3.36; April, 3.77; May, 3.80; June, 3.21; July, 2.89; August, 3.57; September, 3.18; October, 2.56; November, 2.13; December, 2.11.

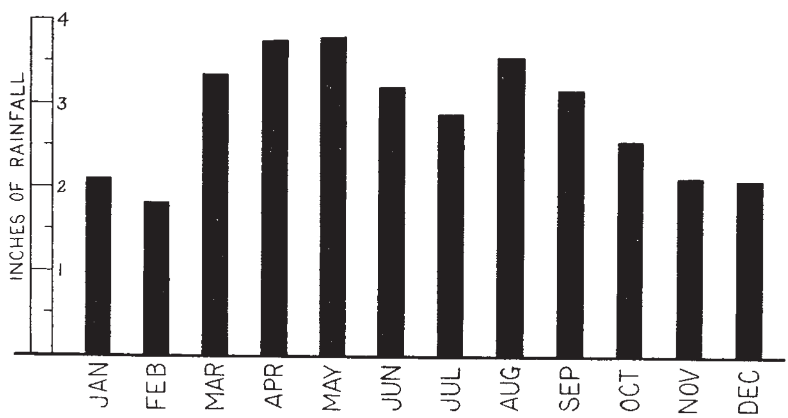

Fig. 1.—The Average Monthly Distribution of Rainfall in Douglas County

It will be noted that the more abundant rainfall occurs mainly during the growing season. This, of course, is favorable to crop production.

[1] R. S. Smith, in charge of soil survey mapping; E. E. DeTurk, in charge of soil analysis; F. C. Bauer, in charge of experiment fields; L. H. Smith, in charge of publications.

AGRICULTURAL PRODUCTION

Douglas county is agricultural in its interests. A very large proportion of the area of the county is suitable for the production of crops. According to the Census of 1925 there were 1,579 farms in the county at that time, which represents a decrease of 446 farms in twenty-five years. About 56 percent of the farms in 1925 were operated by tenants, an increase of about 8 percent in twenty-five years.

The principal crops are those common to the corn belt, as shown by the following figures from the 1925 Census.

Crops	*Acreage*	*Production*	*Yield per acre*
Corn, total acreage	103,038	......	......
Harvested for grain	101,116	3,972,565 bu.	39.3 bu.
Cut for silage	300	2,399 tons	7.99 tons
Cut for fodder	145	......	......
Hogged-off	1,477	......	......
Wheat	21,769	444,508 bu.	20.4 bu.
Oats threshed for grain	38,747	1,564,963 bu.	40.4 bu.
Oats cut and fed unthreshed	85	......	......
Timothy	2,109	......	......
Timothy and clover mixed	2,386	......	......
Clover	6,465	......	......
Alfalfa	942	......	......
Hay of all kinds, both tame and wild	15,434	20,015 tons	1.30 tons

Broom corn is also an important crop in this county, tho the total area devoted to it is not large, having averaged about 4,300 acres during 1924, 1925, and 1926, with an average yield of 525 pounds to the acre. The acreage of sweet clover in Douglas county has increased from 500 in 1919 to 20,000 in 1927.

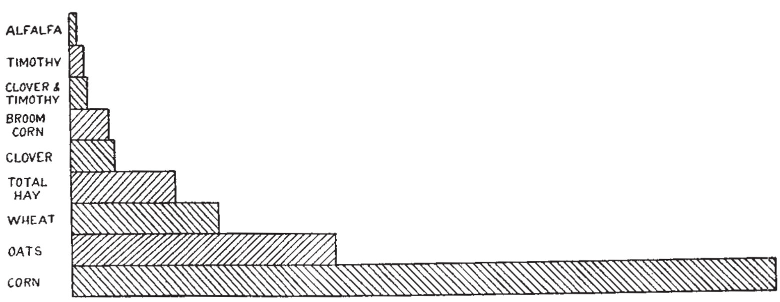

FIG. 2.—RELATIVE ACREAGE OF FIELD CROPS IN DOUGLAS COUNTY

The diagram brings out the preponderance of land devoted to the three grain crops, corn, oats, and wheat. Legume crops might well occupy a larger proportion of the cultivated acreage (data from the 1925 census).

The U. S. Department of Agriculture reports the following average acre-yields for the ten-year period 1916-1925: corn, 35.3 bushels; oats, 32.2 bushels; tame hay, 1.43 tons; winter wheat, 18.9 bushels.

The total value of all livestock and livestock products produced in 1924 was $2,397,316. The following figures, taken from the 1925 Census, show the character of the livestock interests in the county.

Animals and Animal Products	*Number*	*Value*
Horses	9,218	$541,656
Mules	1,058	73,844
Cattle (total)	12,597	498,075
Dairy cows	4,237	.....
Dairy products	....	189,186
Sheep	3,412	33,208
Swine	37,631	448,667
Chickens and eggs	....	435,870
Wool	....	7,922

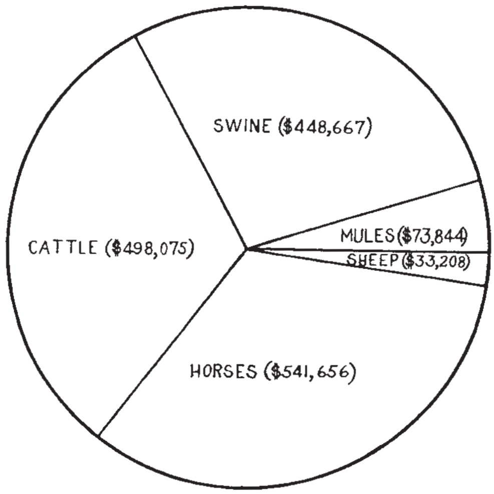

FIG. 3.—RELATIVE VALUE OF THE MORE IMPORTANT CLASSES OF FARM ANIMALS IN DOUGLAS COUNTY

Horses, cattle, and swine are about equal in value.

SOIL FORMATION

GEOLOGICAL ASPECTS

One of the most important periods in the geological history of the county, from the standpoint of soil formation, was the Glacial period, during which and immediately following, the material that later formed the mineral portion of the soils was being deposited. During the Glacial period, great ice sheets moved southward from the centers of accumulation in Labrador, in the Hudson Bay region, and in the northern Rocky mountains. Six great ice movements are generally regarded to have taken place, each of which covered a part of northern United States, altho the same parts were not covered during each advance.

At least two of these great glacial advances designated as the Illinoian and early Wisconsin, covered the area that now constitutes Douglas county. The glacial debris, known as till or drift, deposited by the Illinoian ice sheet, was buried by the debris deposited by the more recent early Wisconsin ice sheet. Altho the Illinoian drift does not enter into the actual composition of the soils of Douglas county, yet the Illinoian glaciation probably had an important effect on the agricultural value of the soils of this county in that it acted as a leveling force, rubbing down the preglacial hills and filling the preglacial valleys.

The soil material of Douglas county is of glacial origin. This material has been reworked by water and wind since the retreat of the last ice sheet. On the higher ridges and steeper slopes erosion has removed the finer soil material nearly as rapidly as it has formed and has deposited much of it on the low-lying, nearly level areas. This action has resulted in youthful soils with little of the horizon development explained below.

PHYSIOGRAPHY AND DRAINAGE

Douglas county is relatively flat except on the morainal ridges in the northeastern and southeastern parts of the county and along narrow belts adjacent to the Embarras and Kaskaskia rivers and their tributaries.

The lower lying portions of the county were swampy until drained by dredge ditches and tile. The swampy condition that prevailed during the period of development of these soils has resulted in the drab and gray color of the lower portions of the profiles. The drainage of the western part of the county is carried by the Kaskaskia river, while that of practically the entire portion of the county east of a north-south line running about a mile west of Arcola is carried by the Embarras river.

The following altitudes indicate the low gradient of the streams in the county. For example, the difference in elevation between Villa Grove and Camargo, both located on the Embarras river, is 10 feet. The distance between these towns is 4½ miles. The following altitudes are given in feet above sea level: Tuscola, 649 feet; Camargo, 637; Newman, 640; Hindsboro, 651; Arcola, 680; Arthur, 658.

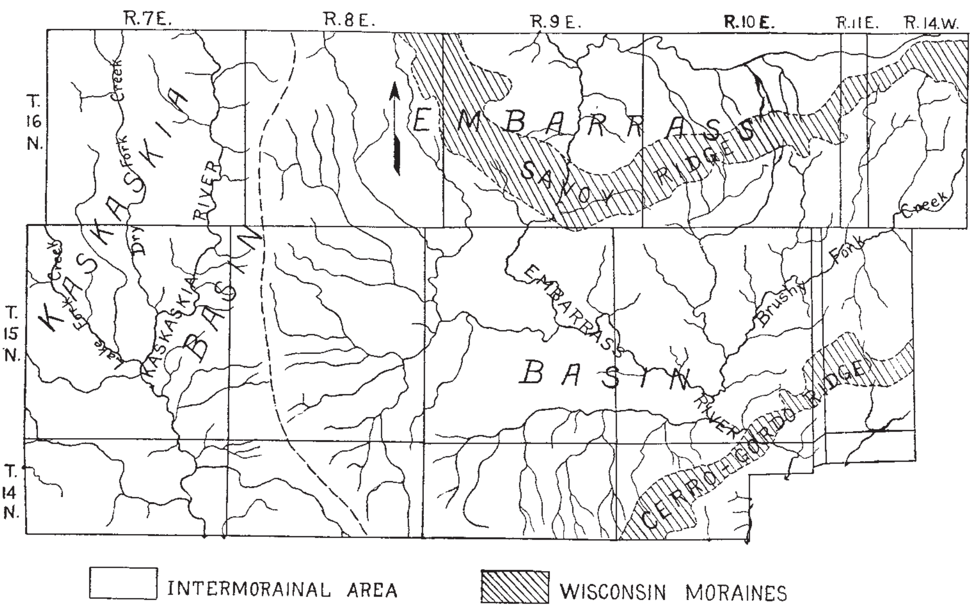

FIG. 4.—DRAINAGE MAP OF DOUGLAS COUNTY SHOWING STREAM COURSES AND OTHER PHYSIOGRAPHIC FEATURES

SOIL DEVELOPMENT

During the time which has elapsed since the last ice invasion, weathering and other processes have been active, resulting in the formation of the soils of the county as we know them today.

When first deposited, the general composition of the soil material was rather uniform thruout, but with the passing of time various physical, chemical, and biological agencies of weathering formed soil out of the parent material by some or all of the following processes: the leaching of certain elements, the accumulation of others; the chemical reduction of certain compounds, the oxidation of others; the translocation of the finer soil particles, and the arrangement of them into zones, or "horizons"; the accumulation of organic matter from the growth and decay of vegetable material. One of the very pronounced characteristics observed in most soils is that they are composed of more or less distinct strata, called horizons. As explained somewhat more fully in the Appendix, these horizons are named, from the surface down; *A*, the layer of extraction; *B*, the layer of concentration or accumulation; and *C*, less-altered material, or the layer in which weathering has had less effect. The development of horizons in a soil is an indication of its age.

Since the upland prairie of this region has been occupied, probably continuously, by grass vegetation, relatively large amounts of organic matter have accumulated, resulting in the formation of productive, dark-colored soils. The areas adjacent to streams, which have been occupied by timber, are light-colored because of the relative deficiency of the surface soil in organic matter. The bottom-land soils are made up, for the most part, of alluvial material brought down from the uplands of the immediate vicinity. These soils are relatively young, or immature, and therefore have not developed horizons as have the more mature soils of the upland.

SOIL GROUPS

The soils of Douglas county have been divided into four groups, as follows:

Upland Prairie Soils, dark-colored and usually rich in organic matter, the organic matter having been derived from the decaying roots of the wild prairie grasses which occupied this land for thousands of years.

Upland Timber Soils, those zones along stream courses over which forests grew for a long period of time. These contain in general less organic matter than the prairie soils.

Terrace Soils, including bench lands and second bottoms formed by deposits from flooded streams overloaded with sediment, perhaps at the time of the melting of the glaciers.

Swamp and Bottom-Land Soils, including the overflow lands or flood plains along streams, the swamps, and the poorly drained lowlands.

Table 1 gives the area of each soil type in Douglas county and its percentage of the total area. It will be observed that 87.24 percent of the county consists of upland prairie, 9.86 percent of upland timber, .01 percent of terrace soils, and 2.89 percent of swamp and bottom-land soils. The accompanying map,

TABLE 1.—SOIL TYPES OF DOUGLAS COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	Upland Prairie Soils (900, 1100)			
926, 1126	Brown Silt Loam[1]	231.23	147 987	55.81
920, 1120	Black Clay Loam	69.39	44 409	16.73
1121	Drab Clay Loam	60.49	38 713	14.60
928, 1128	Brown-Gray Silt Loam On Tight Clay	.38	243	.09
1160	Brown Sandy Loam	.05	32	.01
		361.54	231 384	87.24
	Upland Timber Soils (900, 1100)			
934, 1134	Yellow-Gray Silt Loam	39.42	25 228	9.51
935, 1135	Yellow Silt Loam	1.47	940	.35
		40.89	26 168	9.86
	Terrace Soils (1500)			
1536	Yellow-Gray Silt Loam Over Sand or Gravel	.06	38	.01
	Swamp and Bottom-Land Soils (1400)			
1454	Mixed Loam	11.81	7 558	2.85
1401	Deep Peat	.19	121	.04
		12.00	7 679	2.89
	Total area	414.49	265 287	100.00

[1]Including associated types described in the text but not differentiated on the map.

appearing in two sections, shows the location and boundary lines of the various soil types.

For explanations concerning the classification of soils and the interpretation of the map and tables, the reader is referred to the first part of the Appendix to this report.

INVOICE OF THE ELEMENTS OF PLANT FOOD IN DOUGLAS COUNTY SOILS

Three Depths Represented by Soil Samples

In the Illinois soil survey each soil type is sampled in the manner described below and subjected to chemical analysis in order to obtain a knowledge of its important plant-food elements. Samples are taken, usually in sets of three, to represent different strata in the top 40 inches of soil, namely:

1. An upper stratum extending from the surface to a depth of 6⅔ inches. This stratum, over the surface of an acre of the common kinds of soil, includes approximately 2 million pounds of dry soil.

2. A middle stratum extending from 6⅔ to 20 inches, and including approximately 4 million pounds of dry soil to the acre.
3. A lower stratum extending from 20 to 40 inches, and including approximately 6 million pounds of dry soil to the acre.

By this system of sampling we have represented separately three zones for plant feeding. It is with the upper, or surface layer, that the following discussion is mostly concerned, for it includes the soil that is ordinarily turned with the plow, and is the part with which the farm manure, limestone, phosphate, or other fertilizing material is incorporated. Furthermore, it is the only stratum which can be greatly changed in composition as a result of adding fertilizing materials.

For convenience in making application of the chemical analyses, the results presented in Tables 2, 3, and 4 are given in terms of pounds per acre. It is a simple matter to convert these figures to a percentage basis in case one desires to consider the information in that form. In comparing the proportional composition of the different strata, it must be kept in mind that it is based on different quantities of soil, as indicated above. The figures for the middle and lower strata must, therefore, be divided by two and three respectively before being compared with each other or with the figures for the upper stratum.

The data in Tables 2, 3, and 4, showing plant-food content of Douglas county soils, are based in part upon analyses of samples taken from surrounding counties.

Wide Range in Organic Matter and Nitrogen

It can readily be seen from Table 2 that there is a wide variation among the different soil types of Douglas county with respect to their content of the different plant-food elements in the upper 6⅔ inches of soil. The most striking relationship among these variations is observed with respect to organic carbon and nitrogen, the quantities of which run parallel from type to type tho the organic-carbon content is usually 10 to 12 times as great as the nitrogen. The relationship between organic carbon and nitrogen is explained by the well-established fact that all soil organic matter (of which organic carbon is the measure) contains nitrogen and that most of the soil nitrogen—usually 98 percent or more—is present in a state of organic combination, that is, as a part of the organic matter.

The upland prairie soils of Douglas county are, for the most part, relatively high in organic matter and nitrogen, while the upland timber soils are fairly low, there being no overlapping in the two groups with respect to these constituents. This difference is noticeable not only in the surface soil, but extends to the middle and lower strata as well. The smallest amount of both organic matter and nitrogen are found in Yellow Silt Loam. This type is generally subject to surface erosion, which retards the accumulation of organic matter. The bottom-land soils are represented by only two soil types. Only one has been analyzed, the other being too variable to permit sampling. The Deep Peat, as is usually the case, contains a high percentage of organic carbon. However, the type is not so rich in this constituent here as it is in counties further north where the climatic conditions are more conducive to its accumulation.

TABLE 2.—DOUGLAS COUNTY SOILS: PLANT-FOOD ELEMENTS IN UPPER SAMPLING STRATUM, ABOUT 0 TO 6⅔ INCHES[1]
Average pounds per acre in 2 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (900, 1100)							
926, 1126	Brown Silt Loam	54 680	4 650	1 040	770	35 000	8 270	9 810
920, 1120	Black Clay Loam	74 710	7 090	1 830	1 180	32 830	13 600	19 320
928, 1128	Brown-Gray Silt Loam On Tight Clay	38 970	3 510	1 030	780	31 340	5 940	6 500
1160	Brown Sandy Loam	44 070	3 990	1 010	970	26 430	5 930	11 560
1121	Drab Clay Loam	53 690	5 240	1 500	950	38 260	12 650	16 520
	Upland Timber Soils (900, 1100)							
934, 1134	Yellow-Gray Silt Loam	25 170	2 220	850	550	34 530	5 740	6 410
935, 1135	Yellow Silt Loam	19 070	1 690	870	380	37 040	9 170	9 760
	Terrace Soils (1500)							
1536	Yellow-Gray Silt Loam Over Sand[2]	....	....	....	....	....	....	....
	Swamp and Bottom-Land Soils (1400)							
1454	Mixed Loam[3]	....	....	....	....	....	....	....
1401	Deep Peat[4]	268 560	23 840	1 080	600	11 380	1 830	5 770

LIMESTONE and SOIL ACIDITY.—In connection with these tabulated data, it should be explained that the figures for limestone content and soil acidity are omitted not because of any lack of importance of these factors, but rather because of the peculiar difficulty of presenting in the form of general numerical averages reliable information concerning the limestone requirement for a given soil type. A general statement, however, will be found concerning the lime requirement of the respective soil types in connection with the discussions which follow.

[1]In obtaining the average analyses as presented here samples of some of the types taken in adjacent counties are included. [2]Data not obtained. [3]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [4]Amounts reported are for 1 million pounds of Deep Peat.

All of the soils of the county diminish rapidly in their content of both organic matter and nitrogen with increasing depth. This diminution is noticeable even in the second stratum, 6⅔ to 20 inches, and may be observed even in the Deep Peat of this county.

Phosphorus Slightly Lower in Light-Colored Types

The phosphorus content varies somewhat from type to type. It is noticeably lower in the lighter colored, upland timber types, and highest (1,830 pounds) in Black Clay Loam. There is a tendency for the phosphorus content of soils to parallel the organic carbon to some extent, but not closely as does nitrogen. Phosphorus, in contrast with some other elements, is not appreciably removed from the soil by leaching. It is converted by growing plants into organic forms and tends to accumulate in the surface soil in plant residues at the expense of underlying strata. Investigations at the Illinois Station have shown that in Brown Silt Loam, for example, about 33 percent of the total phosphorus of the

TABLE 3.—DOUGLAS COUNTY SOILS: PLANT-FOOD ELEMENTS IN MIDDLE SAMPLING STRATUM, ABOUT 6⅔ TO 20 INCHES[1]

Average pounds per acre in 4 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (900, 1100)							
926, 1126	Brown Silt Loam............	71 110	6 330	1 680	1 140	70 690	19 950	18 220
920, 1120	Black Clay Loam............	69 600	6 730	2 670	1 400	68 390	28 140	35 660
928, 1128	Brown-Gray Silt Loam On Tight Clay	33 180	3 570	1 530	980	65 770	15 760	11 840
1160	Brown Sandy Loam.........	48 810	4 800	1 840	1 380	52 270	21 880	43 710
1121	Drab Clay Loam............	60 400	6 220	2 480	1 320	77 450	27 840	30 360
	Upland Timber Soils (900, 1100)							
934, 1134	Yellow-Gray Silt Loam	18 640	2 140	1 290	550	71 770	20 350	11 400
935, 1135	Yellow Silt Loam............	17 970	2 080	1 790	740	77 990	24 710	11 920
	Terrace Soils (1500)							
1536	Yellow-Gray Silt Loam Over Sand[2]	....	......	......	......	....	....	......
	Swamp and Bottom-Land Soils (1400)							
1454	Mixed Loam[3]...............	....	......	......	......	....	....	......
1401	Deep Peat[4]..................	471 280	40 300	2 090	1 520	34 240	4 520	18 900

LIMESTONE and SOIL ACIDITY.—See note in Table 2.

[1]In obtaining the average analyses as presented here samples of some of the types taken in adjacent counties are included. [2]Data not obtained. [3]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [4]Amounts reported are for 2 million pounds of Deep Peat.

surface soil is organic, and in Black Clay Loam about 37 percent. It is the second stratum (6⅔ to 20 inches) which furnishes most of the phosphorus thus moved upward. Consequently the phosphorus percentage is higher in the surface soil than in the second stratum, and, except in Yellow Silt Loam, higher than in the lower stratum.

Sulfur Generally Well Supplied

Sulfur, another element used by growing plants, is likewise associated to some degree with organic carbon. This is because a considerable tho varying proportion of the sulfur in the soil exists in the organic form, that is, as a constituent of organic matter. The soils of Douglas county contain from one-half to three-fourths as much sulfur as phosphorus, the amount in the surface soil ranging from 380 to 1,180 pounds per acre. Like phosphorus, the sulfur content generally decreases with increasing depth, partly because some of the sulfur is organic and organic matter decreases with depth, and also in part because organic sulfur is less subject to leaching than calcium sulfate (gypsum), the chief inorganic form of sulfur found in soils. Occasionally very thin strata of nearly pure gypsum are encountered in the lower levels of soils, particularly

TABLE 4.—DOUGLAS COUNTY SOILS: PLANT-FOOD ELEMENTS IN LOWER SAMPLING STRATA, ABOUT 20 TO 40 INCHES[1]

Average pounds per acre in 6 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (900, 1100)							
926 1126	Brown Silt Loam	32 630	3 840	2 190	1 140	108 590	43 070	32 190
920 1120	Black Clay Loam	32 400	3 680	3 210	1 260	104 890	58 790	107 760
928 1128	Brown-Gray Silt Loam On Tight Clay	28 140	3 090	2 270	960	103 580	36 350	29 870
1160	Brown Sandy Loam	25 180	2 720	1 980	1 230	78 120	24 480	28 780
1121	Drab Clay Loam	38 680	4 070	3 020	1 340	113 540	62 060	82 570
	Upland Timber Soils (900, 1100)							
934 1134	Yellow-Gray Silt Loam	17 880	2 450	2 110	880	116 730	42 610	27 520
935 1135	Yellow Silt Loam	17 740	2 580	2 800	960	128 480	40 660	16 400
	Terrace Soils (1500)							
1536	Yellow-Gray Silt Loam Over Sand[2]	......	......	......	......	......	......	......
	Swamp and Bottom-Land Soils (1400)							
1454	Mixed Loam[3]	......	......	......	......	......	......	......
1401	Deep Peat[4]	433 020	37 950	2 480	3 990	80 460	7 920	20 400

LIMESTONE and SOIL ACIDITY.—See note in Table 2.

[1]In obtaining the average analyses as presented here samples of some of the types taken in adjacent counties are included. [2]Data not obtained. [3]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [4]Amounts reported are for 3 million pounds of Deep Peat.

those high in organic matter, and this may account for the high sulfur content, 3,990 pounds per acre, in the lower stratum of Deep Peat, as found in this county.

The sulfur available to crops is affected not only by the soil supply, but also by that brought down from the atmosphere by rain. Sulfur dioxid escapes into the air in the gaseous products from the burning of all kinds of fuel, particularly coal. The gaseous sulfur dioxid is soluble in water and consequently is dissolved out of the air by rain and brought to the earth. In regions of large coal consumption the amount of sulfur thus added to the soil is relatively large. At Urbana during the eight-year period from 1917 to 1924 there was added to the soil by the rainfall an average of 3.5 pounds of sulfur an acre a month. Similar observations have been made in other localities for shorter periods. The precipitation at the various points in the state in a single month has been found to vary from a minimum of ¾ of a pound to more than 10 pounds an acre.

These figures afford some idea of the amounts of sulfur added by rain, and also of the wide variations in amount under different conditions. Considering the amounts which are brought down by rainfall in addition to the soil supply, the facts would indicate that apparently there is little or no need for sulfur fertilizers in Douglas county. In order to determine definitely the response of crops to applications of sulfur fertilizers, experiments with gypsum have been started on a number of experiment fields in various parts of Illinois.

Potassium Content Lower in the Sandy and Peat Soils

The potassium content of the various soil types also exhibits wide variation. Brown Sandy Loam, the only type of a sandy character in the county, is noticeably lower in potassium than the other types thruout the entire depth sampled. Sandy soils carry a large proportion of their potassium in the sand grains. The relatively smaller total surface exposed in the case of these coarser soil particles greatly lowers the rate at which potassium is dissolved, and hence its availability. The deficiency of available potassium in the sandy soils is partly, but not wholly, offset by the greater facility with which the roots of crop plants can ramify in these soils as compared with the heavier types. The potassium concentration in the mineral soils shows very little variation at the different depths.

So far as chemical composition is concerned, Deep Peat as found in Douglas county is not representative of this type as it generally occurs in the state. The comparatively low organic-matter content (for the type) with the accompanying larger proportion of mineral matter, is reflected in the potassium figure, 11,380 pounds, an amount that is two to three times as high as the usual quantity for this type.

Wide Variations in Calcium and Magnesium

Soils, in general, exhibit wide variations in the content of calcium and magnesium, and Douglas county presents no exception to this rule. In the surface soil magnesium varies from 1,830 pounds per acre in Deep Peat to 13,600 pounds in Black Clay Loam, while calcium varies from 5,770 pounds to more than 19,000 pounds. The presence of calcium in amounts of this magnitude is no indication that the soil may not need lime. In acid soils fairly large amounts of calcium may be found. It is locked up, however, by combination in silicate minerals, and thus while serving to reduce acidity, it may become available so slowly in some cases as to make the lack of calcium as a plant-food element a limiting factor in crop growth. The application of lime or limestone supplies readily available calcium and at the same time serves to correct soil acidity.

Some of the variations in total calcium appear to be erratic, particularly in the lower stratum, where very high values are observed in Black Clay Loam, Drab Clay Loam, and Deep Peat. In these types some of the soils contain calcium carbonate (limestone) within the depth sampled, which condition accounts for the high total calcium. Calcium carbonate is readily soluble in soil water, and under natural conditions the surface soil loses its calcium carbonate first by leaching, followed by removal to greater and greater depths. Thus in no case do we find calcium carbonate in the surface soil in Douglas county, even tho an acid surface may be underlain by free calcium carbonate at a greater or less depth.

Some increase in total magnesium ordinarily accompanies the high calcium of the carbonate-containing soils. The increases are not great, however, because of the inability of magnesium carbonate to exist long in the soil in that state. The carbonate of carbonate-containing soils is chiefly calcium carbonate.

In the non-carbonate, upland soils, variations in the amounts of calcium and magnesium at the different depths give some indication of the movement of these elements in soil formation. In the surface soil the calcium usually exceeds the magnesium in amount, as a result of the preponderance of calcium in the soil-forming materials. As we pass into the lower strata we find the magnesium content increasing and gaining on the calcium, even exceeding it in some cases.

These facts aid in explaining what has been going on in the process of soil development with respect to these two elements. As they are dissolved and carried downward in solution, magnesium, owing to its chemical nature, is more readily reabsorbed and held by the soil mass than is calcium. Thus calcium is gradually replaced by magnesium, being forced into solution and carried farther down. Consequently, while magnesium accumulation begins in the middle stratum and increases with depth, the liberated calcium is carried down into or below the third sampling stratum before it is reabsorbed, or it may be washed away entirely in the drainage water. The extent of the translocation of these two elements as revealed by the analyses aids to some extent in estimating the relative degree of maturity of the different types. The increasing proportion of magnesium to calcium in the lower levels becomes more pronounced with increasing maturity of the soil. Thus we see a correlation between this chemical soil characteristic and the processes of soil development.

Local Tests for Soil Acidity Often Required

It is impracticable to attempt to obtain an average quantitative measure of the calcium-carbonate content or of the acidity of a given soil type because, while some samples will contain large amounts of calcium carbonate, others may contain none, but on the other hand may actually have a lime requirement due to the soil acidity. We thus have what may be considered positive and negative values ranging, perhaps widely, on the opposite sides of the zero or neutral point, the numerical average of which could have no significance whatever, since such an average would not necessarily even approach the condition actually existing in a given farm or field. It is for this reason that the tables contain no figures purporting to represent either the lime requirement or the limestone present in the different soil types.

The qualitative field tests made in the process of the soil survey are much more numerous than the chemical analyses made in the laboratory, and do give a general idea of the predominating condition in the various types as to acidity or alkalinity. These tests, therefore, furnish the basis for some general recommendations which are given in the descriptions of individual types on pages 14 to 19. To have a sound basis for the application of limestone the owner or operator of a farm must often determine individually the lime requirements of his different fields. The section in the Appendix dealing with the application of limestone (page 28) is pertinent and should be read in this connection.

Supplies of Different Elements Not Proportional to Crop Removal

In the foregoing discussion we have considered mainly the amounts of the plant-food elements in the surface 6⅔ inches of soil, and rather briefly the relative amounts in the two lower strata. We have noted that some of the elements of plant food exhibit no consistent change in amount with increasing depth. Other elements show more or less marked variation at the different levels, the trend of these variations serving in some cases as clues to the relative maturity of different soil types and the processes involved in their development.

By adding together the corresponding figures for all three strata, we have an approximate invoice of the total plant-food elements within the feeding range of most of our field crops, since the major portion of their feeding range is included in the upper 40 inches of the soil. One of the most striking facts brought out by this consideration of the data is the great variation within a given soil type in the relative abundance of the various elements present as compared with the amounts removed by crops. For example, in one of the important types in Douglas county, Brown Silt Loam, Upland, we find that the total quantity of nitrogen in all three strata is 14,820 pounds. This is about the amount of nitrogen contained in the same number of bushels of corn. The amount of phosphorus is approximately one-third as much, or 4,910 pounds, but this amount is equivalent to the phosphorus in about twice as much corn, namely, 28,800 bushels. In the surface stratum, however, which is the zone of most intensive crop feeding, we find the relative amounts of nitrogen and phosphorus more nearly in accord with the rate of removal of these elements by crops. Here the nitrogen is equivalent to 4,650 bushels of corn, and the phosphorus to 6,000 bushels, or only one-third more than the nitrogen equivalent.

Other types show marked contrast to Brown Silt Loam, just discussed, with respect to total soil content in relation to rate of removal by crops. However, in most soils, except those which are peaty, phosphorus is more abundant than nitrogen when considered in terms of crop equivalents rather than in actual pounds per acre of the respective elements.

Service and Limitations of Chemical Investigations in Soil Improvement

The foregoing discussion should not be taken to mean that it is possible to predict how long any certain soil could be cropped under a given system before it would become exhausted. Nor do the figures alone indicate the immediate procedure to be followed in the improvement of a soil. It must be kept in mind that the *amount* of plant food shown to be present is not the sole measure of the ability of a soil to produce crops. The *rate* at which these elements are liberated from insoluble forms and converted to forms that can be used by growing plants is a matter of at least equal importance, as explained on page 26, and is not necessarily proportional to the total stocks present. One must know, therefore, how to cope with the peculiarities of a given soil type, if he is to secure the full benefit from its stores of the plant-food elements. In addition, there are always economic factors that must be taken into consideration, since it is necessary for one to decide at how high a level of productive capacity he can best afford to maintain his soil.

The chemical investigations carried out in connection with the soil survey, of which the analyses here reported are a part, are of value chiefly in two ways. In the first place, they reveal at once outstanding deficiencies or other chemical characteristics which alone would affect soil productivity to a marked extent, or point the way to corrective measures. It should be borne in mind, however, that fairly wide departures from the usual are necessary before the chemical analysis alone can be followed as a guide in practice without supplementary information from other sources. It is probable that the results of chemical soil analyses are frequently misused by attempting to interpret small differences in the amount of a certain plant-food element as indicative of corresponding differences in the fertilizer need. For example, differences of only 100 or 200 pounds of phosphorus per acre in soils containing 1,000 pounds or thereabout in the surface soil should not be considered as of any agricultural significance. Again, 100 pounds to the acre of active nitrogen added by plowing down a clover crop may be of more importance to the succeeding crop than a difference in soil composition of 1,000 pounds an acre of nitrogen as shown by the analysis. An example of the direct use of the results of chemical investigations is the marked shortage of potassium in peat soils associated with the need for potassium fertilizers; another case is the determination of the lime need of soils by chemical tests.

The second use of chemical methods is in the more detailed study of soils. The processes of soil development leave their imprint upon the soil both in its physical conformation and also in its chemical characteristics. Likewise every operation in the handling of the soil and every application of fertilizer or liming material disturbs its equilibrium, setting up new reactions, which are in turn reflected in crop adaptability, producing capacity, and agricultural usefulness. Chemistry is a most important tool in tracing and characterizing such changes, and chemical investigations are undertaken with the aim of aiding in the classification of soils and making possible more accurate prediction of their agricultural value and fertility needs, as well as response to different methods of management.

DESCRIPTION OF SOIL TYPES

The soil survey of Douglas county, upon which this report is based, was made in 1914. In the meantime there has been a gradual accumulation of new soil facts. As knowledge regarding soils accumulated, additional soil types were recognized. At the present time several types shown on the soil map of Douglas county are each considered to include two or more types. For the purposes of this Report, these types, which are now differentiated but not shown on the map, will be described so that they may, to some extent at least, be recognized in the field.

UPLAND PRAIRIE SOILS

The upland prairie soils of Douglas county occupy 361.54 square miles, or 87.24 percent of the area of the county. The dark color of the prairie soils is due to an accumulation of organic matter from the fibrous roots of the prairie grasses that grew on this land for centuries. A covering of fine soil and a mat of vegetative material by partially excluding the oxygen protected these roots from rapid and complete decay. From time to time the mat of old grass stems and leaves was partially destroyed by prairie fires and decay, but it was constantly being renewed, and while it added but little organic matter to the soil directly, it served to retard the decay. From a sample of virgin bluestem sod, one of the most common prairie grasses, it has been determined that an acre of this soil to a depth of 7 inches may contain as high as 13½ tons of roots.

Brown Silt Loam (926, 1126)

Brown Silt Loam, as mapped in this county, is now recognized to include at least four, and probably five soil types. Four of these will be described. The fifth occurs in portions of Piatt, Macon, Moultrie, and Coles counties, but has not as yet been studied sufficiently to justify considering it an established type. The four types now recognized are Brown Silt Loam On Clay, Brown Silt Loam, Brown Silt Loam On Drift, and Light Brown Silt Loam On Drift. These types all occur on the areas shown on the map as Brown Silt Loam. Their occurrence bears a rather definite relation to topography, as will appear from the descriptions which follow.

Brown Silt Loam On Clay. This type occurs on nearly level areas. It was formed under conditions of intermittently poor drainage which resulted in an accumulation of considerable fine-textured material in the subsoil. Associated with this fine texture and plasticity of the subsoil, or B horizon, is a gray color showing a lack of free air movement. The surface soil, or A_1 horizon, is dark brown in color and is in some cases rather heavy for a silt loam. The subsurface, or A_2 horizon, is heavier than the A_1 and lighter in color.

Management. This type, even tho it has a heavy subsoil, will underdrain satisfactorily. In draining, the strings of tile should be placed closer together than for any of the other types mapped as Brown Silt Loam. After good drainage is secured, regular additions of fresh organic matter should be provided, for otherwise this soil will gradually become more difficult to work. Limestone is needed for sweet clover or alfalfa, tho in light applications. The lowest portions of the type may need no limestone and occasionally small alkali spots occur. The harmful effects of the alkali may be corrected by applying 75 to 100 pounds of potash for corn. This type is similar to the soil on the Hartsburg and Aledo experiment fields. The results from these two fields are in agreement in indicating the value of manure on all the crops of the rotation; the value of residues, particularly for corn; the relatively small returns from limestone used in addition to manure and residues; and the failure of rock phosphate as used on these fields, particularly in the manure system, to cause sufficient increase in yields to justify advising its indiscriminate use on this soil type. If alfalfa is to be seeded, the application of 1,000 pounds of rock phosphate, or 500 pounds of superphosphate an acre would be advisable; or, if sweet clover is to be seeded in wheat, it would be advisable to make a trial application of either of these materials after plowing but before working down the wheat seed bed. The reader is referred to page 31 for a further discussion of the phosphate problem.

Brown Silt Loam. This type occurs on undulating topography. It has good surface drainage and underdrainage and the profile is friable and easily permeable to roots as well as to water. A heavier application of limestone is needed than on the preceding type and it is more uniformly acid, tho it is not strongly acid. The surface soil, or A_1 horizon, is brown in color and unlike the preceding type, does not tend to be too heavy to classify as a true silt loam. The subsurface, or A_2 horizon, is distinctly yellowish and is not much heavier than the A_1. The subsoil, or B horizon, is brownish yellow with some gray mottling present; it is a clay loam but is friable and only medium plastic.

Management.—This type is similar to the soil on the Kewanee experiment field. The results from this field (page 46) show a good response to manure alone and to residues and lime in combination. Where lime was used in addition to manure, an additional increase in yield was secured, but the increase was not so large as where lime was used in addition to residues. This behavior indicates that manure satisfies in part the same deficiency that lime satisfies on this medium-acid soil. The same is true in regard to the use of rock phosphate. In combination with stable manure and limestone the increases in crop yields have been too small to pay the cost of the phosphate. Where green manures and residues were the source of nitrogen and organic matter, however, rock phosphate has been used with increasing benefit which in later years has been sufficient to yield a good profit. The Bloomington experiment field is located in part on this same type of soil. The results from this field (page 48), on which various phosphate carriers have been used, show excellent returns for phosphorus and lead to the recommendation that some form of phosphate be given a trial. The reader is referred to the discussion of phosphatic materials on page 31.

Brown Silt Loam On Drift. This type occurs on rolling topography and is found in the southeastern and northeastern portions of the county. In color the entire profile of Brown Silt Loam On Drift is similar to Brown Silt Loam described above, but it differs from the latter in character of the soil material in the lower horizons, particularly in having much more sand and gravel and in being more compact. The surface soil, or A_1 horizon, to a depth of about 8 inches is brown in color and a silt loam in texture. It frequently contains a limited number of chert and other rock fragments. The A_2 horizon is a yellowish brown silt loam containing some rock fragments and extends to a depth of about 18 or 20 inches. The B horizon is a medium-mottled, dark yellow, sandy and gravelly clay, medium compact and slightly plastic. The C horizon is a yellow, sandy, gravelly clay loam, fairly friable, and not much compacted.

Management.—Brown Silt Loam On Drift is thought to be very similar in management requirements to Brown Silt Loam, the last type described. It differs in being slightly more acid, somewhat lower in organic matter, and more subject to erosion.

Light Brown Silt Loam On Drift. This type differs from Brown Silt Loam On Drift in being much lower in organic matter, more acid, and more subject to serious erosion. It is all tillable, but is spoken of by farmers as being a "thin" soil. This type occurs only on the more pronounced slopes of the two morainal ridges shown on the soil map. The surface, or A_1 horizon, is light brown or reddish brown in color and in places contains considerable glacial gravel. The subsurface, or A_2 horizon, is yellowish brown in color and contains more gravel than the surface. The subsoil, or *B* horizon, is gravelly glacial drift, somewhat compact but not plastic. The thickness of the various horizons varies because of differences in the rate of erosion on different areas. Carbonates commonly occur at a depth of 40 to 50 inches.

Management.—This type is less productive than any of those previously described. It needs frequent additions of fresh leguminous organic matter. It is more acid than less rolling land. It must be handled carefully if erosion is to be reduced below the point where it is very harmful. The trial of either rock phosphate or superphosphate for wheat which is to be seeded to clover is advised on this soil.

Black Clay Loam (920, 1120)

Black Clay Loam, as mapped in Douglas county, is now recognized to include four types. These four types will not be described as they do not differ in topography so strikingly as do the separations noted for Brown Silt Loam and are therefore less easily recognized. Therefore instead of attempting to describe each type as now differentiated, the following generalized description is given.

The A_1 horizon is 10 to 12 inches deep, and is a dark brown to black clay loam. The A_2 horizon usually extends to a depth of about 20 inches, is drabbish black in color, and is somewhat heavier than the A_1 horizon. It usually contains small yellow spots and in the lighter portions of the type is distinctly yellow instead of drabbish black. The *B* horizon in the heavier portions of the type is a gray or heavily mottled, compact, plastic clay; in the lighter portions it is a strongly mottled yellow, compact, medium-plastic clay or clay loam.

Management.—It should be noted that alkali spots occur in Black Clay Loam and that potash treatment is needed on some of them because of the high concentration of soluble salts. Lime is generally not needed on this soil but regular additions of fresh organic matter should be provided as an aid in maintaining a good physical condition. According to the results from the Minonk and Hartsburg experiment fields, the use of phosphate is not likely to prove profitable on this soil. However, if no manure is available it might be well to try rock phosphate at the rate of about 1,000 pounds an acre or superphosphate at the rate of about 250 pounds an acre for wheat. The summarized results from the Minonk and Hartsburg fields are given on pages 52 and 53.

Drab Clay Loam (1121)

Drab Clay Loam is clearly a soil formed under conditions of poor drainage. The reason for its drab color instead of black is not apparent, tho it seems to be associated with a set of conditions which limited the growth of the native grasses.

The surface, or A_1 horizon, is about 7 inches thick and is usually a drabbish black clay loam or silty clay loam. The subsurface, or A_2 horizon, is somewhat lighter in color than the surface, usually being drabbish brown. The subsoil, or *B* horizon, is drab or yellowish drab containing reddish brown spots. It is heavy but will underdrain.

Management.—Drab Clay Loam is usually not acid and in places is alkaline. It is relatively low in organic matter. It requires thoro underdrainage. Much has been done by the construction of dredge ditches and laying of tile to take care of the excess water on this soil. Alkali spots are common and lime concretions and marly material are often found within forty inches of the surface.

Brown-Gray Silt Loam On Tight Clay (928, 1128)

Brown-Gray Silt Loam On Tight Clay is of little importance in Douglas county because of its small extent, occupying a total of less than half a square mile. The areas southeast of Hindsboro are typical of this kind of soil, having a grayish brown surface, gray subsurface, and mottled gray, impervious subsoil. Further information regarding this soil type may be had by correspondence with the Experiment Station.

UPLAND TIMBER SOILS

The upland timber soils are not extensively developed in Douglas county. They cover altogether only about 40 square miles, or a little more than 9 percent of the area of the county. They occur adjacent to the streams.

These soils are usually characterized by a yellow or yellowish gray color which indicates a low organic-matter content, resulting from the long-continued growth of forest trees. As the forests invaded the prairies, the following effects were produced: the shading by the trees prevented the growth of grasses, the roots of which are mainly responsible for the large amount of organic matter in the prairie soils; and the trees themselves added little organic matter to the soil, for the leaves and branches either decayed or were destroyed by forest fires.

The timbered soils are of two kinds, the undulating and the eroded.

Yellow-Gray Silt Loam (934, 1134)

Yellow-Gray Silt Loam as mapped in Douglas county, includes several light-colored soil types. The flat, nearly level areas have a relatively impervious, gray subsoil, while the better drained areas show little accumulation in the subsoil and the color is reddish or yellowish. On the rolling area in the southeastern part of the county, the gravelly drift is near the surface. No attempt will be made here to describe this type in further detail since the variations are so great that a sufficiently broad description would have no meaning.

Management.—The nearly level portions of this type are more acid than the undulating and rolling portions and are naturally poorly drained. Lime is a general requirement, tho the amount needed varies as above indicated and also with other factors, as for example, with the length of time and the intensity with which a field has been farmed. Leguminous organic matter is also a general requirement and everywhere on this type where the land is farmed provision should be made for the regular growth of clover, preferably sweet clover. Phosphate should give profitable returns on the undulating portions of this type, particularly if used for wheat. Either rock phosphate or superphosphate may be tried, the former at the rate of about 1,000 pounds an acre and the latter at the rate of about 250 pounds.

Yellow Silt Loam (935, 1135)

The occurrence of Yellow Silt Loam in Douglas county is limited almost entirely to the southeastern part of the county. It is of little importance because of its limited extent. The slopes are, for the most part, short and steep and suited only to timber or pasture. The character of this soil depends on the nature of its parent material and the amount of erosion which has taken place. Practically no profile development has taken place.

TERRACE SOILS

Relatively small areas of terrace soil occur in Douglas county. The terraces were built up, for the most part, during and immediately following the Glacial period when overloaded and flooded streams deposited an immense amount of material in their channels. Later, as the streams diminished in size or cut their channels deeper, new bottoms were formed leaving the old flood plains above overflow. It was upon these plains that the terrace soils developed.

Yellow-Gray Silt Loam Over Sand or Gravel (1536)

Yellow-Gray Silt Loam Over Sand or Gravel is of little importance in Douglas county because of its limited extent. It is similar to the flat Yellow-Gray Silt Loam, Upland. The underlying sand or gravel is sufficiently deep that it does not cause a drouthy condition, and yet its presence improves the underdrainage. Limestone should be supplied and clover grown as is suggested for Yellow-Gray Silt Loam, Upland, described on the preceding page.

SWAMP AND BOTTOM-LAND SOILS

Swamp and bottom-land soils include the flood plains along the rivers and creeks and the small areas of Peat south and east of Hindsboro.

Mixed Loam (1454)

The name Mixed Loam is given to those narrow tracts of land found in the stream valleys and made up of such a mixture of different kinds of soil as to render impossible any definite type description.

Management.—The diversity of Mixed Loam calls for different tillage methods where the extremes in the type occur. Some areas are so heavy as to require care in working them at the right moisture content, while others are very sandy. The type in general is not acid and needs only fresh organic matter and intelligent tillage. It is a productive soil but is so generally subject to overflow that much of it is used for timber or pasture. It is excellent corn land except where overflow is too frequent.

Deep Peat (1401)

Deep Peat occurs only in three small areas south and east of Hindsboro. Information will be furnished by correspondence regarding these areas.

APPENDIX

EXPLANATIONS FOR INTERPRETING THE SOIL SURVEY

CLASSIFICATION OF SOILS

In order to interpret the soil map intelligently, the reader must understand something of the method of soil classification upon which the survey is based. Without going far into details the following paragraphs are intended to furnish a brief explanation of the general plan of classification used.

The soil type is the unit of classification. Each type has definite characteristics upon which its separation from other types is based. These characteristics are inherent in the strata, or "horizons," which constitute the soil profile in all mature soils. Among them may be mentioned color, structure, texture, and chemical composition. Other items, such as native vegetation (whether timber or prairie), topography, and geological origin and formation, may assist in the differentiation of types, altho they are not fundamental to it.

Since some of the terms used in designating the factors which are taken into account in establishing soil types are technical in nature, the following definitions are introduced:

Horizon. A layer or stratum of soil which differs discernibly from those adjacent in color, texture, structure, chemical composition, or a combination of these characteristics, is called an horizon. In describing a matured soil, three horizons designated as *A*, *B*, and *C* are usually considered.

A designates the upper horizon and, as developed under the conditions of a humid, temperate climate, represents the layer of extraction or eluviation; that is to say, material in solution or in suspension has passed out of this zone thru the processes of weathering.

B represents the layer of concentration or illuviation; that is, the layer developed as a result of the accumulation of material thru the downward movement of water from the *A* horizon.

C designates the layer lying below the *B* horizon and in which the material has been less affected by the weathering processes.

Frequently differences within a stratum or zone are discernible, in which case it is subdivided and described under such designations as A_1 and A_2, B_1 and B_2, etc.

Soil Profile. The soil section as a whole is spoken of as the soil profile.

Depth and Thickness. The horizons or layers which make up the soil profile vary in depth and thickness. These variations are distinguishing features in the separation of soils into types.

Physical Composition. The physical composition, sometimes referred to as "texture," is a most important feature in characterizing a soil. The texture depends upon the relative proportions of the following physical constituents: clay, silt, fine sand, sand, gravel, stones, and organic material.

Structure. The term "structure" has reference to the aggregation of particles within the soil mass and carries such qualifying terms as open, granular, compact, columnar, laminated.

Organic-Matter Content. The organic matter of soil is derived largely from plant tissue and it exists in a more or less advanced stage of decomposition. Organic matter forms the predominating constituent in certain soils of swampy formation.

Color. Color is determined to a large extent by the proportion of organic matter, but at the same time it is modified by the mineral constituents, especially by iron compounds.

Reaction. The term "reaction" refers to the chemical state of the soil with respect to acid or alkaline condition. It also involves the idea of degree, as strongly acid or strongly alkaline.

Carbonate Content. The carbonate content has reference to the calcium carbonate (limestone) present, which in some cases may be associated with magnesium or other carbonates. The depth at which carbonates are found may become a very important factor in determining the soil type.

Topography. Topography has reference to the lay of the land, as level, rolling, hilly, etc.

Native Vegetation. The vegetation or plant growth before being disturbed by man, as prairie grasses and forest trees, is a feature frequently recognized in differentiating soil types.

Geological Origin. Geological origin involves the idea of character of rock materials composing the soil as well as the method of formation of the soil material.

Not infrequently areas are encountered in which type characters are not distinctly developed or in which they show considerable variation. When these variations are considered to have sufficient significance, type separations are made wherever the areas involved are sufficiently large. Because of the almost infinite variability occurring in soils, one of the exacting tasks of the soil surveyor is to determine the degree of variation which is allowable for any given type.

Classifying Soil Types.—In the system of classification used, the types fall first into four general groups based upon their geological relationships; namely, upland, terrace, swamp and bottom land, and residual. These groups may be subdivided into prairie soils and timber soils, altho as a matter of fact this subdivision is applied in the main only to the upland group. These terms are all explained in the foregoing part of this report in connection with the description of the particular soil types.

Naming and Numbering Soil Types.—In the Illinois soil survey a system of nomenclature is used which is intended to make the type name convey some idea of the nature of the soil. Thus the name "Yellow-Gray Silt Loam" carries in itself a more or less definite description of the type. It should not be assumed, however, that this system of nomenclature makes it possible to devise type names which are adequately descriptive, because the profile of mature soils is usually made up of three or more horizons and it is impossible to describe each horizon in the type name. The color and texture of the surface soil are usually included in the type name and when material such as sand, gravel, or rock lies at a depth of less than 30 inches, the fact is indicated by the word "On," and when its depth exceeds 30 inches, by the word "Over"; for example, Brown Silt Loam On Gravel and Brown Silt Loam Over Gravel.

As a further step in systematizing the listing of the soils of Illinois, recognition is given to the location of the types with respect to the geological areas in which they occur. According to a geological survey made many years ago, the state has been divided into seventeen areas with respect to geological formation and, for the purposes of the soil survey, each of these areas has been assigned an index number. The names of the areas together with their general location and their respective index numbers are given in the following list.

000 *Residual,* soils formed in place thru disintegration of rocks, and also rock outcrop
100 *Unglaciated,* including three areas, the largest being in the south end of the state
200 *Illinoian moraines,* including the moraines of the Illinoian glaciations
300 *Lower Illinoian glaciation,* formerly considered as covering nearly the south third of the state
400 *Middle Illinoian glaciation,* covering about a dozen counties in the west-central part of the state
500 *Upper Illinoian glaciation,* covering about fourteen counties northwest of the middle Illinoian glaciation
600 *Pre-Iowan glaciation,* but now believed to be part of the upper Illinoian
700 *Iowan glaciation,* lying in the central northern end of the state
800 *Deep loess areas,* including a zone a few miles wide along the Wabash, Illinois, and Mississippi rivers
900 *Early Wisconsin moraines,* including the moraines of the early Wisconsin glaciation

1000 *Late Wisconsin moraines,* including the moraines of the late Wisconsin glaciation
1100 *Early Wisconsin glaciation,* covering the greater part of the northeast quarter of the state
1200 *Late Wisconsin glaciation,* lying in the northeast corner of the state
1300 *Old river-bottom and swamp lands,* formed by material derived from the Illinoian or older glaciations
1400 *Late river-bottom and swamp lands,* formed by material derived from the Wisconsin and Iowan glaciations
1500 *Terraces,* bench or second bottom lands, and gravel outwash plains
1600 *Lacustrine deposits,* formed by Lake Chicago, the enlarged glacial Lake Michigan

Further information regarding these geological areas is given in connection with the general map mentioned above and published in Bulletin 123 (1908).

Another set of index numbers is assigned to the classes of soils as based upon physical composition. The following list contains the names of these classes with their corresponding index numbers.

Index Number Limits	Class Names
0 to 9	Peats
10 to 12	Peaty loams
13 to 14	Mucks
15 to 19	Clays
20 to 24	Clay loams
25 to 49	Silt loams
50 to 59	Loams
60 to 79	Sandy loams
80 to 89	Sands
90 to 94	Gravelly loams
95 to 97	Gravels
98	Stony loams
99	Rock outcrop

As a convenient means of designating types and their location with respect to the geological areas of the state, each type is given a number made up of a combination of the index numbers explained above. This number indicates the type and the geological area in which it occurs. The geological area is always indicated by the digits of the order of hundreds while the remainder of the number designates the type. To illustrate: the number 1126 means Brown Silt Loam in the early Wisconsin glaciation, 434 means Yellow-Gray Silt Loam of the middle Illinoian glaciation. These numbers are especially useful in designating very small areas on the map and as a check in reading the colors.

A complete list of the soil types occurring in each county, along with their corresponding type numbers and the area covered by each type, will be found in the respective county soil reports in connection with the maps.

SOIL SURVEY METHODS

Mapping of Soil Types.—In conducting the soil survey, the county constitutes the unit of working area. The field work is done by parties of two to four men each. The field season extends from early in April to the last of November. During the winter months the men are engaged in preparing a copy of the soil map to be sent to the lithographer, a copy for the use of the county farm adviser until the printed map is available, and a third copy for use in the office in order to preserve the original official map in good condition.

An accurate base map for field use is necessary for soil mapping. These maps are prepared on a scale of one inch to the mile, the official data of the original or subsequent land survey being used as the basis in their construction.

FIG. 5.—EXAMINING THE SOIL PROFILE

Each surveyor is provided with one of these base maps, which he carries with him in the field; and the soil type boundaries, together with the streams, roads, railroads, canals, town sites, and rock and gravel quarries are placed in their proper location upon the map while the mapper is on the area. With the rapid development in road improvement during the past few years, it is almost inevitable that some recently established roads will not appear on the published soil map. Similarly, changes in other artificial features will occasionally occur in the interim between the preparation of the map and its publication. The detail or minimum size of areas which are shown on the map varies somewhat, but in general a soil type if less than five acres in extent is not shown.

Sampling for Analysis.—After all the soil types of a county have been located and mapped, samples representative of the different types are collected for chemical analysis. The samples for this purpose are usually taken in three depths; namely, 0 to 6⅔ inches, 6⅔ to 20 inches, and 20 to 40 inches, as explained in connection with the discussion of the analytical data on page 6.

PRINCIPLES OF SOIL FERTILITY

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. A fact of equal importance, not so generally recognized, is that they also differ in other characteristics such as response to fertilizer treatment and to management.

The soil is a dynamic, ever-changing, exceedingly complex substance made up of organic and inorganic materials and teeming with life in the form of microorganisms. Because of these characteristics, the soil cannot be considered as a reservoir into which a given quantity of an element or elements of plant food can be poured with the assurance that it will respond with a given increase in crop yield. In a similar manner it cannot be expected to respond with perfect uniformity to a given set of management standards. To be productive a soil must be in such condition physically with respect to structure and moisture as to encourage root development; and in such condition chemically that injurious substances are not present in harmful amounts, that a sufficient supply of the elements of plant food become available or usable during the growing season, and that lime materials are present in sufficient abundance favorable for the growth of the higher plants and of the beneficial microorganisms. Good soil management under humid conditions involves the adoption of those tillage, cropping, and fertilizer treatment methods which will result in profitable and permanent crop production on the soil type concerned.

The following paragraphs are intended to state in a brief way some of the principles of soil management and treatment which are fundamental to profitable and continued productivity.

CROP REQUIREMENTS WITH RESPECT TO PLANT-FOOD MATERIALS

At least ten of the chemical elements are known to be essential for the growth of the higher plants. These are *carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, potassium, calcium, magnesium,* and *iron.* Other elements are absorbed

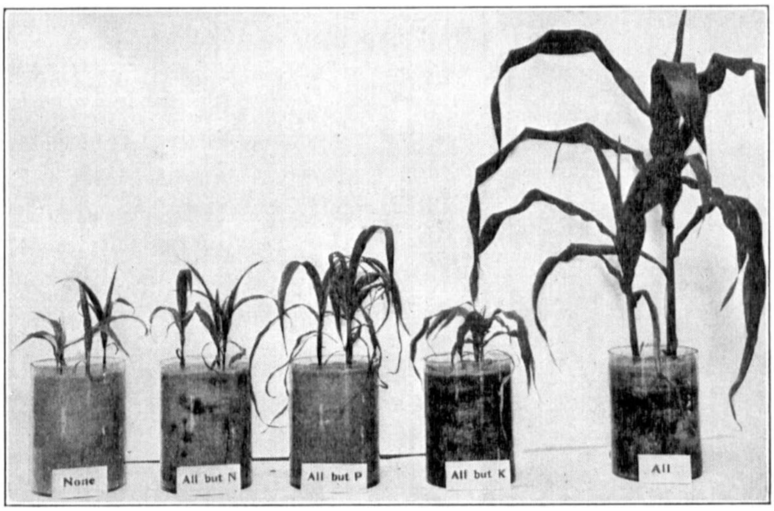

FIG. 6.—ALL ESSENTIAL PLANT-FOOD ELEMENTS MUST BE PRESENT

The jars in which these corn plants are growing contain pure sand to which have been added various combinations of the essential plant-food elements. If a single one of these elements is omitted, the plants cannot develop; they die after the small supply stored in the seed becomes exhausted.

from the soil by growing plants, including manganese, silicon, sodium, aluminum, chlorin, and boron. It is probable that these latter elements are present in plants for the most part, not because they are required, but because they are dissolved in the soil water and the plant has no means of preventing their entrance. There is some evidence, however, which indicates that certain of these elements, notably manganese, silicon, and boron, may be either essential but required in only minute quantities, or very beneficial to plant growth under certain conditions, even tho not essential. Thus, for example, manganese has produced marked increases in crop yields on heavily limed soils. Sodium also has been found capable of partially replacing potassium in case of a shortage of the latter element.

Table 5 shows the requirements of some of our most common field crops with respect to seven important plant-food elements furnished by the soil. The figures show the weight in pounds of the various elements contained in a bushel

TABLE 5.—PLANT-FOOD ELEMENTS IN COMMON FARM CROPS[1]

Produce		Nitrogen	Phosphorus	Sulfur	Potassium	Magnesium	Calcium	Iron
Kind	Amount							
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain......	1 bu.	1.42	.24	.10	.26	.08	.02	.01
Wheat straw......	1 ton	10.00	1.60	2.80	18.00	1.60	3.80	.60
Corn, grain.......	1 bu.	1.00	.17	.08	.19	.07	.01	.01
Corn stover.......	1 ton	16.00	2.00	2.42	17.33	3.33	7.00	1.60
Corn cobs........	1 ton	4.00	.....	.....	4.00	.....	.....	.....
Oats, grain.......	1 bu.	.66	.11	.06	.16	.04	.02	.01
Oat straw........	1 ton	12.40	2.00	4.14	20.80	2.80	6.00	1.12
Clover seed.......	1 bu.	1.75	.50	.....	.75	.25	.13	.....
Clover hay.......	1 ton	40.00	5.00	3.28	30.00	7.75	29.25	1.00
Soybean seed.....	1 bu.	3.22	.39	.27	1.26	.15	.14	.....
Soybean hay......	1 ton	43.40	4.74	5.18	35.48	13.84	27.56	.....
Alfalfa hay.......	1 ton	52.08	4.76	5.96	16.64	8.00	22.26	.....

[1]These data are brought together from various sources. Some allowance must be made for the exactness of the figures because samples representing the same kind of crop or the same kind of material frequently exhibit considerable variation.

or in a ton, as the case may be. From these data the amount of an element removed from an acre of land by a crop of a given yield can easily be computed.

PLANT-FOOD SUPPLY

Of the elements of plant food, three (carbon, oxygen, and hydrogen) are secured from air and water, and the others from the soil. Nitrogen, one of the elements obtained from the soil by all plants, may also be secured from the air by the class of plants known as legumes, in case the amount liberated from the soil is insufficient; but even these plants are dependent upon the soil for the other elements, and they also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

The vast difference with respect to the supply of these essential plant-food elements in different soils is well brought out in the data of the Illinois soil survey. For example, it has been found that the nitrogen in the surface 6⅔ inches, which represents the plowed stratum, varies in amount from 180 pounds per acre to more than 35,000 pounds. In like manner the phosphorus content varies from about 320 to 4,900 pounds, and the potassium ranges from 1,530 to about 58,000 pounds. Similar variations are found in all of the other essential plant-food elements of the soil.

With these facts in mind it is easy to understand how a deficiency of one of these elements of plant food may become a limiting factor of crop production. When an element becomes so reduced in quantity as to become a limiting factor of production, then we must look for some outside source of supply. Table 6 is presented for the purpose of furnishing information regarding the quantity of some of the more important plant-food elements contained in materials most commonly used as sources of supply.

TABLE 6.—PLANT-FOOD ELEMENTS IN MANURE, ROUGH FEEDS, AND FERTILIZERS[1]

Material	Pounds of plant food per ton of material		
	Nitrogen	Phosphorus	Potassium
Fresh farm manure	10	2	8
Corn stover	16	2	17
Oat straw	12	2	21
Wheat straw	10	2	18
Clover hay	40	5	30
Cowpea hay	43	5	33
Alfalfa hay	50	4	24
Sweet clover (water-free basis)[2]	80	8	28
Dried blood	280	.....	.....
Sodium nitrate	310	.....	.....
Ammonium sulfate	400	.....	.....
Raw bone meal	80	180	.....
Steamed bone meal	20	250	.....
Raw rock phosphate	.....	250	.....
Acid phosphate	.....	125	.....
Potassium chlorid	.....	.....	850
Potassium sulfate	.....	.....	850
Kainit	.....	.....	200
Wood ashes[3] (unleached)	.....	10	100

[1]See footnote to Table 5.
[2]Young second-year growth ready to plow under as green manure.
[3]Wood ashes also contain about 1,000 pounds of lime (calcium carbonate) per ton.

LIBERATION OF PLANT FOOD

The chemical analysis of the soil gives the invoice of plant-food elements 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 the choice of crops to be grown, the use of limestone, and the incorporation of organic matter. Tillage, especially plowing, also has a considerable effect in this connection.

Feeding Power of Plants.—Different species of plants exhibit a very great diversity in their ability to obtain plant food directly from the insoluble minerals of the soil. As a class, the legumes—especially such biennial and perennial legumes as red clover, sweet clover, and alfalfa—are endowed with unusual power to assimilate from mineral sources such elements as calcium and phosphorus, converting them into available forms for the crops that follow. For this reason it is especially advantageous to employ such legumes in connection with the application of limestone and rock phosphate. Thru their growth and subsequent decay large quantities of the mineral elements are liberated for the benefit of the cereal crops which follow in the rotation. Moreover, as an effect of the deep-rooting habit of these legumes, mineral plant-food elements are brought up and rendered available from the vast reservoirs of the lower subsoil.

Effect of Limestone.—Limestone corrects the acidity of the soil and supplies calcium, thus encouraging 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 unavailable organic nitrogen into available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve minerals contained in the soil, such as potassium and magnesium compounds.

Organic Matter and Biological Action.—Organic matter may be supplied thru animal manures, consisting of the excreta of animals and usually accompanied by more or less stable litter; and by plant manures, including green-manure crops and cover crops plowed under, and also crop residues such as stalks, straw, and chaff. The rate of decay of organic matter depends largely upon its age, condition, and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which constitutes, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre corresponds to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant-food materials than 20 tons of old, inactive organic matter. The 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 sods of old pastures.

The condition of the organic matter of the soil is indicated to some extent by the ratio of carbon to nitrogen. Fresh organic matter recently incorporated with the soil contains a very much higher proportion of carbon to nitrogen than do the old resistant organic residues of the soil. The proportion of carbon to nitrogen is higher in the surface soil than in the corresponding subsoil, and in general this ratio is wider in highly productive soils well charged with active organic matter than in very old, worn soils badly in need of active organic matter.

The organic matter furnishes food for bacteria, and as it decays certain decomposition products are formed, including much carbonic acid, some nitrous acid, and various organic acids, and these acting upon the soil have the power to dissolve the essential mineral plant foods, thus furnishing available phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

Effect of Tillage.—Tillage, or cultivation, also hastens the liberation of plant-food elements by permitting the air to enter the soil. It should be remembered, however, that tillage is wholly destructive, in that it adds nothing whatever to the soil, but always leaves it poorer, so far as plant-food materials are concerned. 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; and it is much better actually to enrich the soil by proper applications of limestone, organic matter, and other fertilizing materials, and thus promote soil conditions favorable for vigorous plant growth, than to depend upon excessive cultivation to accomplish the same object at the expense of the soil.

PERMANENT SOIL IMPROVEMENT

According to the kind of soil involved, any comprehensive plan contemplating a permanent system of agriculture will need to take into account some of the following considerations.

The Application of Limestone

The Function of Limestone.—In considering the application of limestone to land it should be understood that this material functions in several different ways, and that a beneficial result may therefore be attributable to quite diverse causes. Limestone provides calcium, of which certain crops are strong feeders. It corrects acidity of the soil, thus making for some crops a much more favorable environment as well as establishing conditions absolutely required for some of the beneficial legume bacteria. It accelerates nitrification and nitrogen fixation. It promotes sanitation of the soil by inhibiting the growth of certain fungous diseases, such as corn-root rot. Experience indicates that it modifies either directly or indirectly the physical structure of fine-textured soils, frequently to their great improvement. Thus, working in one or more of these different ways, limestone often becomes the key to the improvement of worn lands.

How to Ascertain the Need for Limestone.—One of the most reliable indications as to whether a soil needs limestone is the character of the growth of certain legumes, particularly sweet clover and alfalfa. These crops do not thrive in acid soils. Their successful growth, therefore, indicates the lack of sufficient acidity in the soil to be harmful. In case of their failure to grow the soil should be tested for acidity as described below. A very valuable test for ascertaining the need of a soil for limestone is found in the potassium thiocyanate test for soil acidity. It is desirable to make the test for carbonates along with the acidity test. Limestone is calcium carbonate, while dolomite is the combined carbonates of calcium and magnesium. The natural occurrence of these carbonates in the soil is sufficient assurance that no limestone is needed, and the acidity test will be negative. On lands which have been treated with limestone, however, the surface soil may give a positive test for carbonates, owing to the presence of undecomposed pieces of limestone, and at the same time a positive test for acidity may be secured. Such a result means either that insufficient limestone has been added to neutralize the acidity, or that it has not been in the soil long enough to entirely correct the acidity. In making these tests, it is desirable to examine samples of soil from different depths, since carbonates may be present, even in abundance, below a surface stratum that is acid. Following are the directions for making the tests:

The Potassium Thiocyanate Test for Acidity. This test is made with a 4-percent solution of potassium thiocyanate in alcohol—4 grams of potassium thiocyanate in 100 cubic centimeters of 95-percent alcohol.[1] When a small quantity of soil shaken up in a test tube with this solution gives a red color the soil is acid and limestone should be applied. If the solution remains colorless the soil is not acid. An excess of water interferes with the reaction. The sample when tested, therefore, should be at least as dry as when the soil is in

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[1] Since undenatured alcohol is difficult to obtain, some of the denatured alcohols have been tested for making this solution. Completely denatured alcohol made over U. S. Formulas No. 1 and No. 4_1 have been found satisfactory. Some commercial firms are also offering other preparations which are satisfactory.

good tillable condition. For a prompt reaction the temperature of the soil and solution should be not lower than that of comfortable working conditions (60° to 75° Fahrenheit).

The Hydrochloric Acid Test for Carbonates. Take a small representative sample of soil and pour upon it a few drops of hydrochloric (muriatic) acid, prepared by diluting the concentrated acid with an equal volume of water. The presence of limestone or some other carbonates will be shown by the appearance of gas bubbles within 2 or 3 minutes, producing foaming or effervescence. The absence of carbonates in a soil is not in itself evidence that the soil is acid or that limestone should be applied, but it indicates that the confirmatory potassium thiocyanate test should be carried out.

Amounts to Apply.—Acid soils should be treated with limestone whenever such application is at all practicable. The initial application varies with the degree of acidity and will usually range from 2 to 6 tons an acre. The larger amounts will be needed on strongly acid soils, particularly on land being prepared for alfalfa. When sufficient limestone has been used to establish conditions favorable to the growth of legumes, no further applications are necessary until the acidity again develops to such an extent as to interfere with the best growth of these crops. This will ordinarily be at intervals of several years. In the case of an inadequate supply of magnesium in the soil, the occasional use of magnesian (dolomitic) limestone would serve to correct this deficiency. Otherwise, so far as present knowledge indicates, either form of limestone—high-calcium or magnesian—will be equally effective, depending upon the purity and fineness of the respective stones.

Fineness of Material.—The fineness to which limestone is ground is an important consideration in its use for soil improvement. Experiments indicate that a considerable range in this regard is permissible. Very fine grinding insures ready solubility, and thus promptness in action; but the finer the grinding the greater is the expense involved. A grinding, therefore, that furnishes not too large a proportion of coarser particles along with the finer, similar to that of the by-product material on the market, is to be recommended. Altho the exact proportions of coarse and fine material cannot be prescribed, it may be said that a limestone crushed so that the coarsest fragments will pass thru a screen of 4 to 10 meshes to the inch is satisfactory if the total product is used.

The Nitrogen Problem

The nitrogen problem is one of foremost importance in American agriculture. There are four reasons for this: nitrogen is becoming increasingly deficient in most soils; its cost when purchased on the open market is often prohibitive; it is removed from the soil in large amounts by crops; and it is readily lost from soils by leaching. A 50-bushel crop of corn requires about 75 pounds of nitrogen for its growth; and the loss of nitrogen from soils by leaching may vary from a few pounds to over one hundred pounds an acre in a year, depending upon the treatment of the soil, the distribution of rainfall, and the protection afforded by growing crops.

An inexhaustible supply of nitrogen is present in the air. Above each acre of the earth's surface there are about 69 million pounds of atmospheric nitrogen. Leguminous plants such as clover are able, with the aid of certain bacteria, to draw upon the inexhaustible supply of air nitrogen, utilizing it in their food requirements. In so doing these leguminous plants, thru the decay of their own

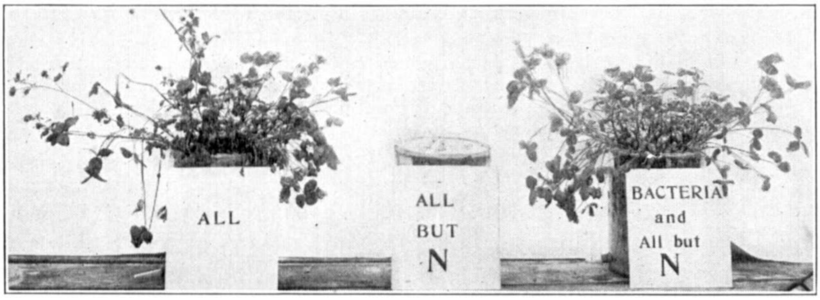

FIG. 7.—LEGUMES CAN OBTAIN THEIR NITROGEN FROM THE AIR

The photograph tells the story of how clover benefits the soil. In the pot at the left all the essential plant-food elements, including nitrogen, are supplied. In the middle jar all the elements, with the single exception of nitrogen, are present. At the right nitrogen is likewise withheld but the proper bacteria are supplied which enable the clover to secure nitrogen from the air.

tissues, add to the soil nitrogen that has been taken from the air and transformed into food material that can be assimilated by other kinds of crops that follow.

There are two methods of collecting the inert nitrogen gas of the air and combining it into compounds that will furnish products for plant growth. These are the chemical and the biological fixation of the atmospheric nitrogen. Farmers have at their command one of these methods. By growing inoculated legumes, nitrogen may be obtained from the air, and by plowing under more than the roots of these legumes, nitrogen may be added to the soil.

Inasmuch as legumes are worth growing for purposes other than the fixation of atmospheric nitrogen, a considerable portion of the nitrogen thus gained may be considered a by-product. Because of that fact, it is questionable whether the chemical fixation of nitrogen will ever be able to replace the simple method of obtaining atmospheric nitrogen by growing inoculated legumes in the production of our great grain and forage crops.

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 contains 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpea hay contains 43 pounds of nitrogen.
1 ton of alfalfa contains 50 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.
1 ton of young sweet clover, at about the stage of growth when it is plowed under as green manure, contains, on water-free basis, 80 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.

The Phosphorus Problem

The element phosphorus is an indispensable constituent of every living cell. It is intimately connected with the life processes of both plants and animals, the nuclear material of the cells being especially rich in this element.

Different soil types display great variation in phosphorus content. In Illinois soils a range from 320 to 4,900 pounds an acre has been found in the surface 6⅔ inches, depending mainly on the origin of the soil.

The removal of phosphorus by continuous cropping slowly reduces the amount of this element available for crop use unless its addition is provided for by natural means such as overflow, or by agricultural practices such as the addition of phosphatic fertilizers and the use of rotations in which deep-rooting leguminous crops are frequently grown.

It should be borne in mind in connection with the application of phosphate, or of any other fertilizing material, to the soil, that no benefit can result until the need for it has become a limiting factor in plant growth. For example, if there is already present in the soil sufficient available phosphorus to produce a forty-bushel crop, and the nitrogen supply or the moisture supply is sufficient for only forty bushels, or less, then extra phosphorus added to the soil cannot increase the yield beyond this forty-bushel limit.

There are several different phosphorus-containing materials that are used as fertilizers. The more important of these are rock phosphate, superphosphate, bone meal, and basic slag.

Rock Phosphate.—Rock phosphate is a mineral substance found in vast deposits in certain regions. A good grade of the rock should contain 12 to 15 percent of the phosphorus element. The rock should be ground to a powder fine enough to pass thru a 100-mesh sieve, or even finer.

Superphosphate.—Superphosphate is produced by treating rock phosphate with sulfuric acid. The two are mixed in about equal amounts; the product therefore contains about one-half as much phosphorus as the rock phosphate itself. By further processing, different concentrations are produced. The most common grades of superphosphate now on the market contain respectively 7, 8¾, and 10½ percent of the element phosphorus, and even more highly concentrated products containing as high as 21 percent are to be had. In fertilizer literature the term phosphorus is usually expressed as "phosphoric acid" (P_2O_5) rather than the element phosphorus (P), and the chemical relation between the two is such as to make the above figures correspond to 16, 20, 24, and 48 percent of phosphoric acid respectively. Besides phosphorus, superphosphate also contains sulfur, which is likewise an element of plant food. In general, phosphorus in superphosphate is considered to be more readily available for absorption by plants than that of raw rock phosphate.

Bone Meal.—Prepared from the bones of animals, bone meal appears on the market in two different forms, raw and steamed. Raw bone meal contains, besides the phosphorus, a considerable percentage of nitrogen. If the material is purchased only for the sake of the phosphorus, the cost of the nitrogen represents a useless expense. Steamed bone meal is prepared by extracting most of the nitrogenous and fatty matter from the bones, thus producing a more nearly pure form of calcium phosphate, containing about 10 to 12 percent of the element phosphorus and about 1 percent of the element nitrogen.

Basic Slag.—Basic slag, known also as Thomas phosphate, is another carrier of phosphorus that might be mentioned because of its considerable usage in Europe and eastern United States. Basic slag is a by-product in the manufacture of steel. It contains a considerable proportion of basic material and therefore tends to influence the soil reaction in the direction of reducing soil acidity.

Comparative Value of Different Forms of Phosphorus.—Obviously the carrier of phosphorus that gives the most economical returns, considered from all standpoints, is the best one to use. Altho this matter has been the subject of much discussion and investigation, the question remains unsettled. The fact probably is that there is no single carrier that will prove the most economical under all circumstances because so much depends upon soil conditions, crops grown, length of haul, and market conditions.

The relative cheapness of raw rock phosphate as compared with the treated material, superphosphate, makes it possible to apply for equal money expenditure considerably more phosphorus per acre in the form of rock than in the form of superphosphate, the ratio being, under present market conditions, roughly speaking 3½ to 1; that is to say, a dollar will purchase about three and a half times as much of the phosphorus element in the form of rock phosphate as in the form of superphosphate, and this is an important consideration if one is interested in building up a phosphorus reserve in the soil.

Rock phosphate may be applied at any time during a rotation, but it is applied to the best advantage either preceding a crop of clover, which plant seems to possess an unusual power for assimilating the phosphorus from raw phosphate, or else at a time when it can be plowed under with some form of organic matter such as animal manure or green manure, the decay of which serves to liberate the phosphorus from its insoluble condition in the rock. It is important that the finely ground rock phosphate be intimately mixed with the organic material as it is plowed under.

In using superphosphate or bone meal in a cropping system which includes wheat, it is a common practice to apply the material in the preparation of the wheat ground. It may be advantageous, however, to divide the total amount to be used and apply a portion to the other crops of the rotation, particularly to corn and to clover.

The Potassium Problem

Our most common soils, the silt loams and clay loams, are well stocked with potassium, altho it exists mainly in a very slowly soluble form. Many field experiments in various sections of Illinois during the past twenty-five years have shown little or no response to the application of potassium in the production of our common grain and hay crops. On the light-colored soils of southern Illinois, however, where stable manure has not been employed, potassium has been applied with profit, the benefit appearing mainly in the corn crop.

Peat soils are usually low in potassium content. It has frequently been demonstrated in field experiments located on peat land that the difference between success and failure in raising crops depends upon the application of a potash fertilizer.

Potassium has proved beneficial also on the so-called "alkali" spots occurring on certain soil types that are rather high in organic matter, including peat and very dark-colored sandy, silt, and clay loams. The potassium salts in this case appear to exert a corrective influence over what seems to be an unbalanced plant-food condition caused by an excess of nitrate in the soil.

Potassium fertilizer may be procured in the form of one of its salts, such as chlorid, sulfate, or carbonate of potassium, and any of these materials may be applied, where needed, at the rate of 50 to 150 pounds an acre, according to the method of distribution. For our most common crops about the only basis for choosing among these forms is the matter of price, taking into consideration the potassium content. Kainit is another substance containing potassium, but it is combined with magnesium in the form of a double salt. It is therefore less concentrated than the salts mentioned, and so should be applied in larger quantities. An application of about 200 pounds or more of kainit to the acre is suggested.

The Calcium and Magnesium Problem

When measured by crop removals of the plant-food elements, calcium is often more limited in Illinois soils than is potassium, while magnesium may be occasionally. In the case of calcium, however, the deficiency is likely to develop more rapidly and become much more marked because this element is leached out of the soil in drainage water to a far greater extent than is either magnesium or potassium.

The annual loss of limestone from the soil depends upon a number of factors aside from those which have to do with climatic conditions. Among these factors may be mentioned the character of the soil, the kind of limestone, its condition of fineness, the amount present, and the sort of farming practiced. Because of this variation in the loss of lime materials from the soil, it is impossible to prescribe a fixed practice in their renewal that will apply universally. The tests for acidity and carbonates described above, together with the behavior of such lime-loving legumes as alfalfa and sweet clover, will serve as general indicators for the frequency of applying limestone and the amount to use on a given field.

Limestone has a direct 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 Illinois) 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.

The Sulfur Question

In considering the relation of sulfur in a permanent system of soil fertility it is important to understand something of the cycle of transformations that this element undergoes in nature. Briefly stated this is as follows:

Sulfur exists in the soil in both organic and inorganic forms, the former being gradually converted to the latter form thru bacterial action. In this inorganic form sulfur is taken up by plants which in their physiological processes change it once more into an organic form as a constituent of protein. When these plant proteins are consumed by animals, the sulfur becomes a part of the animal protein. When these plant and animal proteins are decomposed, either thru bacterial action, or thru combustion, as in the burning of coal, the sulfur passes into the atmosphere or into the soil solution in the form of sulfur dioxid gas. This gas unites with oxygen and water to form sulfuric acid, which is readily washed back into the soil by the rain, thus completing the cycle, from soil—to plants and animals—to air—to soil.

In this way sulfur becomes largely a self-renewing element of the soil, altho there is a considerable loss from the soil by leaching. Observations taken at the Illinois Agricultural Experiment Station show that 40 pounds of sulfur per acre are brought into the soil thru the annual rainfall. With a fair stock of sulfur, such as exists in our common types of soil, and with an annual return, which of itself would more than suffice for the needs of maximum crops, the maintenance of an adequate sulfur supply presents little reason at present for serious concern. There are regions, however, where the natural stock of sulfur in the soil is not nearly so high and where the amount returned thru rainfall is small. Under such circumstances sulfur soon becomes a limiting element of crop production, and it will be necessary sooner or later to introduce this substance from some outside source. Investigation is now under way to determine to what extent this situation may apply under Illinois conditions.

Physical Improvement of Soils

In the management of most soil types, one very important matter, 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. Organic matter in producing good tilth helps to control washing of soil on rolling land, raises the temperature of drained soil, increases the moisture-holding capacity of the soil, slightly retards capillary rise and consequently loss of moisture by surface evaporation, and helps to overcome the tendency of some soils to run together badly.

The physical effect of organic matter is to produce a granulation or mellowness, by cementing the fine soil particles into crumbs or grains about as large as grains of sand, which produces a condition very favorable for tillage, percolation of rainfall, and the development of plant roots.

Organic matter is undergoing destruction during a large part of the year and the nitrates produced in its decomposition are used for plant growth. Altho this decomposition is necessary, it nevertheless reduces the amount of organic matter, and provision must therefore be made for maintaining the supply. The practical way to do this is to turn under the farm manure, straw, cornstalks, weeds, and all or part of the legumes produced on the farm. The amount of legumes needed depends upon the character of the soil. There are farms, especially grain farms, in nearly every community where all legumes could be turned under for several years to good advantage.

Manure should be spread upon the land as soon as possible after it is produced for if it is allowed to lie in the barnyard several months as is so often the case, from one-third to two-thirds of the organic matter will be lost.

Straw and cornstalks should be turned under, and not burned. There is considerable evidence indicating that on some soils undecomposed straw applied in excessive amount may be detrimental. Probably the best practice is to apply the straw as a constituent of well-rotted stable manure. Perhaps no form of organic matter acts more beneficially in producing good tilth than cornstalks. It is true, they decay rather slowly, but it is also true that their durability in the soil is exactly what is needed in the production of good tilth. Furthermore, the nitrogen in a ton of cornstalks is one and one-half times that of a ton of manure, and a ton of dry cornstalks incorporated in the soil will ultimately furnish as much humus as four tons of average farm manure. When burned, however, both the humus-making material and the nitrogen are lost to the soil.

It is a common practice in the corn belt to pasture the cornstalks during the winter and often rather late in the spring after the frost is out of the ground. This trampling by 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 corn is planted. Whether the crop be corn or oats, it necessarily suffers and if the season is dry, much damage may be done. If the field is put in corn, a poor stand is likely to result, and if put in oats, the soil is so compact as to be 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 effect becomes worse if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

Systems of Crop Rotations

In a program of permanent soil improvement one should adopt at the outset a good rotation of crops, including, for the reasons discussed above, a liberal use of legumes. No one can say in advance for every particular case what will prove to be the best rotation of crops, because of variation in farms and farmers and in prices for produce. As a general principle the shorter rotations, with the frequent introduction of leguminous crops, are the best adapted for building up poor soils.

Following are a few suggested rotations which may serve as models or outlines to be modified according to special circumstances.

Six-Year Rotations

First year —Corn
Second year—Corn
Third year —Wheat or oats (with clover)
Fourth year—Clover
Fifth year —Wheat (with clover)
Sixth year —Clover, or clover and grass

In grain farming, with small grain grown the third and fifth years, most of the unsalable products should be returned to the soil, and the clover may be clipped and left on the land or returned after threshing out the seed; or, in livestock 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, as indicated below.

The two following rotations are suggested as especially adapted for combating the corn borer:

First year —Corn
Second year—Soybeans
Third year —Small grain (with legume)
Fourth year—Legume
Fifth year —Corn (for silage)
Sixth year —Wheat (with sweet clover)

First year —Corn
Second year—Soybeans
Third year —Small grain (with legume)
Fourth year—Legume
Fifth year —Wheat (with alfalfa)
Sixth year —Alfalfa

Five-Year Rotations

First year —Corn
Second year—Wheat or oats (with clover)
Third year —Clover
Fourth year—Wheat (with clover)
Fifth year —Clover

First year —Corn
Second year—Soybeans
Third year —Corn
Fourth year—Wheat (with legume)
Fifth year —Legume

First year —Corn
Second year—Cowpeas or soybeans
Third year —Wheat (with clover)
Fourth year—Clover
Fifth year —Wheat (with clover)

The last rotation mentioned above allows legumes to be grown four times. Alfalfa may be grown on a sixth field rotating over all fields if moved every six years.

Four-Year Rotations

First year —Corn
Second year—Wheat or oats (with clover)
Third year —Clover
Fourth year—Wheat (with clover)

First year —Corn
Second year—Corn
Third year —Wheat or oats (with clover)
Fourth year—Clover

First year —Corn
Second year—Cowpeas or soybeans
Third year —Wheat (with clover)
Fourth year—Clover

First year —Wheat (with clover)
Second year—Clover
Third year —Corn
Fourth year—Oats (with clover)

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.

Three-Year Rotations

First year —Corn
Second year —Oats or wheat (with clover)
Third year —Clover

First year —Wheat or oats (with clover)
Second year —Corn
Third year —Cowpeas or soybeans

By allowing the clover, in the last rotation mentioned, to grow in the spring before preparing the land for corn, we have provided a system in which legumes grow on every acre every year. This is likewise true of the following suggested two-year system:

Two-Year Rotations

First year —Oats or wheat (with sweet clover)
Second year —Corn

Altho in this two-year rotation either oats or wheat is suggested, as a matter of fact, by dividing the land devoted to small grain, both of these crops can be grown simultaneously, thus providing a three-crop system in a two-year cycle.

It should be understood that in all of the above suggested cropping systems it may be desirable in some cases to substitute barley or rye for the wheat or oats. Or, in some cases, it may become desirable to divide the acreage of small grain and grow in the same year more than one kind. In all of these proposed rotations the word *clover* is used in a general sense to designate either red clover, alsike clover, or sweet clover, or it may include alfalfa used as a biennial. The mixing of alfalfa with clover seed for a legume crop is a recommendable practice. In connection with livestock production it may be desirable to mix grass with the clover for pasture or hay. The value of sweet clover, especially as a green manure for building up depleted soils, as well as a pasture and hay-crop, is becoming thoroly established, and its importance in a crop-rotation program may well be emphasized.

SUPPLEMENT: EXPERIMENT FIELD DATA

(Results from Experiment Fields on Soil Types Similar to Those Occurring in Douglas County)

The University of Illinois has conducted altogether about fifty soil experiment fields in different sections of the state and on various soil types. Altho some of these fields have been discontinued, the majority are still in operation. It is the present purpose to report the summarized results from certain of these fields located on soil types described in the accompanying soil report.

A few general explanations at this point, which apply to all the fields, will relieve the necessity of numerous repetitions in the following pages.

Size and Arrangement of Fields

The soil experiment fields vary in size from less than two acres up to forty acres or more. They are laid off into series of plots, the plots commonly being either one-fifth or one-tenth acre in area. Each series is occupied by one kind of crop. Usually there are several series so that a crop rotation can be carried on with each crop represented every year.

Farming Systems

On most of the fields the treatment provides for two distinct systems of farming, livestock farming and grain farming.

In the livestock system, stable manure is used to furnish organic matter and nitrogen. The amount applied to a plot is based upon the amount that can be produced from crops raised on that plot.

In the grain system no animal manure is used. The organic matter and nitrogen are applied in the form of plant manures, including the plant residues produced, such as cornstalks, straw from wheat, oats, clover, etc., along with leguminous catch crops plowed under. It was the plan in this latter system to remove from the land, in the main, only the grain and seed produced, except in the case of alfalfa, that crop being harvested for hay the same as in the livestock system but certain modifications have been introduced in recent years, as explained in the descriptions of the respective fields.

Crop Rotations

Crops which are of interest in the respective localities are grown in definite rotations. The most common rotation used is wheat, corn, oats, and clover; and often these crops are accompanied by alfalfa growing on a fifth series. In the grain system a legume catch crop, usually sweet clover, is included, which is seeded on the young wheat in the spring and plowed under in the following spring in preparation for corn. If the red clover crop fails, soybeans are substituted.

Soil Treatment

The treatment applied to the plots at the beginning was usually standardized according to a rather definite system. With advancing experience, however, new problems arose calling for new experiments, so that on most of the fields plots have been divided and a portion given over to new systems of treatment, at the same time maintaining the original system essentially unchanged from the beginning.

Following is a brief explanation of this standard system of treatment.

Animal Manures.—Animal manures, consisting of excreta from animals, with stable litter, are spread upon the respective plots in amounts proportionate to previous crop yields, the applications being made in the preparation for corn.

Plant Manures.—Crop residues produced on the land, such as stalks, straw, and chaff, are returned to the soil, and in addition a green-manure crop of sweet clover is seeded in small grains to be plowed under in preparation for corn. (On plots where limestone is lacking the sweet clover seldom survives.) This practice is designated as the *residues system.*

Mineral Manures.—Limestone has usually been applied at the rate of 4 tons an acre as an initial application, and 2 tons an acre every four years thereafter until a considerable excess has accumulated in the soil. Rock phosphate has been applied at the rate of one ton an acre at the beginning, followed by an annual acre-rate of 500 pounds applied once in the rotation until a considerable excess has accumulated. Potassium has been applied usually in the form of 200 pounds of kainit a year. When kainit was not available, owing to conditions brought on by the World War, potassium carbonate was used.

Explanation of Symbols Used

0 = Untreated land or check plots
M = Manure (animal)
R = Residues (from crops, and includes legumes used as green manure)
L = Limestone
P = Phosphorus, in the form of rock phosphate unless otherwise designated, (sP = superphosphate, bP = bone meal, rP = rock phosphate, slP = slag phosphate)
K = Potassium (usually in the form of kainit)
( ) = Parentheses enclosing figures, signifying tons of hay, as distinguished from bushels of seed

THE ALEDO FIELD

An experiment field representing the soil type Brown Silt Loam on Clay is located in Mercer county just west of Aledo. This field has been in operation since 1910. From its physical aspects this field should be well adapted to experimental work, the land being unusually uniform in topography and in soil profile.

There are two general systems of plots and they are designated as the major and the minor systems. The major system comprizes four series made up of 10 plots each. The plots were handled substantially as described for standard treatment until 1918, when it was planned to harvest the first crop of red clover on the residues plots for hay and to plow down the second crop if no seed were formed. In 1921 the return of the oat straw was discontinued. In 1923 the rotation was changed to one of corn, corn, oats and wheat. In this rotation it was planned to seed hubam clover in the oats on all plots, for use as hay or for soil improvement, and common sweet clover in the wheat on the residues plots for use as a green manure. Since this change, no residues except cornstalks and the green manure have been returned to the residues plots. The limestone applications were temporarily abandoned in 1923 after the different series had received 7½ to 9 tons an acre and no more will be applied until a need for lime appears. The phosphate applications were evened up to a total of 4 tons an acre in 1924, and no more will be applied for some time at least.

A summary of the results, showing the average annual yields obtained for the period beginning when complete soil treatment came into sway is given in Table 7. Comparisons in terms of crop increases, intended to indicate the effect of the different fertilizing materials applied is shown in the lower section of the table.

In looking over these results, one may observe first the beneficial effect of animal manure on all crops but especially on corn. This suggests the advisa-

TABLE 7.—ALEDO FIELD: SUMMARY OF CROP YIELDS
Average Annual Crop Yields 1912-1928—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat	Corn	Oats	Clover	Soy-beans[1]	Stubble Clover: Sweet clover	Stubble Clover: Hubam[2]
		14 crops	*23 crops*	*16 crops*	*6 crops*	*3 crops*	*2 crops*	*2 crops*
1	0	29.9	56.0	58.6	(2.21)	(1.60)	......	......
2	M	35.1	69.9	65.7	(2.74)	(1.63)	......	......
3	ML	35.5	73.5	68.5	(3.12)	(1.60)	......	(1.12)
4	MLP	37.2	74.7	69.5	(3.05)	(1.61)	......	(1.20)
5	0	31.0	58.0	60.0	(2.00)	(1.61)	......	......
6	R	31.8	64.5	61.5	(1.91)	(1.65)	......	......
7	RL	34.2	71.7	66.8	(1.79)	(1.88)	(1.57)	(.52)
8	RLP	37.9	74.1	68.3	(2.08)	(2.03)	(1.66)	(.80)
9	RLPK	37.8	75.4	70.7	(1.73)	(2.09)	(1.99)	(.57)
10	0	30.2	56.3	58.8	(2.38)	(1.62)	......	......
	Crop Increases							
	M over 0	5.2	13.9	7.1	(.53)	(.03)	......	......
	R over 0	.8	6.5	1.5	−(.09)	(.04)	......	......
	ML over M	.4	3.6	2.8	(.38)	−(.03)	......	(1.12)
	RL over R	2.4	7.2	5.3	−(.12)	(.23)	(1.57)	(.52)
	MLP over ML	1.7	1.2	1.0	−(.07)	(.01)	......	(.08)
	RLP over RL	3.7	2.4	1.5	(.29)	(.15)	(.09)	(.28)
	RLPK over RLP	− .1	1.3	2.4	−(.35)	(.06)	(.33)	−(.23)

[1]Soybeans all evaluated as hay, altho some plots were harvested as seed.
[2]Two crops hubam on Plots 3 and 4 but only 1 crop on 7, 8, and 9.

bility of carefully conserving and regularly applying all stable manure. Residues alone have been beneficial for the second year corn but have shown little effect on the other crops of the rotation.

Where limestone has been applied, there is usually some increase in average yields, sufficient, at least, to cover the cost of the limestone.

The addition of rock phosphate to the treatment has had very little effect in the manure system. Somewhat more favorable are the results in the residues system, but under present market conditions, the cost of rock phosphate applied in the manner of these experiments exceeds the value of the crop increase. However, the economic story has not all been told, for the application of lime and phosphate has been discontinued in order to observe the residual effects. The results of the next few years, therefore, will be awaited with great interest.

For the effect of potassium treatment Plots 8 and 9 should be compared. No significant response appears from this treatment so far as these common field crops show.

Special Phosphate Experiments

The so-called minor system of plots on the Aledo field is given over to a comparison of the effectiveness of different carriers of phosphorus.

In this experiment each series contains four plots. Plot 1 receives residues treatment only; Plot 2 receives residues and phosphorus in one of the forms under test; Plot 3 receives residues, limestone, and phosphorus; and Plot 4 is similar to Plot 3 with phosphorus omitted. On one series steamed bone meal is used as the carrier of phosphorus and is applied at the rate of 200 pounds per acre per year. On another series superphosphate is applied at the yearly rate of 333⅓ pounds per acre. On a third series rock phosphate serves as the source of phosphorus and is applied at the rate of 666⅔ pounds per acre per year. On the last series basic slag phosphate is applied at the rate of 250 pounds per acre per year.

The yields for all crops harvested on these plots are recorded in Table 8. Table 9, which is derived from Table 8, shows the value of the increase in crop yield presumed to have resulted from applying the various forms of phosphatic fertilizers for the 13 crops harvested since the beginning of the applications up to 1928. In computing these comparisons, each phosphate plot is compared with its neighboring non-phosphate plot. Aside from the soybeans, the figures show without exception more or less crop increase on the phosphorus plots, no matter what the form of carrier employed.

The difficulty in arriving at a general conclusion regarding the comparative economy in the use of these different phosphorus materials is obvious, for all depends upon their relative cost, which fluctuates from time to time. Furthermore, the prices received from farm produce likewise fluctuate; and to complicate matters still further, these fluctuations do not necessarily run parallel with those of the fertilizer cost. However, one may compute for himself the relative economy of producing these crop increases by applying any set of prices for crops and fertilizers which appear to be most applicable according to prevailing market conditions. For the purpose of furnishing an illustration

TABLE 8.—ALEDO FIELD: PHOSPHATE EXPERIMENT

Annual Crop Yields—Bushels or (tons) per acre

Plot No.	Soil treatment applied	1916[1] Corn	1917[1] Oats	1918[1] Soy-beans	1919 Wheat	1920 Corn	1921 Oats	1922 Clover hay	1923 Corn	1924 Corn	1925 Oats	1926 Wheat	1927 Corn	1928 Corn
501	R......	53.4	85.5	18.9	32.4	72.8	48.9	(2.88)	83.5	58.2	63.9	44.0	33.9	69.8
502	RbP....	61.7	91.7	19.0	34.7	86.4	61.9	(3.25)	82.7	66.0	75.0	59.2	63.2	71.7
503	RLbP...	61.5	90.6	23.2	35.6	87.3	53.3	(3.48)	82.5	66.8	73.4	62.0	71.3	78.3
504	RL.....	55.1	80.5	22.6	32.9	77.7	47.7	(2.61)	88.2	60.3	64.5	44.6	58.5	72.0
601	R......	55.2	84.7	19.5	33.0	71.2	53.6	(3.17)	84.7	57.3	64.4	43.3	37.2	71.3
602	RsP....	57.8	87.7	18.7	38.3	87.1	60.9	(3.23)	82.5	65.9	76.1	60.6	54.8	73.2
603	RLsP...	64.7	83.4	23.1	38.2	88.1	52.3	(3.53)	77.6	64.7	78.1	64.4	67.0	74.9
604	RL.....	51.9	81.7	24.6	32.8	84.9	50.2	(3.06)	84.1	51.9	64.1	47.3	60.8	74.4
701	R......	54.3	83.1	20.8	34.2	75.6	52.8	(3.41)	82.8	61.2	66.6	44.8	39.9	72.3
702	RrP ...	58.8	83.3	23.3	36.7	80.4	63.0	(3.60)	87.8	69.3	70.3	59.2	61.8	74.3
703	RLrP...	57.2	81.2	28.1	36.7	80.2	53.3	(3.82)	86.6	70.8	67.8	57.5	67.8	76.5
704	RL.....	52.1	81.7	26.9	34.1	82.0	48.9	(3.15)	84.6	62.5	66.3	48.8	63.0	74.6
801	R......	57.6	73.8	18.0	33.7	68.1	54.8	(2.62)	74.3	58.8	45.0	45.8	42.2	70.4
802	RslP....	56.4	87.8	20.6	38.1	81.0	66.2	(3.66)	80.0	69.1	66.3	60.2	60.7	69.3
803	RLslP. .	53.3	78.9	23.7	38.4	83.6	57.0	(3.63)	82.0	70.2	66.7	66.0	73.1	71.0
804	RL.....	51.8	77.5	21.8	33.3	70.4	59.8	(2.99)	82.6	59.9	53.9	48.2	60.4	75.1

[1]No residues.

of such a computation, the December 1 market quotations for the years in which the respective crops were actually produced have been applied to the results of these Aledo plots. The value of soybeans is arbitrarily set at $1.50 a bushel. For the cost of fertilizer materials the prices of phosphates are estimated as follows: bone meal, $40 a ton; superphosphate, $24; rock phosphate, $12; and slag phosphate, $20 a ton.

Reckoned on the basis of the above prices, it appears from the last column of Table 9 that slag phosphate has produced the most profitable returns of the four phosphorus carriers in the test, bringing an average profit of $4.89 an acre yearly where applied without limestone and $3.57 where applied with limestone. Bone meal has given an average profit of $2.45 applied without limestone and $1.92 applied with limestone. Superphosphate has returned $1.54 used without limestone and $1.21 used with limestone. Rock phosphate has produced a profit of $1.22 an acre a year when applied without limestone and a loss of 55 cents when used with limestone.

In considering these results, it may be pointed out that the quantities of phosphatic materials employed in these experiments are, with the possible exception of the slag phosphate, greater than ordinarily would be used, or need to be used, in good farm practice. Moreover, no consideration is given in these comparisons to the relative phosphorus reserves which should have accumulated in the soil. Finally, it should be emphasized that the order of these values might be easily shifted by relatively small change in commodity prices.

Limestone at the rate of 4 tons an acre was applied to Plots 3 and 4 in 1912 when the land was still under alfalfa, and another dressing was added in 1917 after the present experiments were under way. The results from the limestone treatment are shown in Table 10.

TABLE 9.—ALEDO FIELD: PHOSPHATE EXPERIMENTS

Value of Crop Increases Produced by the Various Forms of Phosphate, Computed from Yields in Table 8

Comparison of treatments	Wheat *2 crops*	Corn *6 crops*	Oats *3 crops*	Clover *1 crop*	Soy-beans *1 crop*	Total increase *13 crops*	Cost of phos-phate *13 years*	Profit from *13 crops*	Profit per acre per year
Bone meal, residues, *over* residues	$23.35	$44.04	$11.67	$ 4.63	$ .15	$83.83	$52.00	$31.83	$2.45
Bone meal, residues, lime, *over* residues, lime	26.90	27.01	11.31	10.88	.90	77.00	52.00	25.00	1.92
Superphosphate, residues, *over* residues	32.23	32.12	8.15	.75	−1.20	72.05	52.00	20.05	1.54
Superphosphate, residues, lime, *over* residues, lime	32.20	25.33	6.62	5.88	−2.25	67.77	52.00	15.77	1.21
Rock phosphate, residues, *over* residues	22.81	34.51	4.38	2.38	3.75	67.83	52.00	15.83	1.22
Rock phosphate, residues, lime, *over* residues, lime	16.07	17.15	1.49	8.38	1.80	44.89	52.00	− 7.11	− .55
Slag phosphate, residues, *over* residues	26.80	32.46	19.86	13.00	3.90	96.02	32.50	63.52	4.89
Slag phosphate, residues, lime, *over* residues, lime	32.43	24.59	11.07	8.00	2.85	78.94	32.50	46.44	3.57

At the prices for produce and limestone assumed in these computations, a profit of $1.69 an acre a year for limestone applied without phosphate of any kind is found. Where limestone was applied with bone meal, the limestone

TABLE 10.—ALEDO FIELD: PHOSPHATE EXPERIMENTS

Value of Crop Increases Produced by Limestone, Computed From Yields in Table 8

Comparison of treatments	Wheat *2 crops*	Corn *6 crops*	Oats *3 crops*	Clover *1 crop*	Soy-beans *1 crop*	Total increase *13 crops*	Cost of lime-stone[1] *13 years*	Profit from *13 crops*	Profit per acre per year
Limestone, residues, *over* residues	$3.25	$22.14	$−.40	$−.84	$7.01	$31.16	$9.18	$21.98	$1.69
Limestone, residues, bone meal, *over* residues, bone meal	5.31	11.35	−3.76	2.88	6.30	22.08	9.18	12.90	.99
Limestone, residues, superphosphate, *over* residues, superphosphate	4.43	11.93	−4.58	3.75	6.60	22.02	9.18	12.84	.99
Limestone, residues, rock phosphate, *over* residues, rock phosphate	− 2.07	5.00	−5.04	2.75	7.20	7.84	9.18	− 1.34	−.10
Limestone, residues, slag phosphate, *over* residues, slag phosphate	7.71	11.26	−1.81	−.38	4.65	21.44	9.18	12.26	.94

[1]Owing to the fact that the first application of limestone on these plots was made for alfalfa four years before the present experiments were started, the total expense of $12 an acre for limestone is prorated, leaving a charge of $9.18 for the 13 crops involved in the present experiments.

profit was 99 cents an acre a year, and with superphosphate it was likewise 99 cents an acre. Used with rock phosphate, the crop increases were so small that there was a loss of 10 cents an acre a year. Applied with slag phosphate, the returns show a profit of 94 cents an acre a year.

It appears, therefore, that by distributing the cost of the limestone over the years since its first application, this material has returned a moderate profit except where used with rock phosphate.

It should be observed that the Aledo field represents one of those borderline cases, so to speak, in which the upper soil is nearly neutral or only slightly acid and the lime requirement, therefore, is not very marked. As time goes on, however, and cropping continues, a greater need for lime will probably develop. By discontinuing liming on these plots the annual cost of the limestone already applied is automatically reduced, so that net returns which hitherto have perhaps represented an actual loss may sooner or later result in a positive profit.

THE MORROW PLOTS

As representing the soil type Brown Silt Loam, the field experiments on the Morrow Plots, which have been continued for more than half a century, will be of special interest.

The Morrow Plots are located on the campus of the University of Illinois. This series now consists of three plots divided into halves, and the halves are subdivided into quarters. On one plot, corn is grown continuously; on the second, corn and oats are grown in rotation; and on the third, corn, oats, and clover are rotated. The north half of each plot has had no fertilizing material applied from the beginning of the experiments, while the south half has been treated since 1904. Besides farm manure, phosphorus has been applied in two different forms: rock phosphate to the southwest quarter at the rate of 600 pounds, and steamed bone meal to the southeast quarter at the rate of 200 pounds per acre per year up to 1919, when the rock phosphate was increased sufficiently to bring up the total amount applied to four times the quantity of bone meal applied. In 1925 the phosphates were evened up to a total of 3,300 pounds of bone meal and 13,200 pounds of rock phosphate and their application discontinued. In 1904 ground limestone was applied at the rate of 1,700 pounds per acre to the south half of each plot, and in 1918 a further application was made at the rate of 5 tons per acre. From 1903 until 1920, legumes were seeded in the corn on the south half of each plot. Legumes, chiefly red clover until 1918 and sweet clover since that time, have been seeded in the oats on the south half of Plot 4.

Summarizing the data from these Morrow plots into two periods, with the second period beginning in 1904, when the treatment began on the half-plots, some interesting comparisons may be made. In the first place we find in the untreated, continuous corn plot a marked decrease in the second period in the average yield of corn, amounting to one-third of the crop. In the two-year rotation there is a decrease in both corn and oat production. The averages for the three-year system on the untreated land show a slight increase in corn yield, a small decrease in oats, and a considerable reduction in clover.

TABLE 11.—URBANA FIELD, MORROW PLOTS: GENERAL SUMMARY
Average Annual Yields—Bushels or (tons) per acre

Years	Soil treatment applied	Corn every year	Two-year rotation		Three-Year Rotation		
			Corn	Oats	Corn	Oats	Clover[1]
		16 crops	*9 crops*	*6 crops*	*4 crops*	*4 crops*	*4 crops*
1888 to 1903	None......	39.7	41.0	44.0	48.0	47.6	(2.03)
		25 crops	*12 crops*	*13 crops*	*9 crops*	*8 crops*	*8 crops*
1904 to 1928	None......	25.0	35.1	34.0	49.3	45.1	(1.49)
	MLP......	40.2	60.6	59.2	67.2	62.7	(2.83)

[1]Including all legume crops evaluated as clover hay.

Crop rotation has noticeably improved the yields over continuous corn growing. The three-year rotation has been more effective than the two-year rotation in maintaining yields over the entire period. The two-year rotation, however, has been gaining on the three-year rotation in recent years probably because of the influence of sweet clover.

FIG. 8.—CORN ON THE MORROW PLOTS IN THE THREE-YEAR ROTATION

Both of these plots are under a good crop rotation of corn, oats, and clover. No soil treatment is applied to the plot at the left, while that at the right receives manure, limestone, and phosphate. The one is yielding at the rate of 50 bushels an acre, the other at 67 bushels.

The increase brought about by soil treatment stands out in all cases, showing the possibility not only of restoring but also of greatly improving the productive power of this land that has been so abused by continuous cropping without fertilization.

Thruout the season the crops growing on the treated soil are usually at a more advanced stage of development than those growing on the untreated soil. In corn this shows up at husking time in drier, sounder ears than those found on the untreated land.

An important principle of soil management is demonstrated in these experiments; namely, that the best results are not obtained thru crop rotation alone nor thru soil fertilization alone, but it is the combination of these two practices that brings out the highest possibilities for production.

The practices in rotation and soil treatment which have been the most effective in increasing the crop-producing capacity of the soil have also been the most profitable financially. These better practices not only have increased the yields but they have made possible a greater economy in production, an important factor in increasing farm profits.

For further information concerning these long-time soil experiments, the reader is referred to Bulletin 300, "Lessons from the Morrow Plots," where these investigations are described and discussed in detail.

THE KEWANEE FIELD

The Kewanee experiment field, representing the soil type Brown Silt Loam, is located in Henry county about midway between Kewanee and Galva. This field has been in operation since 1915. It includes 20 acres of the dark-colored loessial soil characteristic of the region. Altho the main soil type represented is Brown Silt Loam, a detailed examination reveals the presence of a second type occupying the basin of the draw which traverses the field in a winding direction. This minor type is classified as Black Clay Loam On Drab Clay. The topography of the land is rather rolling and it has a tendency to wash at certain spots. The field is laid out in two systems of plots designated as the Major and the Minor series.

The Major Series

A rotation system of wheat, corn, oats, and clover has been practiced on the Major series, the crops being managed mainly as described on page 38. Since 1921 the clover on the residues plots has been harvested for hay instead of seed and the oat straw has not been returned to the land. Since 1922 the periodic application of limestone has been suspended after the different series had received an average total of 6¾ tons to the acre, and no more is to be applied until it is needed again. The practice of returning the wheat straw has been discontinued since 1922, and since 1925 only one crop of clover hay on the residues plots has been removed, the second crop being plowed down as green manure. The phosphate applications were suspended in 1927 after evening up all phosphate plots to a total of 4 tons per acre.

Table 12 gives a summary of the results showing the average annual yields for the different kinds of crops, including the years since the complete soil treatments have been in effect.

In looking over these results one may observe first the effect of animal manure, which has given profitable increases in all the crops. Residues alone show no significant effect.

Limestone in addition to manure has resulted in a small improvement, probably sufficient to cover the cost. It has been somewhat more effective in the grain system than in the livestock system.

Phosphorus, as usual, shows up in these averages to best advantage on the wheat crop in the residues system. Where used with manure and limestone, little effect was produced except on the wheat; but where used with residues and limestone, fair increases were produced in all crops, sufficient to return a financial profit under present market conditions. A study of the detailed data reveals a fact of interest in this connection which these averages do not bring out,

TABLE 12.—KEWANEE FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1917-1928—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat 10 crops	Corn 12 crops	Oats 12 crops	Clover[1] 11 crops
1	0	29.0	54.6	59.0	(1.64)
2	M	32.4	66.0	71.0	(2.23)
3	ML	35.2	70.6	73.2	(2.30)
4	MLP	40.0	72.1	72.4	(2.48)
5	0	30.3	56.1	60.6	(1.56)
6	R	31.6	58.2	59.6	(1.46)
7	RL	34.2	66.5	63.3	(1.71)
8	RLP	39.8	70.9	69.0	(1.89)
9	RLPK	40.6	74.4	70.6	(1.97)
10	0	28.1	50.3	56.4	(1.29)
	Crop Increases				
	M over 0	3.4	11.4	12.0	(.59)
	R over 0	1.3	2.1	− 1.0	−(.10)
	ML over M	2.8	4.6	2.2	(.07)
	RL over R	2.6	8.3	3.7	(.25)
	MLP over ML	4.8	1.5	− .8	(.18)
	RLP over RL	5.6	4.4	5.7	(.18)
	RLPK over RLP	.8	3.5	1.6	(.08)

[1]Including some seed evaluated as hay.

and that is that the phosphate exerted very little influence during the earlier years of the experiments. Within the past seven or eight years, however, the phosphorus treatment has come suddenly into evidence and the trend of its effectiveness seems at present to be on the upgrade.

No significant response appears as the result of potassium fertilization, thus indicating the futility of purchasing potassium fertilizer for use in this kind of a cropping system on this kind of soil.

Comparative Phosphate Experiments

Four short series having only 4 plots each constitute the so-called Minor system on the Kewanee field. These plots are now given over to a comparison of the effectiveness of rock phosphate and superphosphate.

Alfalfa was grown on these plots until 1922. In the beginning, limestone was applied to Plots 3 and 4 at the rate of 4 tons an acre. This application was repeated in 1919. In 1922 the present experiments with phosphates were begun and the same rotation practiced on the larger series described above was established on these series. In this comparison rock phosphate is used on Plots 1 and 3 at the annual rate of 400 pounds an acre, applied once in the rotation ahead of the wheat, but beginning with 1927 rock phosphate will be applied at the same time as the superphosphate. Superphosphate is used on Plots 2 and 4 at the annual rate of 200 pounds an acre. It is applied twice in the rotation, one-half for wheat and one-half for oats. A summary of the annual crop yields and corresponding money values is given in Table 13.

TABLE 13.—KEWANEE FIELD: PHOSPHATE EXPERIMENT
Average Annual Crop Yields and Corresponding Money Values 1922-1928
Bushels or (tons) per acre

Soil treatment applied	Wheat *7 crops*	Corn *7 crops*	Oats *7 crops*	Legume hay *7 crops*	Value per acre
Residues, rock phosphate..........	43.3	74.1	76.5	3.09	$43.89
Residues, superphosphate..........	45.1	73.0	78.2	3.02	44.17
Residues, limestone, rock phosphate.	38.8	73.0	73.5	3.09	42.05
Residues, limestone, superphosphate.	46.6	75.1	77.0	3.01	44.83

In comparing these two forms of phosphate the following set of prices are assumed as representing the average market conditions for the past seven years (December 1 quotations): wheat, $1.21 a bushel; corn, 68 cents; oats, 39 cents; and hay, $13.90 a ton. For the cost of two phosphorus carriers, an estimate of $12 a ton for rock phosphate and $24 a ton for superphosphate may be taken, thus making the expense for the two kinds of phosphate equal.

With these prices applied to the yields given in Table 13, it is found that without limestone there is very little difference in value of crops produced under the two forms of phosphate. The 38 cents in favor of the superphosphate is scarcely significant in view of the experimental errors involved in this sort of tests. In the presence of limestone the difference in crop values is $2.78 per acre per year in favor of superphosphate. Wheat has been the crop most affected by the form of phosphate applied.

It is to be borne in mind that the order of values can easily be shifted by a change in the relative yields of the respective crops or by a change in commodity prices. Furthermore no consideration has been given here to any possible difference in the residual effects of the two forms of phosphate which might appear upon discontinuing the treatments.

THE BLOOMINGTON FIELD

The experiments on the Bloomington field are of interest in connection with the management of Brown Silt Loam. This field is located in McLean county, northeast of the city of Bloomington. The work was started in 1902. Altho a fairly long period of years has been covered in these experiments, the field has only a single series of plots, so that only one kind of crop is represented each season. The crops employed have been corn, corn, oats, clover, and wheat; and, since 1905, they have been grown in the sequence named.

Commercial nitrogen applied in the form of dried blood was used in the early years up to 1905, when crop residues and clover were substituted. For 20 years all of the phosphorus on this field was applied in the form of steamed bone meal at the rate of 200 pounds an acre a year.

Table 14 presents a summary of the work to 1923 by average annual yields. The comparisons in the lower part of the table show the effect of the different plant-food materials in the various combinations in which they were applied.

The value of limestone on this field is difficult to assess on account of the erratic results found upon comparing Plots 1 and 2. Here both corn and wheat

TABLE 14.—BLOOMINGTON FIELD: SUMMARY OF CROP YIELDS

Average Annual Yields 1902-1923—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Corn 10 crops	Oats 4 crops	Wheat 4 crops	Clover[1] 3 crops
1	0	44.6	40.6	26.5	(.74)
2	L	41.5	44.7	24.1	(.80)
3	LR	47.5	46.2	27.9	(.88)
4	LbP	55.8	54.3	45.7	(2.54)
5	LK	46.2	43.5	25.5	(.90)
6	LRbP	60.6	66.0	49.7	(1.19)
7	LRK	48.6	46.8	27.5	(.82)
8	LbPK	60.9	57.2	44.5	(2.44)
9	LRbPK	64.2	63.1	50.4	(.81)
10	RbPK	58.8	52.8	49.3	(.83)
	Crop Increases				
	For limestone				
	L over 0	− 3.5	4.1	− 2.4	(.06)
	LRbPK over RbPK	5.4	10.3	1.1	−(.02)
	For residues				
	LR over L	6.0	1.5	3.8	(.08)
	LRbP over LbP	4.8	11.7	4.0	−(1.35)
	LRK over LK	2.4	3.3	2.0	−(.08)
	LRbPK over LbPK	3.3	5.9	5.9	−(1.63)
	For phosphorus				
	LbP over L	14.3	9.6	21.6	(1.74)
	LRbP over LR	13.1	19.8	21.8	(.31)
	LbPK over LK	14.7	13.7	19.0	(1.54)
	LRbPK over LRK	15.6	16.3	22.9	−(.01)
	For potassium				
	LK over L	4.7	− 1.2	1.4	(.10)
	LRK over LR	1.1	.6	− .4	−(.06)
	LbPK over LbP	5.1	2.9	− 1.2	−(.10)
	LRbPK over LRbP	3.6	− 2.9	.7	−(.38)

[1]Two crops of seed on Plots 3, 6, 7, and 9 evaluated as hay.

appear to have suffered from the application of limestone, but the difficulty may well be attributable to soil variability. Comparing Plots 9 and 10, it would appear that in combination with residues, phosphorus, and potassium, the limestone on the whole was beneficial.

The residues treatment, supplying organic matter and nitrogen, shows a beneficial effect on the grain crops, but not on the clover.

The prominent feature of the results on the Bloomington field is the effect of phosphorus. In all of the grain crops on every plot where bone meal was applied, there was a remarkable response to the treatment, as shown by the increases in yields. This response appears in all the combinations, even without the presence of residues, altho in combination with either residues or potassium the effect is accentuated. For example, comparing Plot 3 with Plot 6 (limestone and residues, with limestone, residues, and phosphorus) we find that the phosphorus treatment produced an average annual increase in the yield of corn of about 13 bushels an acre, while the yield of oats was increased by about 20 bushels, and that of wheat by about 22 bushels. Similar increases, tho not so pronounced, appear in comparing Plot 5 with Plot 8, where potassium instead of residues was present.

Quite different are the results from the use of potassium on this field. The potassium was applied mainly in the form of potassium sulfate, but in 1917 when this material became unavailable thru war conditions, potassium carbonate was substituted. There was a moderate increase in the corn yield where potassium was used and particularly where residues were absent. Otherwise, the small gains shown on some plots are offset by losses on other plots, but these small differences are probably well within the limits of experimental error.

Thus it appears that on this field, under this system of farming, the lack of phosphorus is the outstanding limiting factor in production and the application of this element in the form of steamed bone meal is attended by a high financial profit.

New Phosphate Experiments

In view of this remarkable response to bone meal on the Bloomington field, it was of interest to know how other carriers of phosphorus would behave, and accordingly some experiments were planned to investigate this question. For this purpose, the plots were divided in 1924 and certain new treatments were applied in order to compare the effects of rock phosphate and of superphosphate with bone meal, and at the same time to determine the residual effect of the accumulated phosphorus resulting from the continuous application of the bone meal in presumably somewhat excessive amounts.

The following modifications of the original plots were introduced:

An extra plot, No. 11, was added to the series and all plots were divided into north and south halves. Residues including cornstalks, the second crop of red clover, and other leguminous green manure crops are plowed down on all plots except Plot 1-S. Different phosphorus carriers are applied at the following acre rates per rotation: bone meal, 1000 pounds, to Plots 2-N, 4-N, 6-N, 8-N, 9-N, and 10-N; rock phosphate, 2500 pounds, to Plots 3-N, 5-N, 7-N, and 11-N; superphosphate, 1000 pounds, to Plots 3-S, 5-S, 7-S, and 11-S. Two-fifths of the rotation application of these phosphates are made preceding the oats crop, two-fifths ahead of the wheat crop, and one-fifth in preparation for the corn crop.

Table 15 indicates the arrangement of these modified plots and also gives the results of the five years in which these later experiments have been in progress.

In arriving at the financial results presented in the table, the values of the crops are based upon December 1 farm price quotations for the years in which the respective crops were produced. In deducting the annual cost for the different treatments, the total amounts of materials applied during the entire period of operation on the field were prorated. The expense for limestone is reckoned here at $3 a ton, rock phosphate at $14, superphosphate at $28, bone meal at $48, and residues at 75 cents an acre.

It should be mentioned in considering the results that the soil of these plots is rather variable, with little provision for duplication; and also that some of the treatments are not now strictly comparable with one another on account of the previous history of the plots. Nevertheless, making allowances for these

TABLE 15.—BLOOMINGTON FIELD: NEW PHOSPHATE EXPERIMENTS
Crop Yields and Values 1924-1928—Bushels or (tons) and dollars per acre

Plot No.	Soil treatment applied		1924	1925	1926	1927	1928	Average annual acre values		
	Previous	Present	Oats	Clover	Wheat	Corn	Corn	Gross	Cost of treatment	Net
1-N	0	R	60.6	(.79)	29.3	49.8	49.0	$29.29	$ .75	$28.54
1-S	0	0	58.4	(2.54)	19.5	41.0	33.4	28.82	......	28.82
2-N	L	RLP (bone)	72.6	(1.63)	35.0	58.6	52.2	36.18	6.55	29.63
2-S	L	RL	53.2	(.75)	18.7	46.0	35.2	23.41	1.75	21.66
3-N	RL	RLP (rock)	68.2	(2.18)	32.5	63.6	64.6	39.35	5.25	34.10
3-S	RL	RLP (super)	71.3	(1.74)	41.0	67.6	59.6	40.18	4.55	35.63
4-N	LP (bone)	RLP (bone)[1]	57.6	(1.81)	37.3	60.0	49.6	35.79	6.55	29.24
4-S	LP (bone)	RLP (bone)[2]	67.2	(1.89)	36.7	63.6	60.0	38.71	5.30	33.41
5-N	LK	RLKP (rock)	63.2	(1.66)	32.5	61.4	56.2	35.73	7.65	28.08
5-S	LK	RLKP (super)	78.4	(1.59)	40.7	69.4	55.6	39.99	6.95	33.04
6-N	RLP (bone)	RLP (bone)[1]	68.8	(2.18)	40.5	60.8	55.8	39.73	6.55	33.18
6-S	RLP (bone)	RLP (bone)[2]	71.6	(2.21)	40.0	64.2	60.4	41.09	5.30	35.79
7-N	RLK	RLKP (rock)	71.2	(2.11)	35.3	66.4	58.4	39.62	7.65	31.97
7-S	RLK	RLKP (super)	80.9	(1.66)	40.7	74.8	62.8	42.23	6.95	35.28
8-N	LKP (bone)	RLKP (bone)[1]	60.9	(1.69)	39.2	67.4	56.2	38.10	8.95	29.15
8-S	LKP (bone)	RLKP (bone)[2]	65.0	(1.59)	36.0	69.4	63.0	38.62	7.70	30.92
9-N	RLKP (bone)	RLKP (bone)[1]	60.9	(2.18)	43.8	75.8	60.4	42.56	8.95	33.61
9-S	RLKP (bone)	RLKP (bone)[2]	72.2	(1.65)	41.5	77.8	62.6	41.97	7.70	34.27
10-N	RKP (bone)	RKP (bone)[1]	48.2	(1.93)	45.7	56.6	51.2	37.02	7.95	29.07
10-S	RKP (bone)	RKP (bone)[2]	51.2	(1.53)	43.0	60.6	58.0	36.89	6.70	29.99
11-N	[3]	RP (rock)	70.4	(1.68)	45.3	61.8	47.4	38.43	4.25	34.18
11-S	[3]	RP (super)	60.0	(1.78)	44.5	63.0	57.2	39.11	3.55	35.56

[1]Bone meal applications omitted from 1917 to 1924. [2]No bone meal applied since 1917. [3]New plot added in 1924.

facts, certain figures in the last column of the table showing the net average acre value per year indicate effects worthy of consideration.

In answering the question as to whether other carriers of phosphorus would be as effective as the bone meal in building up this soil, attention is called to the results on Plots 2-N, 3-N, and 3-S where bone meal, rock phosphate, and superphosphate respectively have been employed in addition to limestone and residues. Unfortunately the comparison here is not altogether perfect in that the residues treatment on Plot 2-N was not introduced until 1924, whereas the other two plots had been under residues in the old system before the present experiments were begun and may, therefore, have an advantage in this respect over the bone-meal plot. However this may be, the results as they stand at present place both rock phosphate and superphosphate ahead of bone meal.

Between rock phosphate and superphosphate four direct comparisons in different combinations with other materials are afforded (Plots 3, 5, 7, and 11.) In some years on some plots the results are in favor of superphosphate; in other years on the same plots the reverse is true. As the results stand at present, the majority are in favor of superphosphate but their inconsistency makes it difficult to come to any final conclusion. It may be noted that in these comparisons the two materials are not applied in amounts proportionate to equal cost as in other cases reported. Here 200 pounds per acre per year of superphosphate figured at $2.80 are applied against 500 pounds of rock phosphate valued at $3.50 per acre per year.

For light on the question of residual effect of accumulated phosphorus in the soil, attention is called to the results on Plots 4, 6, 8, 9, and 10, where the north half-plots are now regularly receiving bone meal, while the south halves have received none since 1917. Invariably the net return is higher on the south half, thus indicating that the reserve phosphate accumulated in the soil from previous applications is still exerting a beneficial effect that is more than adequate to offset the expense involved in renewed applications.

By way of a summary of the main lessons brought out at this time by the Bloomington experiments, the following statements may be made.

The results indicate an outstanding phosphorus hunger.

This phosphorus need is satisfied by the application of either bone meal, rock phosphate, or superphosphate.

There is a pronounced residual effect from previous excessive applications of phosphorus carried in the form of bone meal.

THE MINONK FIELD

A University experiment field representing the soil type Black Clay Loam On Drab Clay is located in Woodford county near Minonk. This field was established in 1910. It comprizes 15 acres of dark-colored prairie soil of loessial and drift origin. The experiment plots lie mainly on Black Clay Loam On Drab Clay, altho a detailed examination reveals the presence of three other soil types distinguishable on account of certain profile characteristics. These are Brown Silt Loam, Brown Silt Loam On Calcareous Drift, and Brown Silt Loam On Calcareous Clay.

The field is laid out into four series of 10 plots each. The plots are one-fifth acre in size except in Series 100, where they are one-tenth acre. A crop rotation of corn, oats, clover, and wheat was practiced until 1923, when it was changed to corn, corn, oats, and wheat, with a seeding of hubam clover in the oats on all plots and biennial sweet clover in the wheat on the residues plots. In 1921 the practice of returning the oat straw on the residues plots was discontinued, and in 1922 the return of the wheat straw was likewise discontinued. Up to that time limestone, varying in total quantity from 7½ to 9 tons an acre on the different series, had been applied. These applications were then suspended until such time as the need for more lime becomes apparent. The applications of rock phosphate were likewise indefinitely suspended in 1923 after evening up the total applications to 4 tons an acre on all the phosphate plots.

The average annual yields of all crops produced since the complete soil treatments have been in effect are given in Table 16.

In looking over these results, one observes from the good yields on the untreated plots the naturally high productiveness of this land. There is more or less response to farm manure; in the corn the yield is markedly increased by its use. Residues alone have likewise increased the yields of the grain crops.

TABLE 16.—MINONK FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1912-1928—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat	Corn	Oats	Clover[1]	Soybeans	Stubble clover	
							Hubam	Sweet clover
		14 crops	*23 crops*	*16 crops*	*5 crops*	*4 crops*	*2 crops*	*2 crops*
1	0	30.1	50.2	58.8	(2.58)	19.3	(.72)	......
2	M	33.8	60.6	61.3	(2.81)	20.5	(.94)	......
3	ML	32.4	61.0	60.3	(2.74)	21.7	(.83)	......
4	MLP	34.4	61.0	59.2	(2.93)	21.0	(.97)	......
5	0	31.4	48.6	55.5	(1.36)	20.7	(.86)	......
6	R	33.8	59.3	61.7	(1.50)	20.6	(.91)	(1.19)
7	RL	30.8	61.1	61.6	(1.51)	19.3	(.90)	(1.16)
8	RLP	32.7	62.3	63.0	(1.47)	19.7	(1.06)	(1.33)
9	RLPK	32.0	59.9	63.2	(1.49)	17.2	(1.20)	(1.50)
10	0	26.1	44.0	55.2	(2.30)	15.3	(.58)	......
				Crop Increases				
	M over 0	3.7	10.4	2.5	(.23)	1.2	(.22)	......
	R over 0	2.4	10.7	6.2	(.14)	− .1	(.05)	(1.19)
	ML over M	− 1.2	.4	− 1.0	−(.07)	1.2	−(.11)	......
	RL over R	− 3.0	1.8	− .1	(.01)	− 1.3	−(.01)	−(.03)
	MLP over ML	2.0	0.0	− 1.1	(.19)	− .7	(.14)	......
	RLP over RL	1.9	1.2	1.4	−(.04)	.4	(.16)	(.17)
	RLPK over RLP	− .7	− 2.4	.2	(.02)	− 2.5	(.14)	(.17)

[1]Including some seed evaluated as hay.

Limestone seems to have had no material effect on crop yields. Evidently this soil does not need lime. The use of rock phosphate has not been profitable either in the manure or the residues system. Potassium, as used in these experiments, has likewise been ineffective.

These results therefore indicate the advisability of furnishing plenty of organic matter, either thru stable manure or thru crop residues, including leguminous green manure, as the best practical means, for the present, of improving the productiveness of this naturally fertile soil. As time goes on, with changing soil conditions and shifting market values, the situation may develop under which a different recommendation will be warranted.

THE HARTSBURG FIELD

Black Clay Loam as noted on page 6, occupies nearly 70 square miles in Douglas county. The results of the Hartsburg field, situated in Logan county just east of the town of Hartsburg, are suggestive of the treatments that are effective on this type of soil.

The Hartsburg field was started in 1911. It is laid off in five series of 10 plots each. The crop rotation up to 1923 was wheat, corn, oats, and clover, with alfalfa growing on a fifth series.

The crops were handled mainly as described on page 38 until 1918 when it was planned to remove one hay crop and one seed crop of clover from the residues plots. In 1921 it was decided to harvest all the clover as hay. At that time the

TABLE 17.—HARTSBURG FIELD: SUMMARY OF CROP YIELDS

Average Annual Yields 1913-1928—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat *13 crops*	Barley *1 crop*	Corn *24 crops*	Oats *17 crops*	Clover *7 crops*	Soybeans *2 crops*	Alfalfa *8 crops*	Stubble clover: Hubam *1 crop*	Stubble clover: Sweet clover *1 crop*
1	0.	24.9	35.4	48.1	48.1	(1.84)	(1.29)	(3.47)	(.83)	. . . . . .
2	M.	29.2	44.2	58.8	52.9	(2.16)	(1.64)	(3.67)	(1.15)	. . . . . .
3	ML.	34.0	50.0	64.5	58.3	(2.32)	(1.82)	(3.91)	(.91)	. . . . . .
4	MLP.	36.2	50.0	63.8	57.8	(2.39)	(1.92)	(4.19)	(1.17)	. . . . . .
5	0.	29.7	42.7	53.3	47.0	(1.28)	25.8	(3.33)	(.71)	. . . . . .
6	R.	32.7	47.5	63.7	53.3	(1.67)	26.8	(3.78)	(.75)	(.85)
7	RL.	30.1	53.3	66.9	51.3	(1.64)	28.4	(3.45)	(.68)	(.75)
8	RLP.	34.3	46.9	67.3	55.4	(1.79)	26.1	(4.04)	(.72)	(.90)
9	RLPK.	33.4	55.6	65.4	54.5	(1.70)	26.4	(4.16)	(.80)	(1.00)
10	0.	30.5	45.8	52.8	48.0	(2.02)	(1.69)	(3.20)	(.75)	. . . . . .
	Crop Increases									
	M over 0.	4.3	8.8	10.7	4.8	(.32)	(.35)	(.20)	(.32)	. . . . . .
	R over 0.	3.0	4.8	10.4	6.3	(.39)	1.0	(.45)	(.04)	(.85)
	ML over M.	4.8	5.8	5.7	5.4	(.16)	(.18)	(.24)	−(.24)	. . . . . .
	RL over R.	− 2.6	5.8	3.2	− 2.0	−(.03)	1.6	−(.33)	−(.07)	−(.10)
	MLP over ML. .	2.2	0.0	− .7	− .5	(.07)	(.10)	(.28)	(.26)	. . . . . .
	RLP over RL. . .	4.2	− 6.4	.4	4.1	(.15)	− 2.3	(.59)	(.04)	(.15)
	RLPK over RLP	− .9	8.7	− 1.9	− .9	−(.09)	.3	(.12)	(.08)	(.10)

return of the oat straw to the land was discontinued. In 1922 the return of the wheat straw was likewise discontinued. The application of limestone was discontinued in 1922 after amounts ranging from 7½ to 10 tons an acre on the different series had been applied, and no more will be added until further need for it becomes apparent. In 1923 the phosphate applications were evened up to a total of 4 tons an acre on all phosphate plots, and no more will be applied for an indefinite period. At that time the rotation on the first four series was changed to corn, corn, oats, and wheat with a seeding of hubam clover in the oats on all plots, and a seeding of biennial sweet clover in the wheat on the residues plots. The rotation was changed also on the fifth series to corn, oats, wheat, and a mixture of alfalfa with red clover. The soil treatments are as indicated in Table 17, which summarizes by crops the yields for the period during which the plots have been under full treatment.

The outstanding feature of the results on the Hartsburg field is the large increases produced by organic manure whether in the form of crop residues or stable manure. The behavior of limestone is rather peculiar in that it has been more beneficial where applied with manure than where used with residues. Used with manure it shows some increase in practically all crops, while with residues its effect on several of the crops appears negative.

Altho rock phosphate has given some increases in wheat yield in both the manure and the residues systems, the results with other crops have been such as to render the use of this material unprofitable on this field. The addition of potassium appears to have produced no significant effect except on the one barley crop.

List of Soil Reports Published

1 Clay, 1911
2 Moultrie, 1911
3 Hardin, 1912
4 Sangamon, 1912
5 LaSalle, 1913
6 Knox, 1913
7 McDonough, 1913
8 Bond, 1913
9 Lake, 1915
10 McLean, 1915
11 Pike, 1915
12 Winnebago, 1916
13 Kankakee, 1916
14 Tazewell, 1916
15 Edgar, 1917
16 DuPage, 1917
17 Kane, 1917
18 Champaign, 1918
19 Peoria, 1921
20 Bureau, 1921
21 McHenry, 1921
22 Iroquois, 1922
23 DeKalb, 1922
24 Adams, 1922
25 Livingston, 1923
26 Grundy, 1924
27 Hancock, 1924
28 Mason, 1924
29 Mercer, 1925
30 Johnson, 1925
31 Rock Island, 1925
32 Randolph, 1925
33 Saline, 1926
34 Marion, 1926
35 Will, 1926
36 Woodford, 1927
37 Lee, 1927
38 Ogle, 1927
39 Logan, 1927
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42 Morgan, 1928
43 Douglas, 1929

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