UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT No. 42

MORGAN COUNTY SOILS

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

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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.

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 Morgan county was conducted, and Mr. F. W. Wascher, who as leader of the field party, was in direct charge of the mapping.

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MORGAN COUNTY SOILS

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

Morgan county is located in the west-central part of Illinois. Part of its western boundary is formed by the Illinois river. The location of this county along a water course which at one time carried an immense amount of sediment has an important bearing on the character of the soils, as will appear later.

The climate of Morgan county is typical of central Illinois. It is characterized by a wide range between the extremes of winter and summer and has an abundant, usually well-distributed rainfall. The greatest range in temperature for any one year for the twenty-five years from 1902 to 1927, as recorded at the weather station at Alexander, Illinois, was 127 degrees, in 1914. The highest temperature recorded was 108° in 1918; the lowest, 27° below zero, in 1905. The average date of the last killing frost in spring was April 24; the earliest in the fall, October 16. The average length of the growing season is 175 days.

The average annual rainfall, as recorded at Alexander for this 25-year period, was 36.18 inches. The average rainfall by months for this period was as follows: January, 1.72 inches; February, 1.51; March, 3.02; April, 3.54; May, 4.20; June, 5.02; July, 3.07; August, 4.02; September, 4.56; October, 2.66; November, 2.06; December, 1.80.

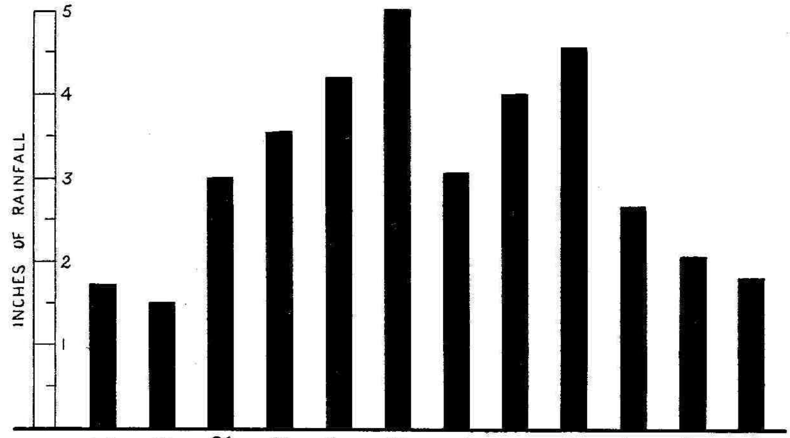


Fig. 1.—Average Monthly Distribution of Rainfall in Morgan County

It will be noted that the more abundant rainfall occurs mainly during the growing season which, of course, is favorable to crop production. The relatively dry July favors the harvesting of grain but the wet June presents an obstacle to the gathering of hay.

[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

Morgan county is agricultural in its interest, tho nearly 30 percent of the area of the county is too rough for ordinary farming. According to the United States Census of Agriculture, 1925, there were 2,326 farms in the county, a decrease of 94 since 1920. About 40 percent of the farms were operated by tenants in 1925.

The principal crops are those common to the corn belt, as shown by the following figures for 1924.

Crops	*Acreage*	*Production*	*Yield per acre*
Corn, total acreage	109,084	....	....
Harvested for grain	97,337	3,815,784 bu.	39.2 bu.
Cut for silage	601	5,105 tons	8.49 tons
Cut for fodder	7,054	....	....
Hogged off	4,092	....	....
Wheat	59,065	1,183,199 bu.	20.0 bu.
Oats threshed for grain	25,149	1,023,108 bu.	40.7 bu.
Oats cut and fed unthreshed	4,424	....	....
Timothy	8,078	....	....
Timothy and clover mixed	4,828	....	....
Clover	5,955	....	....
Alfalfa	1,034	....	....
Hay of all kinds, both tame and wild	21,130	24,430 tons	1.16 tons

These census figures are for but a single year. For the ten-year period 1916 to 1925 the U. S. Department of Agriculture gives the average yield of corn as 38.8 bushels; oats, 34.3 bushels; winter wheat, 19.4 bushels; and tame hay, 1.37 tons.

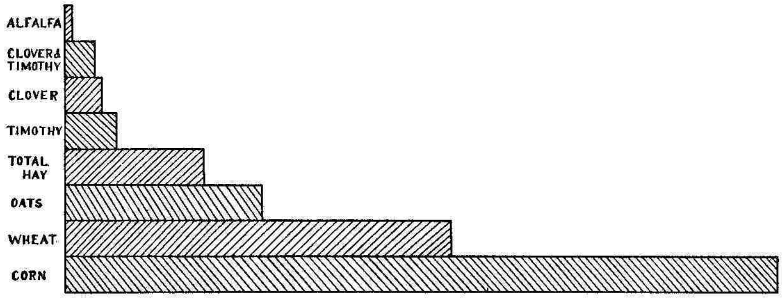


FIG. 2.—RELATIVE ACREAGE OF FIELD CROPS IN MORGAN COUNTY
The diagram brings out the preponderance of land devoted to the three grain crops, corn, oats, and wheat. Legume crops might well occupy a larger proportion of the cultivated acreage. (Data from the 1925 Census)

The following figures taken from the 1925 Census show the character of the livestock interests in the county for the year 1924.

Animals and Animal Products	*Number*	*Value*
Horses	11,159	$645,349
Mules	2,417	190,547
Cattle (total)	23,202	904,564
Dairy cows	4,942	....
Dairy products	......	326,560
Sheep	6,181	63,091
Swine	70,832	903,436
Chickens and eggs	......	620,322
Wool	......	14,798

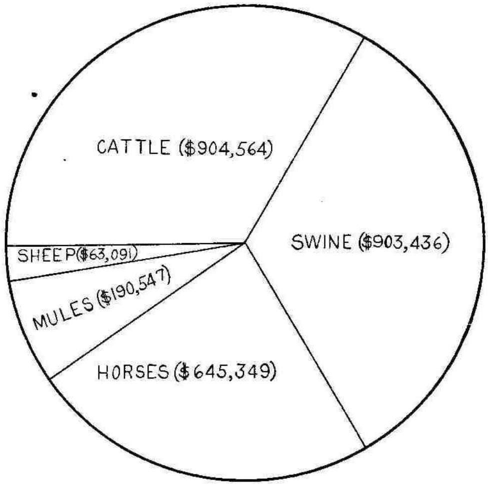


FIG. 3.—RELATIVE VALUE OF THE MORE IMPORTANT CLASSES OF FARM ANIMALS IN MORGAN COUNTY

The value of horses and mules in Morgan county is about equal to that of cattle or of swine. Sheep are of least importance.

SOIL FORMATION

GLACIATION

One of the most important periods in the geological history of the county, from the standpoint of soil formation, was the Glacial period. During and immediately following this remote period, the material that later formed the mineral portion of the soils was being deposited. At that time snow and ice accumulated in the region of Labrador and to the west of Hudson Bay to such an amount that the mass pushed outward from these centers, chiefly southward, until a region was reached where the ice melted as rapidly as it advanced. In moving across the country from the far north, the ice gathered up all sorts and sizes of material, including clay, silt, sand, gravel, boulders, and even immense masses of rock. Some of these materials were carried for hundreds of miles and rubbed against surface rocks and against each other until largely ground into powder. When the ice sheet, or glacier, reached the limit of its advance, the rock material carried by it accumulated along the front edge in a broad, undulating ridge or moraine. With rapid melting, the terminus of the glacier receded, and the material was deposited somewhat irregularly over the area previously covered. The mixture of materials deposited by the glacier is known as boulder clay, till, glacial drift, or simply drift. The average depth of this deposit over the state of Illinois is estimated at 115 feet.

Previous to the ice invasion this region was generally rough and hilly in character. Morgan county was covered by the Illinoian glaciation. The general effect of this glacier was to change the surface from hilly to gently undulating by rubbing down the hills and filling the valleys. Only two small moraines were formed in this county. They both occur just west of Jacksonville.

Altho it did not touch the county, a later ice sheet, known as the Iowan, played an important role in the formation of the soils. During the time when the melting ice front of the Iowan glacier lay to the north of the area now comprizing Morgan county, immense volumes of water, heavily laden with fine sediment, flowed from the ice. This water filled the drainage channels and overflowed the adjacent lowlands, forming terraces. Following each flood state, the water would recede and sediment which had been deposited would be picked up by the wind and redeposited on the upland. This wind-blown deposit, known as loess, is the material from which the upland soils of Morgan county are formed.

PHYSIOGRAPHY AND DRAINAGE

As shown by the accompanying drainage map, Morgan county is well provided with drainage channels which have cut back into the upland from Illinois river. The divides are, for most part, flat or slightly undulating and the erosion

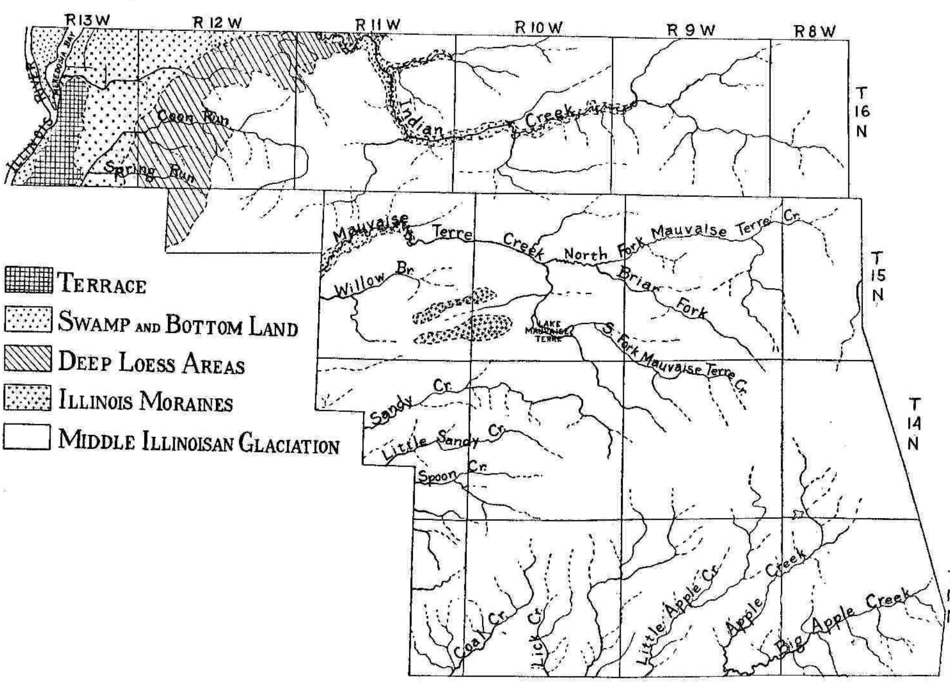


FIG. 4.—DRAINAGE MAP OF MORGAN COUNTY SHOWING STREAM COURSES AND OTHER PHYSIOGRAPHIC FEATURES

slopes on either side of the creeks are steep. The portions of the county which are occupied by the dark-colored soils contain much land which is so nearly level that surface drainage is not good and underdrainage has to be depended on to remove excess water.

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 any soil material, particularly loess, is rather uniform. With the passing of time, however, various physical, chemical, and biological agencies of weathering form 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; and the accumulation of organic material 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,* which includes the surface and subsurface; *B,* the upper subsoil; and *C,* the lower subsoil. Each of these horizons may be and usually is divided into subdivisions; for example, the surface soil is designated as A_1, and the subsurface as A_2. In case there are subdivisions of the subsurface, each is designated by *A*, so we have in certain soils an A_2, an A_3, and an A_4, all being above the *B* horizon, or upper subsoil.

SOIL GROUPS

The soils of Morgan 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, including 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 Lands, which include the large flood plain along Illinois river and also the small flood plains along the creeks which provide drainage for Morgan county.

Table 1 gives the list of soil types in Morgan county, the area of each in square miles and in acres, and also the percentage of the total area. The accompanying colored map, shown in two sections, gives the location and boundary of each soil type which has been mapped in the county.

TABLE 1.—SOIL TYPES OF MORGAN COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	Upland Prairie Soils (200, 400)			
226, 426	Brown Silt Loam[1]	162.76	104 166	28.52
220, 420	Black Clay Loam	58.53	37 459	10.26
225.1, 425.1	Black Silt Loam On Clay	16.74	10 713	2.93
228, 428	Brown-Gray Silt Loam On Tight Clay	.27	174	.05
		238.30	152 512	41.76
	Upland Timber Soils (400, 800)			
434	Yellow-Gray Silt Loam	170.73	109 267	29.92
435	Yellow Silt Loam	80.20	51 328	14.03
874	Yellow-Gray Fine Sandy Loam	5.68	3 635	1.00
875	Yellow Fine Sandy Loam	14.76	9 446	2.59
881	Dune Sand	2.30	1 472	.40
		273.67	175 148	47.94
	Terrace Soils (1500)			
1534	Yellow-Gray Silt Loam	6.92	4 429	1.21
1581	Dune Sand	.18	115	.03
		7.10	4 544	1.24
	Swamp and Bottom-Land Soils (1400)			
1426	Brown Silt Loam	3.26	2 087	.57
1420	Black Clay Loam	2.06	1 318	.36
1420.1	Sandy Black Clay Loam	.30	192	.05
1415	Drab Clay	.47	301	.09
1460	Brown Sandy Loam	2.62	1 677	.46
1471	Brown Fine Sandy Loam	5.87	3 757	1.03
1479	Yellowish Brown Fine Sandy Loam	3.01	1 927	.53
1454	Mixed Loam	31.17	19 948	5.46
1428	Brown-Gray Silt Loam On Tight Clay	.15	96	.03
1468	Brown-Gray Sandy Loam On Tight Clay	.25	160	.04
1401	Deep Peat	.02	13	.01
		49.18	31 476	8.63
	Water	2.44	1 561	.43
	Total	570.69	365 241	100.00

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

INVOICE OF THE ELEMENTS OF PLANT FOOD IN MORGAN 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 whose composition can be greatly changed by adding plant-food 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 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.

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 Morgan county with respect to their content of the different plant-food elements in the upper 6⅔ inches of soil. There appears to be but little relationship among these variations except 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. This 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. This relationship is also maintained in the middle and lower sampling strata.

The upland soils of Morgan county vary in their content of organic matter and nitrogen, the prairie soils being, for the most part, relatively high in these constituents while the timber soils are fairly low. The bottom-land soils likewise vary a great deal in their content of organic matter and of nitrogen. The soils of this group as they occur in Morgan county are in general intermediate between the upland prairie and timber soils in these constituents. The smallest amounts of both nitrogen and organic carbon, 1,220 and 16,240 pounds per acre respectively, are found in Dune Sand, Terrace. However, a sample of the same type taken in the upland was richer in these constituents than the other upland timber types. This is decidedly better, in fact, than Dune Sand, as it usually occurs.

In sandy soils the rapid oxidation and easy drainage permitted by the open, porous character of the soil result in rapid disappearance of organic materials added. For this reason frequent use of green manuring crops or farm manure where available is particularly important, in order to maintain suitable conditions for crop growth.

Nearly all of the soils of the county diminish rapidly in their content of both organic matter and nitrogen with increasing depth. This diminution is usually noticeable in the second stratum, 6⅔ to 20 inches.

Phosphorus High in Bottom-Land Types

The phosphorus content varies quite as widely as do organic matter and nitrogen. The terrace Dune Sand is strikingly low, with only 580 pounds of this element in 2 million pounds of surface soil. The same type in the upland contains nearly twice as much, but as noted above, the upland Dune Sand in Morgan county is decidedly above the average for this type as it usually occurs. The bottom-land types run generally higher in this element than do most of the upland types. However, two bottom-land types contain less than 1,000 pounds, namely, Brown Sandy Loam and Brown-Gray Silt Loam On Tight Clay. On the whole, soils which are very high in organic matter are usually somewhat high in total phosphorus.

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 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 in the majority of the soil types in Morgan county the surface soil contains a larger proportion of phosphorus than the middle stratum and, in some cases, more than the lower stratum.

Sulfur Generally Well Supplied

While other elements are not so closely associated with each other as are organic matter and nitrogen, there is some degree of correlation between sulfur, another element used by growing plants, and 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.

Morgan county soils are only fairly well supplied with sulfur. It ranges, in the surface soil, from a minimum of 80 pounds an acre in Dune Sand, Terrace, up to 1,110 pounds in Black Clay Loam. The average in Morgan county soils is a little more than half that of phosphorus.

The sulfur content decreases with depth in nearly all cases, as may be seen from a comparison of the figures in Tables 2, 3, and 4. This is to be expected since, as stated above, a portion of the sulfur exists in combination with the organic matter of the soil, and not only is the organic matter more abundant in the upper stratum, but also the organic forms of sulfur are held more tenaciously against the leaching action of water than are the inorganic forms.

If growing crops were dependent entirely upon the sulfur contained in the soil for their supply for growth, it would appear questionable from these analyses whether there might be some need for added sulfur fertilizers.

The sulfur available to crops, however, depends not only on the soil supply, but also on the amount 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 three-fourths 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 in rainfall in addition to the soil supply, the facts would indicate that apparently there is little need for sulfur fertilizers in Morgan 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 different parts of the state.

Potassium Content Varies Thruout County

The potassium content of the various soil types also exhibits considerable variation. Dune Sand is noticeably low, especially in the terrace, where it amounts to only 11,580 pounds in the surface soil. Sand soils carry a large proportion of their potassium in the sand grains. The relatively smaller 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 may be partly, if not wholly, offset by the greater facility with which crop roots can penetrate soils of that character as compared with the heavier types. In the other types the potassium content ranges from 17,560 pounds to 35,530 pounds per acre in the surface soil. These amounts are somewhat below those frequently found in the same types as they occur in other counties. However, the total amount is so greatly in excess of crop requirements that the matter of soil management for its liberation, such as good rotations and green manuring, is probably of greater importance than potassium fertilization. The potassium concentration shows practically no variation at different depths.

Calcium and Magnesium Vary Widely Within the Type

The variations in the amounts of calcium and magnesium present in the soils of Morgan county are very wide. Only two of the types, Dune Sand, Terrace, and Brown Sandy Loam, Bottom, are particularly low in either of these elements. In very acid soils it sometimes happens that the calcium present is in such highly insoluble forms that it does not become available rapidly enough for crop growth. The benefit realized from liming such soils may therefore be due, not wholly to the correction of acidity, but probably in part to the fact that the limestone supplies calcium as a plant-food element in a form which rapidly becomes available.

Variations in the amounts of calcium and magnesium in the different depths of those soils which do not contain native calcium carbonate furnish a clue as to the translocations of these elements during the long period in which the different types were developing. In the surface stratum calcium exceeds magnesium in most cases. This would indicate a larger percentage of calcium than of magnesium in the soil-forming materials. The idea is also in harmony with geological evidence. In the second stratum we find the calcium concentration about the same as in the surface, or slightly less, while an increase in magnesium occurs in the second stratum and becomes very pronounced in the lower.

This situation may be explained by the fact that as these two elements are dissolved from the surface soil, they are carried downward in solution. In the downward movement the nature of magnesium causes it to be more rapidly reabsorbed by the soil mass than calcium, tending to force the calcium into the solution to be carried farther down. Consequently, while magnesium begins to accumulate in the middle stratum as well as the lower, the liberated calcium generally begins to accumulate in the third or at still greater depths or may be washed away entirely. These movements of calcium and magnesium, as indicated by the analyses of the different strata, constitute one factor in estimating the relative maturity of the various soil types. The increasing proportion of magnesium to calcium in the lower levels, as compared with the surface soil, tends to be more pronounced in more fully developed or mature profiles. Thus we see a correlation of this chemical characteristic of the soil with the processes of its development.

Some of the calcium figures, as given in the tables, appear to be very erratic. The very large amounts of calcium in some of the types are the result of the presence of finely divided native calcium carbonate (limestone) in some or all of the samples of such types. Sometimes calcium carbonate is present in the surface stratum, and when this is the case it will be found also in the underlying layers. An example is the Dune Sand, Upland, which is in sharp contrast to the same type as sampled in the terrace, where it is acid to the full depth sampled. In the calcareous Dune Sand we have 134,100 pounds of calcium in an acre of surface soil, 284,840 pounds in the middle stratum and 528,180 pounds in the lower. In the acid areas of Dune Sand the amounts of calcium in the three layers are only 5,180 pounds, 9,120 pounds and 15,720 pounds, respectively. Calcium carbonate is readily soluble in the soil water and as it is removed by leaching it disappears from the surface soil first. Thus soils are frequently encountered which contain calcium carbonate in the deeper levels even tho the surface soil is acid. This is the case in Yellow Silt Loam. Here the surface soil is acid, yet it contains 13,800 pounds of total calcium. The second stratum still contains some of its calcium carbonate and therefore has not yet become acid. The calcium content is 89,880 pounds. The lower stratum is still heavily charged with calcium carbonate and contains 249,480 pounds of calcium in 6 million pounds of soil, which after converting to the 2 million pound basis for comparison with the surface stratum is found to be more than six times as concentrated.

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 to persist in the soil in the form of carbonate. The carbonate of carbonate-containing soils is chiefly that of calcium.

Local Tests for Soil Acidity Often Required

It is impracticable to attempt to obtain an average quantitative measure of the calcium carbonate or acidity present in a given soil type because, while some samples may contain large amounts of calcium carbonate, others may contain none, or may actually have a lime-requirement due to soil acidity. We thus have what might 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 15 to 24. To have a sound basis for the application of limestone the owner or operator of a farm must in many cases determine individually the lime requirements of his different fields. The section in the Appendix dealing with the application of limestone (page 33) 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 types and the processes involved in their development.

By adding together the figures for all three strata, as given in Tables 2, 3, and 4, 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

TABLE 2.—MORGAN COUNTY SOILS: PLANT-FOOD ELEMENTS IN UPPER SAMPLING STRATUM, ABOUT 0 TO 6⅔ INCHES

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 (200, 400)							
226, 426	Brown Silt Loam	59 310	4 770	970	810	19 740	7 190	10 120
220, 420	Black Clay Loam	71 400	6 190	1 480	1 110	18 070	11 760	17 930
225.1, 425.1	Black Silt Loam On Clay	69 020	5 070	990	760	18 000	8 300	20 910
228, 428	Brown-Gray Silt Loam On Tight Clay[1]	30 490	2 700	680	([2])	35 530	5 320	8 630
	Upland Timber Soils (400, 800)							
434	Yellow-Gray Silt Loam	31 690	3 100	750	570	21 200	5 470	7 050
435	Yellow Silt Loam	21 740	1 880	1 140	360	23 300	5 880	13 800
874	Yellow-Gray Fine Sandy Loam	21 640	2 220	540	120	20 220	4 040	10 220
875	Yellow Fine Sandy Loam	18 160	1 940	1 240	440	23 380	7 920	16 600
881	Dune Sand	36 660	3 680	920	640	16 500	59 980	134 100
	Terrace Soils (1500)							
1534	Yellow-Gray Silt Loam[3]	......	......	......	......	......	......	......
1581	Dune Sand	16 240	1 220	580	80	11 580	1 760	5 180
	Swamp and Bottom-Land Soils (1400)							
1426	Brown Silt Loam	47 540	3 360	1 660	660	21 280	8 300	17 800
1420	Black Clay Loam	51 380	4 500	1 240	800	18 220	7 880	22 120
1420.1	Sandy Black Clay Loam	50 280	4 340	1 300	680	18 820	5 780	14 420
1415	Drab Clay	47 920	4 260	1 660	980	21 960	8 320	11 960
1460	Brown Sandy Loam	20 360	1 640	800	340	17 560	2 820	5 600
1471	Brown Fine Sandy Loam	43 880	3 400	1 600	540	21 300	5 680	10 560
1479	Yellowish Brown Fine Sandy Loam	28 700	2 320	1 100	720	21 700	4 320	6 060
1454	Mixed Loam[4]	......	......	......	......	......	......	......
1428	Brown-Gray Silt Loam On Tight Clay	37 980	3 360	880	360	22 740	4 820	10 020
1468	Brown-Gray Sandy Loam On Tight Clay	54 920	5 720	1 420	700	21 040	9 100	18 700
1401	Deep Peat[5]	......	......	......	......	......	......	......

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]Samples from an adjoining county were used in these averages. [2]Sulfur analysis not available. [3]See data for soil type No. 434. [4]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [5]This type was not sampled.

feeding range is included in the upper 40 inches. One of the most striking facts brought out of 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. In one of the important types in the county, Brown Silt Loam, Upland, we find that the total quantity of nitrogen in all three strata is 18,070 pounds. This is about the amount of nitrogen contained in the same number of bushels of corn. The amount of phosphorus is a little over one-fourth as much, or 4,760 pounds, but this amount

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

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 (200, 400)							
226, 426	Brown Silt Loam............	90 910	7 720	1 670	1 480	38 910	18 250	26 590
220, 420	Black Clay Loam............	99 430	8 560	2 590	1 840	36 110	22 670	36 130
225.1, 425.1	Black Silt Loam On Clay.....	91 020	6 860	1 740	1 380	35 440	18 900	30 200
228, 428	Brown-Gray Silt Loam On Tight Clay[1]...............	31 680	2 760	1 120	(2)	70 660	15 180	16 880
	Upland Timber Soils (400, 800)							
434	Yellow-Gray Silt Loam[3]......	39 510	4 200	1 390	850	42 040	15 040	12 920
435	Yellow Silt Loam............	18 160	1 680	2 360	440	44 080	50 720	89 880
874	Yellow-Gray Fine Sandy Loam	28 080	3 000	800	160	41 360	15 800	17 320
875	Yellow Fine Sandy Loam.....	18 520	2 200	2 400	160	46 960	23 680	48 040
881	Dune Sand................	53 120	5 120	1 480	1 280	33 160	52 920	284 840
	Terrace Soils (1500)							
1534	Yellow-Gray Silt Loam[3]......	......	......	......	......	......	......	......
1581	Dune Sand................	19 200	1 040	1 160	280	23 000	4 520	9 120
	Swamp and Bottom-Land Soils (1400)							
1426	Brown Silt Loam............	69 920	4 360	2 640	600	42 360	13 920	24 360
1420	Black Clay Loam............	72 040	5 840	1 960	1 200	37 280	18 440	32 200
1420.1	Sandy Black Clay Loam......	69 560	6 120	2 240	1 000	38 240	19 320	31 760
1415	Drab Clay..................	84 560	7 840	3 400	1 560	43 640	18 280	31 640
1460	Brown Sandy Loam..........	38 880	3 600	1 320	400	37 440	6 640	6 720
1471	Brown Fine Sandy Loam.....	82 280	6 520	3 240	1 000	43 680	9 600	17 040
1479	Yellowish Brown Fine Sandy Loam....................	57 320	4 720	2 280	1 000	43 680	5 400	13 920
1454	Mixed Loam[4]...............	......	......	......	......	......	......	......
1428	Brown-Gray Silt Loam On Tight Clay...............	42 080	3 160	920	200	44 120	10 560	16 800
1468	Brown-Gray Sandy Loam On Tight Clay...............	52 760	4 880	2 600	400	40 560	15 160	39 840
1401	Deep Peat[5].................	......	......	......	......	......	......	......

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

[1]Samples from an adjoining county were used in these averages. [2]Sulfur analyses not available. [3]See data for soil type No. 434. [4]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [5]This type was not sampled.

is equivalent to the phosphorus in about 50 percent more corn, namely, 28,000 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 4,770 bushels of corn, and the phosphorus to 5,700 bushels.

Other types show marked contrast to the Brown Silt Loam, just discussed, with respect to total supply 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 the actual number of pounds per acre of the respective elements.

TABLE 4.—MORGAN COUNTY SOILS: PLANT-FOOD ELEMENTS IN LOWER SAMPLING STRATA, ABOUT 20 TO 40 INCHES
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 (200, 400)							
226, 426	Brown Silt Loam............	58 860	5 580	2 120	1 280	61 120	31 720	33 100
220, 420	Black Clay Loam............	54 750	4 580	3 060	1 220	55 060	39 860	69 180
225.1, 425.1	Black Silt Loam On Clay.....	47 220	4 140	2 640	1 440	54 000	35 340	46 230
228, 428	Brown-Gray Silt Loam On Tight Clay[1]..............	37 110	3 720	2 490	(2)	97 650	36 810	33 000
	Upland Timber Soils (400, 800)							
434	Yellow-Gray Silt Loam.......	37 980	3 960	2 600	1 300	63 320	30 020	17 300
435	Yellow Silt Loam............	21 000	1 320	3 660	240	61 800	127 380	249 480
874	Yellow-Gray Fine Sandy Loam	35 280	3 960	1 920	300	61 020	48 000	57 900
875	Yellow Fine Sandy Loam.....	26 640	1 500	3 120	240	71 940	29 100	60 660
881	Dune Sand................	28 200	4 020	2 340	1 260	46 200	31 680	528 180
	Terrace Soils (1500)							
1534	Yellow-Gray Silt Loam[3]......	....	......	......	......	....	......	....
1581	Dune Sand................	18 600	2 520	1 560	180	34 500	4 800	15 720
	Swamp and Bottom-Land Soils (1400)							
1426	Brown Silt Loam............	59 220	3 060	3 840	720	62 160	22 440	34 320
1420	Black Clay Loam............	57 300	4 500	2 340	1 320	60 720	32 520	42 300
1420.1	Sandy Black Clay Loam.....	59 220	5 460	2 520	720	56 580	30 540	46 920
1415	Drab Clay.................	95 340	9 420	4 440	1 620	65 640	26 160	45 360
1460	Brown Sandy Loam..........	43 080	3 720	1 800	1 080	56 520	14 460	11 520
1471	Brown Fine Sandy Loam.....	71 460	5 580	4 440	900	68 580	17 700	39 240
1479	Yellowish Brown Fine Sandy Loam..................	78 960	5 580	3 240	1 680	66 060	29 760	56 700
1454	Mixed Loam[4]..............	....	......	......	......	....	....	....
1428	Brown-Gray Silt Loam On Tight Clay..............	42 480	3 000	3 600	240	64 500	19 380	24 960
1468	Brown-Gray Sandy Loam On Tight Clay..............	46 140	3 600	7 260	1 080	62 880	15 840	24 060
1401	Deep Peat[5]...............	....	......	......	......	....	....	....

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

[1]Samples from an adjoining county were used in these averages. [2]Sulfur analysis not available. [3]See data for soil type No. 434. [4]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type. [5]This type was not sampled.

The 120,000 pounds of potassium present in Brown Silt Loam is equivalent to the amount of this element which is contained in over a half million bushels of corn.

Practical Value and Limitations of Soil Analyses

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 31), 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 soil analysis made in connection with the soil survey is seen to be of value chiefly in two ways. In the first place it reveals at once outstanding deficiencies or other chemical characteristics which alone would affect its 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. As examples of the direct use of the results of chemical investigations may be mentioned the following cases: the marked shortage of potassium in peat soils associated with the need for potassium fertilizers, and the determination of the lime need of soils by chemical tests. It is quite 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 similar differences in the fertilizer need. For example, differences of 100 or 200 pounds of phosphorus per acre in soils containing 1,000 pounds or thereabout should not be considered as of any agricultural significance. Again, the addition of 100 pounds of active nitrogen made 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 of nitrogen.

The second function of soil analysis is to aid in the scientific study of soils from many angles, the ultimate aim of which is, of course, the more economical utilization of the soil for efficient crop production. Not only do chemical studies aid in determining the processes involved in soil development under natural conditions, but also in determining the effects of different soil management and fertilizing practices upon the soil and upon the utilization by crops of the plant-food elements involved.

DESCRIPTION OF SOIL TYPES

UPLAND PRAIRIE SOILS

The upland prairie soils of Morgan county occupy 238.30 square miles, or somewhat less than half the upland area of the county. These soils are uniformly dark in color. There is, however, considerable difference in the color, not only of the various types, but within types, particularly in the case of Brown Silt Loam. 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.

The upland prairie soils in this county include some areas of recent timber growth, where certain kinds of trees have spread over the prairie, but this forestation has not been of sufficient duration to produce the characteristic timber soils. These areas of greater or less width are found along the border of most timber tracts and also on the morainal ridges near Jacksonville.

Brown Silt Loam (226, 426)

Brown Silt Loam, as mapped in Morgan county, occupies 162.76 square miles. It varies in character depending on topography, and would now be separated into at least three types. Each of these differs from the other in character of soil profile, in agricultural value, and in treatment and fertilizer requirements. In the following discussion these types, even tho not shown on the map, are described in such a way that it should not be difficult to recognize each one in the field.

1. Light Brown Silt Loam. This prairie type occurs on areas where the surface drainage is good or even excessive. It has a light brown or even yellowish brown surface, or A_1 horizon. Below the surface horizon, which is usually about 7 inches thick, the material is distinctly yellowish brown and is very friable and permeable. The subsoil, or B horizon, is not easily distinguished because of the absence of much clay accumulation and its consequent friability. It differs, however, from the subsurface, or A_2 horizon, immediately above it in being somewhat less friable, finer in texture, and slightly reddish yellow in color. Other differences, which need not be described here, also help in distinguishing it. Immediately below this subsoil layer, usually at a depth of about 36 inches, the material is very friable and permeable again and is more of a pale yellow in color. The outstanding feature which characterizes this type, as contrasted to the other two about to be described, is its permeability thruout the entire section. This characteristic, together with its topographic position, gives it perfect surface drainage and underdrainage, thus allowing deep root penetration.

Management.—Care must be exercised in farming this type to prevent erosion. Much of the surface material is easily carried off in the form of little-noticed sheet erosion. This soil is not high in organic matter, as its color shows, and therefore is lower in nitrogen than the darker soils. It is medium acid and requires about 3 tons, and in some cases 4 tons, of limestone an acre for alfalfa or sweet clover. The best information available on the treatment of this type comes from the Mt. Morris and Dixon experiment fields which are located in part on Light-Brown Silt Loam. The results from these fields show a very marked response to manure. Where limestone was applied in addition to manure, a further increase was secured which was sufficiently large to pay a good profit on the cost of the limestone. Another treatment which has given very good increases is residues and limestone used in combination. Potash has not increased the yields sufficiently to justify its use. Rock phosphate has not been effective in either the manure or residues systems and its use on this soil cannot be advised on the basis of present information. The reader is asked to turn to pages 44 and 46 for the summarized yields on the Mt. Morris and Dixon fields.

2. **Brown Silt Loam.** This type occupies intermediate topographic positions. It occurs neither on the flat areas nor on the very well-drained slopes. The surface, or A_1 horizon, is darker colored and usually thicker than that of the preceding type, Light Brown Silt Loam; the yellow color of the subsurface, or A_2 horizon, is not so pronounced; and the subsoil, or B horizon, is heavier, less friable, and of a different color. Other differences which are chiefly of technical interest may be omitted here.

Management.—Brown Silt Loam is somewhat less acid than Light Brown Silt Loam but requires limestone to grow alfalfa, sweet clover, or the best red clover. It was originally well supplied with organic matter and has been subject to but little loss of soil material thru erosion. The Kewanee experiment field is located, for the most part, on this soil type. A description of the work on this field, including the experimental data, will be found on page 48. Unfortunately the Kewanee field has several draws crossing the plots, which are a much heavier soil, so that the results from the field cannot be applied to Brown Silt Loam with as much confidence as would otherwise be the case. It is almost certainly true, however, that the presence of the heavier type on the Kewanee field has the effect of diminishing the increases due to treatment. This field shows very good results for manure on corn and oats, but less effect on wheat. Limestone has given profitable increases, particularly in the residues system. Rock phosphate has produced a profitable return in the residues system but has failed to pay for its cost in the manure system. A comparison of rock and superphosphate (acid phosphate) on the Kewanee field, which has been in progress too short a time to allow final conclusions, suggests that better results might be secured on this soil type with superphosphate than with rock phosphate. The need for some form of phosphate is also indicated by the results from the Bloomington field (see page 50), which is located in part on this soil type.

The only concrete suggestion for the fertilization of this soil type which can be made at the present time is that if manure is not available one of the phosphates be applied for wheat after taking care of the nitrogen needs by growing legumes.

3. **Brown Silt Loam On Clay.** This type occupies the nearly level or only gently sloping areas of the upland prairie. Its occurrence should not be confused with the occurrence of the other dark-colored types described below. It is characterized by a dark brown surface soil, or A_1 horizon, which is usually 9 or 10 inches thick. The subsurface, or A_2 horizon, is often darker and heavier than the surface and breaks into well-defined granules. The subsoil, or *B* horizon, occurs at a depth of about 18 inches and is heavy and fairly plastic. The angular granules in the upper portion of this horizon are coated with black and in the lower portion with drab. At a depth of about 38 inches the color becomes gray or drab and there are numerous reddish yellow spots present.

Management.—This type is either not acid or only slightly so. The subsoil, while more compact and plastic than that of either of the preceding types discussed, drains well with tile. The Aledo experiment field is located on Brown Silt Loam On Clay, and the results from this field may be used as a guide in the treatment of this soil type in Morgan county. Manure has given very good returns on this field. Limestone is showing more benefit than it did at first and without it sweet clover has failed to grow. It is advisable, however, on this soil type to make the test for soil acidity before applying limestone. Especially is this important in preparing for alfalfa and sweet clover, for there are portions of the type on which these crops will not grow without liming. Rock phosphate has not caused increases in yield on the manure plots. On the residues plots some increases have followed its use, but with present information as a basis the use of this material on this soil cannot be advised at this time. Phosphate comparisons have been in progress on the Aledo field since 1916, and the reader is asked to turn to page 54 and make a study of the results there discussed, as an aid in solving his phosphate problem on Brown Silt Loam On Clay.

Black Clay Loam (220, 420)

Black Clay Loam is well distributed thruout the dark-soil portions of Morgan county, occupying, all told, nearly 60 square miles. This type is now recognized as made up of two or more types. The several types, however, cannot be easily recognized in the field in spite of the fact that soil differences are associated with topographic differences. The difference in topography between the flat and slightly undulating areas is often so small as to be unnoticed unless attention is called to it. No distinction is made on the map, and a generalized description only can be written for the reason noted above. The surface, or A_1 horizon, is black and heavy and is about 9 inches thick. Below this, to a depth of 16 to 18 inches, the material is drabbish black and is usually heavier than the surface. The subsoil, or *B* horizon, varies in color, plasticity, and other features, depending on which type, as now recognized, is present. In any event it is of such nature that it underdrains satisfactorily.

Management.—The type as mapped varies in lime requirement. The flat. nearly level areas will grow good sweet clover without lime, while the slightly undulating portions require 1 to 2 tons an acre. Particular attention is called to the slight difference in topography, not readily discernible, which is associated with this difference in lime requirement.

Black Clay Loam is a productive soil and needs no treatment other than limestone, as above noted, and fresh organic matter to help keep it in good physical condition. The reader is asked to turn to page 59, where the results and discussion of the Hartsburg experiment field, which is located on this soil type, will be found.

Black Silt Loam On Clay (225.1, 425.1)

Black Silt Loam On Clay occurs thruout the dark-soil portions of Morgan county in association with Black Clay Loam. It differs from the latter type chiefly in having a silty surface, or A_1 horizon, as a result of its topographic position, which is such as to subject it to the deposition of sediment. It is a highly productive soil when well drained and is somewhat easier to work than Black Clay Loam. It occupies a total of nearly 17 square miles in Morgan county and is of considerable agricultural importance even tho of relatively small total area.

Management.—The management recommended for this type is the same as that described for Black Clay Loam, with the exception that rarely, if ever, is limestone needed for good sweet-clover growth. Alkali occurs infrequently on this soil. In places where it is sufficiently concentrated to be harmful, the bad effects may be overcome by the use of potash and the condition slowly improved by good underdrainage.

Brown-Gray Silt Loam On Tight Clay (228, 428)

Brown-Gray Silt Loam On Tight Clay, Upland, is of little importance in Morgan county because of its small total area. Slightly over 170 acres is all that is found and practically all of it occurs in a few small areas in the southeastern corner of the county. It is characterized by a grayish-brown surface soil, or A_1 horizon, a gray subsurface, or A_2 horizon, and a very plastic impervious subsoil, or B horizon.

Management.—This type requires from 2 to 4 tons of limestone an acre for sweet clover, except on spots, of varying size, where lime is present in abundance. These spots are locally known as "slick spots" or "scald spots," and no lime should be applied to them without the advice of the farm adviser or the Experiment Station. Drainage must be taken care of on this soil thru furrows and open ditches. Further suggestions for the management of this soil may be had from the farm adviser or by correspondence with the Agricultural Experiment Station.

UPLAND TIMBER SOILS

The upland timber soils in Morgan county exceed in area the upland prairie soils. They occur adjacent to the streams, presumably because, with the development of natural drainage, conditions became favorable for tree growth. That is to say, forests invaded the prairie as the streams cut their way back by headwater erosion and furnished drainage for the intermittent swamps, which were common. These soils are yellowish gray in color, indicating a deficiency in organic matter. This deficiency results from conditions produced as the forests invaded the prairies. The shade of 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 very little organic matter to the soil, for the leaves and branches either decayed or were destroyed by forest fires.

Yellow-Gray Silt Loam (434)

Yellow-Gray Silt Loam is the most extensive type in Morgan county, aggregating a total of about 171 square miles. It is now recognized that the type as mapped in Morgan county includes three types each of which is definitely correlated with topography. No. 1 occurs on flat, practically level areas; No. 2 on areas of an intermediate or gentle slope; No. 3 on slopes that are very pronounced but which are not sufficiently steep to be classed with eroded land.

Type No. 1, which occurs on the nearly level areas has a gray or slightly brownish gray surface soil, or A_1 horizon, an ashy gray or almost white subsurface, or A_2 horizon, and a subsoil, or B horizon, which is so plastic and compact as to be only slowly permeable to water. The subsoil is perhaps sufficiently impervious to be called "tight clay," but this soil should not be confused with the light-colored tight-clay soils which occur farther south in the state.

Management.—The level areas of Yellow-Gray Silt Loam are strongly acid and low in nitrogen and organic matter. The greatest difficulty encountered in the improvement of this soil is its poor surface drainage and underdrainage. Tile do not draw well because of the nature of the subsoil, and excess water must therefore be taken care of by means of open ditches and furrows. This is sometimes difficult to accomplish because of the nearly level topography. Sweet clover does well on this soil following the application of 3 or 4 tons of limestone an acre. Satisfactory corn crops can be grown following sweet clover, except during seasons which are climatically unfavorable, and small grain may be grown following the corn. This soil is probably best adapted to hay, but in any event limestone must be applied for satisfactory results.

Type No. 2, constituting the undulating portions of Yellow-Gray Silt Loam, is made up of a soil very different from that on the level areas described above. The surface, or A_1 horizon, has a distinctly yellowish cast, the subsurface, or A_2 horizon, is a drabbish gray, never ashy, and the subsoil, or B horizon, is not impervious tho it is compact. Surface drainage and underdrainage are both good on this soil.

Management.—This soil is somewhat less acid than No. 1, but it is nearly as deficient in nitrogen and organic matter. Detailed tests should be made to determine the exact amount of limestone necessary, and following its application sweet clover should be grown in preparation for corn and the small grains. No information is available from experiment fields as to the treatment of this soil. There appears to be no question but that the application of limestone and the growing of sweet clover should be the first step in its improvement. Following this, it is suggested that superphosphate (acid phosphate) be applied for wheat. Rock phosphate may be used instead of superphosphate, tho which would be the more economical cannot be stated without accurate experimental evidence.

Type No. 3, on the rolling portions of Yellow-Gray Silt Loam, is much less extensive than the undulating type described above. This soil has good underdrainage, and the slopes are steep enough to allow such rapid runoff as to be harmful unless precautions are taken to control it. The surface soil, or A_1 horizon, is shallow, rarely exceeding 6 or 7 inches in depth. It contains less gray and more yellow and red material than the more level-lying types. The subsurface, or A_2 horizon, is distinctly gray but frequently is only a very thin layer and is never white and ashy. The subsoil, or B horizon, is non-plastic but may be compact. It is dull brick red in color on the best drained areas.

Management.—This soil is deficient in organic matter, is acid, and requires careful handling to reduce erosion to the minimum. It is a good fruit soil and is well adapted to alfalfa following the application of limestone. The amount of limestone needed varies, but probably is never less than 2 tons an acre for sweet-clover or alfalfa. Detailed tests should be made of each field before liming. It is questionable whether any treatment other than the application of limestone and the growing of sweet-clover should be attempted on this soil.

Yellow Silt Loam (435)

Yellow Silt Loam is extensively developed in Morgan county, occupying a total of 80 square miles. Much of it is unsuited to general farming because of its steep topography. Erosion is active, and surface, subsurface, and subsoil horizons therefore have not usually been developed. However, where there has been sufficient protection to greatly retard the rate of erosion, a shallow surface soil has formed.

Management.—Yellow Silt Loam should, for the most part, be used for permanent pasture, orchard, or timber. There are areas having a slope sufficiently gentle to be farmed successfully if care is taken to reduce erosion to the minimum. A very good use to make of the less-steep slopes is to seed alfalfa after applying limestone. If the alfalfa is preceded by sweet clover, little difficulty should be encountered in getting a stand. See Vienna Field experiments, page 60.

Yellow-Gray Fine Sandy Loam (874)

Yellow-Gray Fine Sandy Loam is very similar to Yellow-Gray Silt Loam. It differs from the silt loam in that it is somewhat coarser in texture, particularly immediately adjacent to the bluffs, it is somewhat less acid, and a smaller proportion of it is level lying. Both these types are formed from loess, but as the loess was blown from the bottom land to the west the coarser particles were deposited first, resulting in material of somewhat coarser texture near the bluff line than farther back on the upland. The reader is therefore referred to the descriptions of the types mapped as Yellow-Gray Silt Loam (page 19) for descriptions of corresponding types mapped as Yellow-Gray Fine Sandy Loam and also for management suggestions.

Yellow Fine Sandy Loam (875)

Yellow Fine Sandy Loam is formed in the same way as Yellow Silt Loam. The two types differ but little except that immediately adjacent to the bluff line, where the former is found, the texture of the material is somewhat coarser than it is farther to the east. The reader is therefore referred to the discussion of Yellow Silt Loam on this page for further information about the character and use of this type.

Dune Sand (881)

Dune Sand is the coarse-textured material laid down by the wind in dune-like formations in certain places adjacent to the bluff line. It is of value for little else than pasture or timber and does not produce very good pasture. In places where the topography permits, sweet-clover pasture may be established. Care must be used to control both wind and water erosion until the growing vegetation acts as a protection.

TERRACE SOILS

Yellow-Gray Silt Loam (1534)

Yellow-Gray Silt Loam, Terrace, occurs in small areas as bench-like formations along the small streams in the county. This type is very similar to the type described as No. 2 under Yellow-Gray Silt Loam (434), page 20, but differs in not having as good surface drainage. The reader is asked to turn to the above description and discussion for information regarding this terrace type.

Dune Sand (1581)

Dune Sand, Terrace, occurs between the bluffs and the Illinois river. It is a recent, wind-deposited formation and is of relatively low agricultural value. The surface 5 or 6 inches is very light brown sand, and immediately below this thin surface horizon the color becomes yellow or reddish yellow. The texture of the material is coarse and there is no subsoil development.

Management.—Dune Sand, Terrace, is drouthy, low in organic matter and nitrogen, and is subject to drifting by the wind where it is not protected by trees or other vegetation. It is a good watermelon soil but does not rank very high for general farming. The Oquawka experiment field is located on this kind of soil, and the reader is asked to turn to the results from this field and their discussion, page 62, for suggestions regarding the management of this soil.

SWAMP AND BOTTOM-LAND SOILS

This group includes the bottom land along the Illinois river and along the creeks of the county. These bottom lands are made up of soil material deposited from running water, and they vary in character with the source of the material deposited, the velocity of the stream flow at the time of the deposition, and drainage conditions since the material was deposited. The soils occurring in these areas vary in age, as indicated by different degrees of development of the horizons of the profiles. Some of the types mapped are of little importance because they occupy only a small area or are swampy.

Brown Silt Loam (1426)

Brown Silt Loam, Bottom, is mapped only in the Illinois bottom in Morgan county. It covers a total area of 3.26 square miles and is a productive type except where poorly drained. Considerable variation occurs in this soil, particularly in the subsurface and subsoil. The areas which are, or have been, poorly drained contain much gray and drab color in these horizons, while the areas which have developed under good drainage conditions show little gray or drab in the lower horizons. The horizons are imperfectly developed in this type and a general type description cannot be written because of the variations in color, texture, plasticity of the subsoil, and other features.

Management.—Brown Silt Loam, Bottom, is not acid except on the higher portions of the type, which are beginning to show a slight acidity. No fertilizer treatment is advised for this soil at the present time, but fresh organic matter should be provided by growing clover at regular intervals.

Black Clay Loam (1420)

Black Clay Loam, Bottom, is found only in the Illinois bottom in Morgan county. Drainage has been provided for much of this type by the construction of ditches, but the drainage is still poor on some areas. The type occupies a total of about 2 square miles. It has a clay loam surface and is drab or gray below 8 or 10 inches in depth. It is a productive soil, needs no lime, and requires only frequent additions of fresh organic matter to insure its continued productivity for many years to come.

Sandy Black Clay Loam (1420.1)

Sandy Black Clay Loam, Bottom, is of little importance in Morgan county because of its limited area. It is similar to the preceding type (1420) except that sufficient sand has become mixed with it to give it a sandy clay loam texture. This type is alkaline in places where it is so situated as to receive seepage water from the adjacent Dune Sand.

Drab Clay (1415)

Drab Clay, Bottom, is of little importance in Morgan county because of its small extent, less than one-half square mile, and because of its low agricultural value. It is poorly drained and no attempt should be made, under present conditions, to bring it under cultivation.

Brown Sandy Loam (1460)

Brown Sandy Loam, Bottom, aggregates a little over 2½ square miles in Morgan county and is located in the Illinois bottom. Portions of this type are swampy and other portions are under cultivation.

The surface soil of this type is light brown in color, and the lower portions of the profile are reddish yellow with little or no horizon development. The texture is sandy thruout the profile.

Management.—There is little encouragement for developing the swampy portions of the type, but the areas which are well drained may be farmed to advantage. Particular attention should be given to plowing down clover, preferably sweet clover, applying lime if necessary to grow this crop.

Brown Fine Sandy Loam (1471)

Brown Fine Sandy Loam, Bottom, is the most extensive type in the Illinois bottom. It covers a total of nearly 6 square miles. This soil is formed from material washed into the bottom from the adjacent bluffs and shows very little horizon development. The surface is light brown fine sandy loam. At a depth of about 7 inches, the color becomes somewhat yellowish and at a depth of about 20 inches a very imperfectly developed subsoil occurs. The youth of this soil, together with the good quality of the material from which it is formed, makes it productive. It is easily worked, very permeable to plant roots, and either not acid or only slightly so.

Management.—Brown Fine Sandy Loam, Bottom, is well adapted to any of the general farm crops, and, with good farming, gives excellent yields. Particular attention should be given to returning leguminous organic matter to this soil as it is relatively low in nitrogen and organic matter. No fertilizer treatment is recommended for this soil at the present time.

Yellowish Brown Fine Sandy Loam (1479)

Yellowish Brown Fine Sandy Loam, Bottom, is closely related to the preceding type, Brown Fine Sandy Loam (1471). It is of the same origin and differs from it only in being younger, and therefore in having a lighter colored surface soil and less development of subsurface and subsoil horizons. It requires the same management as Brown Fine Sandy Loam.

Mixed Loam (1454)

Mixed Loam is very diverse in character. It is the most extensive bottomland type in Morgan county, aggregating a little over 31 square miles. It occurs, for the most part, along the creeks thruout the county. It consists of distinct types occurring in such small areas that they cannot be shown on the map and consequently they are all grouped together and called Mixed Loam. The texture of the surface varies from a sandy loam to a clay loam. The subsurface and subsoil vary in the same way as does the surface.

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.

Brown-Gray Silt Loam On Tight Clay (1428)

Brown-Gray Silt Loam On Tight Clay, Bottom, is of little importance in Morgan county. It occupies only 96 acres and is relatively low in agricultural value. It occurs in the Illinois bottom along the Cass county line. This soil was developed under conditions which resulted in the formation of a thick, impervious subsoil. The surface soil is grayish brown silt loam and the subsurface is more or less gray.

Brown-Gray Sandy Loam On Tight Clay (1468)

Brown-Gray Sandy Loam On Tight Clay is similar in properties and occurrence to Brown-Gray Silt Loam On Tight Clay, but it is somewhat lower in agricultural value. Only 160 acres occur in Morgan county.

Deep Peat (1401)

Only 13 acres of Deep Peat occur in Morgan county. It may be found on the map on the line between Sections 12 and 13, Township 16 North, Range 13 West.

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 of 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

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

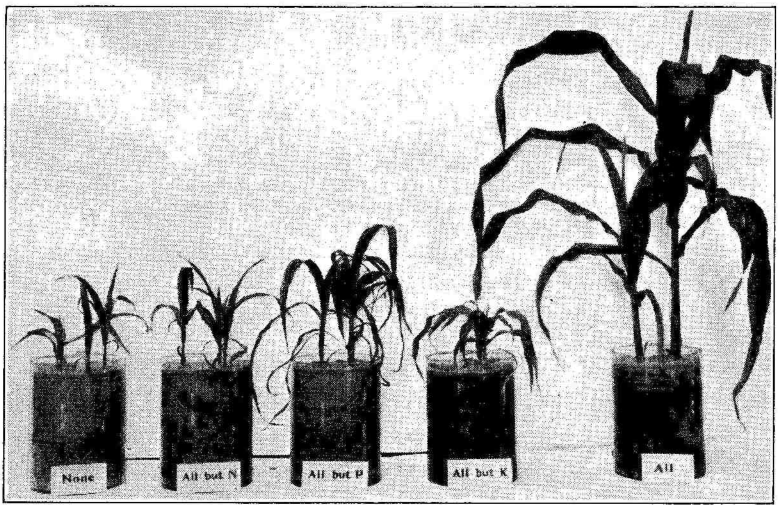


FIG. 6.—ALL ESSENTIAL PLANT-FOOD ELEMENTS MUST BE PRESENT

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: Kind	Produce: Amount	Nitrogen	Phosphorus	Sulfur	Potassium	Magnesium	Calcium	Iron
		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, which include only the clovers, peas, beans, and vetches among our common agricultural plants, are dependent upon the soil for the other six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), 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 bonemeal	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 the 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

[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

Nitrogen presents the greatest practical soil problem in American agriculture. Four important reasons for this are: its increasing deficiency in most soils; its cost when purchased on the open market; its removal in large amounts by crops; and its loss from soils thru leaching. Nitrogen usually costs from four to five times as much per pound as phosphorus. A 100-bushel crop of corn requires 150 pounds of nitrogen for its growth, but only 23 pounds of phosphorus. The loss of nitrogen from soils within a single season may vary from a few pounds to over one hundred pounds per acre, 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 sixty-nine million pounds of atmospheric nitrogen. The nitrogen above one square mile weighs twenty million tons, an amount sufficient to supply the entire world for four or five decades. This large supply of nitrogen in the air is the one to which the world must eventually turn.

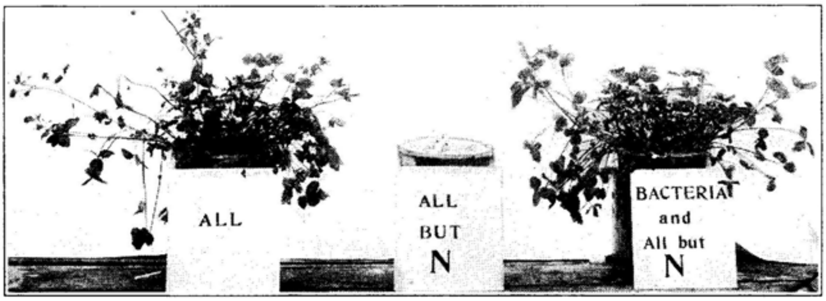


FIG. 7.—LEGUMES CAN OBTAIN THEIR NITROGEN FROM THE AIR

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.

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.

The phosphorus content of the soil is dependent upon the origin of the soil. The removal of phosphorus by continuous cropping slowly reduces the amount of this element in the soil 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 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 materials containing phosphorus which are applied to land as fertilizer. The more important of these are bone meal, acid phosphate, natural raw rock phosphate, and basic slag. Obviously that carrier of phosphorus which gives the most economical returns, as considered from all standpoints, is the most suitable one to use. Altho this matter has been the subject of much discussion and investigation the question still remains unsettled. Probably there is no single carrier of phosphorus that will prove to be the most economical one to use under all circumstances because so much depends upon soil conditions, crops grown, length of haul, and market conditions.

Bone meal, prepared from the bones of animals, appears on the market in two different forms, raw and steamed. Raw bone meal contains, besides the phosphorus, a considerable percentage of nitrogen which adds a useless expense if the material is purchased only for the sake of the phosphorus. As a source of phosphorus, steamed bone meal is preferable to raw bone meal. 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.

Superphosphate (acid phosphate) 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. Besides phosphorus, superphosphate also contains sulfur, which is likewise an element of plant food. The phosphorus in superphosphate is more readily available for absorption by plants than that of raw rock phosphate. Superphosphate of good quality should contain 6 percent or more of the element phosphorus.

Rock phosphate, sometimes called floats, is a mineral substance found in vast deposits in certain regions. The phosphorus in this mineral exists chemically as tri-calcium phosphate, and a good grade of the rock should contain 12½ percent, or more, of the element phosphorus. The rock should be ground to a powder, fine enough to pass thru a 100-mesh sieve, or even finer.

The relative cheapness of raw rock phosphate, as compared with the treated or acidulated material, makes it possible to apply for equal money expenditure considerably more phosphorus per acre in this form than in the form of superphosphate, the ratio being, under the market conditions of the past several years, about 4 to 1. That is to say, under these market conditions, a dollar will purchase about four times as much of the element phosphorus in the form of rock phosphate as in the form of superphosphate, which is an important consideration if one is interested in building up a phosphorus reserve in the soil. As explained above, more very carefully conducted comparisons on various soil types under various cropping systems are needed before definite statements can be given as to which form of phosphate is most economical to use under any given set of conditions.

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 phosphate is a by-product in the manufacture of steel. It contains a considerable proportion of basic material and therefore it tends to influence the soil reaction.

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, which are silt loams and clay loams, are well stocked with potassium, altho it exists largely in a slowly soluble form. Such soils as sands and peats, however, are likely to be low in this element. On such soils this deficiency may be remedied by the application of some potassium salt, such as potassium, sulfate, potassium chlorid, kainit, or other potassium compound, and in many instances this is done at great profit.

From all the facts at hand it seems, so far as our great areas of common soils are concerned, that, with a few exceptions, the potassium problem is not one of addition but of liberation. The Rothamsted records, which represent the oldest soil experiment fields in the world, show that for many years other soluble salts have had practically the same power as potassium salts to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

Further evidence on this matter is furnished by the Illinois experiment field at Fairfield, where potassium sulfate has been compared with kainit both with and without the addition of organic matter in the form of stable manure. Both sulfate and kainit produced a substantial increase in the yield of corn, but the cheaper salt—kainit—was just as effective as the potassium sulfate, and returned some financial profit. Manure alone gave an increase similar to that produced by the potassium salts, but the salts added to the manure gave very little increase over that produced by the manure alone. This is explained in part, perhaps, by the fact that the potassium removed in the crops is mostly returned in manure properly cared for, and perhaps in larger part by the fact that decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

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

In considering the conservation of potassium on the farm it should be remembered that in average livestock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phophorus from the food they consume, but that they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in livestock farming, is negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

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, of course, 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 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 Morgan County)

The University of Illinois has operated altogether about fifty soil experiment fields in different sections of the state and on various types of soil. Altho some of these fields have been discontinued, the large majority are still in operation. It is the present purpose to report the results from certain of these fields located on types of soil 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 40 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 every crop represented every year.

Farming Systems

On many 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 alfafa, that crop being harvested for hay the same as in the livestock system. Some modifications have been introduced in recent years as will be 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 has, for the most part, been standardized according to a rather definite system, altho deviations from this system occur now and then, particularly in the older fields.

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 grain 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.—The yearly acre-rates of application have been: for limestone, 1,000 pounds; for raw rock phosphate, 500 pounds; and for potassium, usually 200 pounds of kainit. When kainit was not available, owing to conditions brought on by the World war, potassium carbonate was used. The initial application of limestone has usually been 4 tons per acre.

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 (acid phosphate), bP = bonemeal, rP = rock phosphate
K = Potassium (usually in the form of kainit)
N = Nitrogen (usually in the form contained in dried blood)
Le = Legume used as green manure
Cv = Cover crop
( ) = Parentheses enclosing figures, signifying tons of hay, as distinguished from bushels of seed

THE MT. MORRIS FIELD

The Mt. Morris experiment field was established in 1910 at Mt. Morris in Ogle county. The soil represents fairly well the type Light Brown Silt Loam, altho the plots are not althogether uniform in this respect. The plots considered here comprize four series under a rotation of corn, oats, clover, and wheat, with soil treatments as indicated in the accompanying table. The application of straw to the residues plots has been discontinued in these later years. In 1922 the application of limestone, and in 1923 the application of rock phosphate, were indefinitely suspended in order to observe the residual effect of these materials.

A summary of the results of the work is given in Table 7, in the form of the average annual crop yields for the years since the complete soil treatments have been in effect.

The outstanding results from these records are those produced by the manure treatment. Over 14 bushels of corn, over 9 bushels of oats, 4.7 bushels of wheat. and a half ton of clover have been the average annual acre increases in crop yields from the manure plots over the corresponding checks. Residues alone have

FIG. 8.—CORN ON THE MT. MORRIS FIELD

The two pictures represent the extremes in corn production on this field. Where the untreated land has produced as a fourteen-year average 44.6 bushels an acre, the land under the residues, limestone, phosphate, potash treatment has yielded 67.2 bushels. The most profitable treatment on this field, however, has been that of residues and limestone, which has produced 62.2 bushels an acre.

TABLE 7.—MT. MORRIS FIELD: SUMMARY OF CROP YIELDS

Average Annual Fields 1913-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat *13 crops*	Corn *15 crops*	Oats *15 crops*	Clover *12 crops*	Soybeans *2 crops*
1	0	22.8	44.4	57.7	(1.94)	(1.56)
2	M	27.5	59.0	67.1	(2.54)	(1.70)
3	ML	33.6	64.1	70.6	(2.96)	(1.80)
4	MLP	35.0	63.7	71.5	(2.89)	(1.92)
5	0	23.0	43.9	54.2	(1.65)	(1.34)
6	R	24.8	50.7	58.5	(1.70)	(1.60)
7	RL	32.0	62.2	68.2	(2.20)	(1.89)
8	RLP	35.2	65.5	69.9	(2.21)	(2.07)
9	RLPK	35.4	66.9	70.2	(2.24)	(2.00)
10	0	24.1	42.9	51.9	(1.61)	(1.68)
	Crop Increases					
	M over 0	4.7	14.6	9.4	(.60)	(.14)
	R over 0	1.8	6.8	4.3	(.05)	(.26)
	ML over M	6.1	5.1	3.5	(.42)	(.10)
	RL over R	7.2	11.5	9.7	(.50)	(.29)
	MLP over ML	1.4	− .4	.9	−(.07)	(.12)
	RLP over RL	3.2	3.3	1.7	(.01)	(.18)
	RLPK over RLP	.2	1.4	.3	(.03)	−(.07)

also produced increases in the crop yields altho the effect is much less pronounced than that of manure alone.

Limestone has been profitably used in both the manure and residues systems but the benefit has been greater in the residues system.

The rock phosphate, as usual, has been somewhat more effective used with residues than with manure, but under present market conditions and used in the quantity employed in these experiments, it has thus far not returned its costs, even with residues. However, as noted above, applications of phosphate have been suspended and the residual effect of the accumulated phosphorus in the soil during the years to come will be awaited with interest.

No significant effect is apparent from potassium as used in these experiments.

THE DIXON FIELD

A summary of the results from the Dixon experiment field are presented here, inasmuch as the soil of this field is similar to some of that found in Morgan county. This field includes about 21 acres and is laid out into two general systems of plots, a major and a minor system. The results from the major system will be considered here.

The rotation practiced has been wheat, corn, oats, and clover. The treatment of the plots and management of the crops were, for the most part, maintained up to 1922 according to the general plan described on pages 43 and 44. The most important modification of the plan has been the discontinuance, within the last few years, of the applications of limestone, phosphate, and straw residues.

TABLE 8.—DIXON FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1912-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat *12 crops*	Corn *16 crops*	Oats *15 crops*	Barley *1 crop*	Clover *10 crops*	Soybeans *4 crops*
1	0	20.4	36.3	48.3	43.3	(1.71)	(1.46)
2	M	26.6	55.3	61.5	46.4	(2.45)	(1.78)
3	ML	30.2	59.8	64.8	55.2	(2.70)	(1.92)
4	MLP	33.4	62.3	66.6	58.3	(2.83)	(1.97)
5	0	21.4	41.9	53.5	49.5	(1.41)	(1.18)
6	R	24.2	49.8	57.6	53.8	(1.49)	(1.35)
7	RL	27.4	56.3	61.4	54.5	(1.79)	(1.35)
8	RLP	32.0	57.6	64.1	59.0	(2.04)	(1.33)
9	RLPK	32.9	61.1	63.6	56.9	(2.21)	(1.15)
10	0	19.8	40.5	50.8	45.4	(1.81)	(1.45)
	Crop Increases						
	M over 0	6.2	19.0	13.2	3.1	(.74)	(.32)
	R over 0	2.8	7.9	4.1	4.3	(.08)	(.17)
	ML over M	3.6	4.5	3.3	8.8	(.25)	(.14)
	RL over R	3.2	6.5	3.8	.7	(.30)	(0.00)
	MLP over ML	3.2	2.5	1.8	3.1	(.13)	(.05)
	RLP over RL	4.6	1.3	2.7	4.5	(.25)	−(.02)
	RLPK over RLP	.9	3.5	− .5	−2.1	(.17)	−(.18)

FIG. 9.—CLOVER ON UNTREATED LAND, DIXON FIELD

A cutting of red-clover hay obtained from an untreated plot. Compare with the crop shown in Fig. 10.

Table 8 gives a summary of the results in terms of the average annual crop yields obtained since the plots have been under complete treatment.

In considering these results, the most striking feature to be observed is the outstanding effect of farm manure (M). The average annual increase due to the use of manure alone has amounted to 19 bushels of corn an acre, more than 13 bushels of oats, over 6 bushels of wheat, $\frac{3}{4}$ of a ton of clover, and $\frac{1}{3}$ of a ton of soybean hay.

FIG. 10.—CLOVER ON TREATED LAND, DIXON FIELD

A cutting of red-clover hay produced under the residues-limestone-phosphate treatment. Here we have a yield of 1,319 pounds, more than two and one-third times the yield on the untreated land.

Organic manure in the form of crop residues (R) has also produced increases in yields altho not to the extent of those produced by animal manure.

Limestone (L) in addition to organic manures has, with a single exception, effected more or less improvement, probably sufficient to cover the expense of application.

Rock phosphate (P), as usual, shows up to best advantage when used with residues on the wheat crop. The effect on other crops, however, has been such that the increases in yield are not sufficient to cover the cost of the application under existing market conditions.

Altho potassium (K) has produced an average increase of 3.5 bushels an acre in corn, the effects on other crops are such as to render its use unprofitable in growing these common field crops.

THE KEWANEE FIELD

Experiments on the Major Series

The Kewanee field, located in Henry county, represents in the main the soil type Brown Silt Loam, altho a draw traversing the field in a winding direction contains a narrow streak of a heavier type designated as Black Clay Loam On Drab Clay. The Kewanee field has been in operation since 1915. The crops grown on the main series of plots are wheat, corn, oats, and clover. The arrangement of plots as well as the systems of soil treatment are indicated in Table 9.

TABLE 9.—KEWANEE FIELD: SUMMARY OF CROP YIELDS

Average Annual Yields 1917-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat *9 crops*	Corn *11 crops*	Oats *11 crops*	Clover *10 crops*
1	0	30.0	53.9	59.4	(1.64)
2	M	33.6	65.0	70.3	(2.26)
3	ML	35.8	68.7	73.0	(2.30)
4	MLP	40.7	70.0	71.2	(2.46)
5	0	31.8	54.5	60.6	(1.60)
6	R	33.3	56.7	59.2	(1.55)
7	RL	35.3	64.9	61.9	(1.78)
8	RLP	40.9	69.5	68.2	(1.98)
9	RLPK	41.2	73.0	70.1	(2.03)
10	0	29.4	49.7	56.6	(1.38)
	Crop Increases				
	M over 0	3.6	11.1	10.9	(.62)
	R over 0	1.5	2.2	− 1.4	−(.05)
	ML over M	2.2	3.7	2.7	(.04)
	RL over R	2.0	8.2	2.7	(.23)
	MLP over ML	4.9	1.3	− 1.8	(.16)
	RLP over RL	5.6	4.6	6.3	(.20)
	RLPK over RLP	.3	3.5	1.9	(.05)

The table gives a summary of the crop yields by annual averages, including the years since the complete soil treatments have been in effect. In the lower part of the table the comparisons expressed as crop increases resulting from the respective soil treatments bring out the following points of interest.

Animal manure (M) used alone has had a very beneficial effect, especially with corn, oats, and clover. Residues alone (R) have had little effect on crop yields.

Limestone (L) used in addition to organic manures appears to have effected more or less improvement in all cases altho where used with animal manure on the clover the increase is scarcely significant.

Phosphorus (P) shows up to advantage on the wheat crop, and in the residues system the rock phosphate has produced a profitable return. A fact which these general averages fail to show is that with both limestone and phosphate the effects have been more favorable in recent years than in the earlier years of the experiments.

Altho an increase of 3.5 bushels of corn appears as a result of potassium (K) application, in view of the insignificant response by the other crops the purchase of potassium fertilizer for use in this kind of a cropping system on this kind of soil would appear not to be profitable.

Experiments on the Minor Series

In addition to the experiments described above, the same rotation is being conducted on a smaller series of plots where a comparison of rock phosphate and superphosphate (acid phosphate) is being made.

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 as practiced on the larger series was established on these series. In this phosphate comparison rock phosphate was 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 has been applied at the same time as the superphosphate. Superphosphate is used on Plots 2 and 4 and 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 their values are given in Table 10.

TABLE 10.—KEWANEE FIELD: PHOSPHATE EXPERIMENT
Average Annual Yields and Corresponding Money Values 1922-1927
Bushels or (tons) per acre

Soil treatment	Wheat *6 crops*	Corn *6 crops*	Oats *6 crops*	Hay *6 crops*	Value per acre
Rock phosphate..................	44.7	71.7	75.6	(3.50)	$45.41
Superphosphate[1]..................	47.1	70.9	78.4	(3.44)	46.06
Limestone, rock phosphate.........	40.7	69.1	74.4	(3.52)	43.72
Limestone, superphosphate[1]........	47.8	70.3	76.7	(3.61)	46.60

[1]Acid phosphate.

The difficulty of 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 readily 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 this purpose the following set of prices are assumed as representing the average market conditions for the past six years (December 1 quotations): wheat, $1.20 a bushel; corn, 68 cents; oats, 40 cents; and hay, $14.00 a ton. For the cost of the 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.

Applying these prices to the yields given in Table 10, it appears that, of the four different tests, the highest average annual gross return, $46.60, was given by the superphosphate with limestone. Upon adding the limestone, the return from superphosphate was increased by only 54 cents an acre, thus indicating that the purchase of limestone for this combination was unprofitable. The returns from rock phosphate with limestone were $1.69 an acre less than those from rock phosphate alone. Thus of the treatments included in this test the most profitable lies in one of the two forms of phosphates used alone, and the results thus far show a greater gross return per acre of 65 cents in favor of the superphosphate.

It is of interest to note that 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 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 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. The phosphorus on this field has been supplied in the form of steamed bone meal at the rate of 200 pounds an acre a year.

Table 11 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 combinations in which they have been applied.

TABLE 11.—BLOOMINGTON FIELD: SUMMARY OF CROP YIELDS

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

Serial plot No.	Soil treatment applied	Corn	Oats	Wheat	Clover[1]
		10 crops	*4 crops*	*4 crops*	*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 are evaluated as hay.

The value of limestone (L) 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 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 has been beneficial.

The residues treatment (R) 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 applied in the form of steamed bone meal (bP). In all the grain crops on every plot where bone meal has been applied there is 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 the phosphorus treatment has produced an average increase in the yield of corn of about 13 bushels an acre, while the yield of oats has been increased by about 20 bushels, and that of wheat by about 22 bushels an acre. Similar increases, tho not so pronounced, appear in comparing Plot 5 with Plot 8 where potassium instead of residues is present.

Quite different are the results from the use of potassium (K) on this field. The potassium has been applied mainly in the form of potassium sulfate, but in 1917 when this material became unavailable thru war conditions, potassium carbonate was substituted. There is a moderate increase in the corn yield where potassium has been used and particularly where residues are absent. Otherwise, the small gain 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.

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 (acid phosphate) with bone meal, and at the same time to determine the residual effect of the accumulated phosphorus resulting from its continuous application in presumably somewhat excessive amounts. Table 12 indicates the arrangement of these new treatments and also gives the results of the four 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.

In considering the results it should be borne in mind that they are based upon only four years' experience, a rather short period for drawing final conclusions in this sort of experimentation; also that the soil of these plots is somewhat variable, with little provision for duplication; and that some of the treatments are not now strictly comparable with one another on account of the previous treatment of the plots. Nevertheless, making allowances for all of these facts, certain figures in the last column of the table indicate effects worthy of consideration.

In answering the question 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 (acid phosphate) 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

TABLE 12.—BLOOMINGTON FIELD: NEW PHOSPHATE EXPERIMENTS
Crop Yields and Values 1924-1927—Bushels or (tons) and dollars per acre

Serial plot No.	Treatment		1924	1925	1926	1927	Average annual acre values		
	Previous	Present	Oats	Clover	Wheat	Corn	Gross	Cost of treatment	Net
1-N	0	R	60.6	(.79)	29.3	49.8	$28.09	$ .75	$27.29
1-S	0	0	58.4	(2.54)	19.5	41.0	30.18	......	30.18
2-N	L	RLP (bone)	72.6	(1.63)	35.0	58.6	36.09	6.55	29.54
2-S	L	RL	53.2	(.75)	18.7	46.0	22.85	1.75	21.10
3-N	RL	RLP (rock)	68.2	(2.18)	32.5	63.6	37.88	5.25	32.63
3-S	RL	RLP (super)	71.3	(1.74)	41.0	67.6	39.80	4.55	35.25
4-N	LP (bone)	RLP (bone)[1]	57.6	(1.81)	37.3	60.0	35.74	7.75	27.99
4-S	LP (bone)	RLP (bone)[2]	67.2	(1.89)	36.7	63.6	37.89	5.35	32.54
5-N	LK	RLKP (rock)	63.2	(1.66)	32.5	61.4	34.83	7.54	27.29
5-S	LK	RLKP (super)	78.4	(1.59)	40.7	69.4	40.26	6.84	33.42
6-N	RLP (bone)	RLP (bone)[1]	68.8	(2.18)	40.5	60.8	39.89	7.75	32.14
6-S	RLP (bone)	RLP (bone)[2]	71.6	(2.21)	40.0	64.2	40.79	5.35	35.44
7-N	RLK	RLKP (rock)	71.2	(2.11)	35.3	66.4	39.30	7.54	31.76
7-S	RLK	RLKP (super)	80.9	(1.66)	40.7	74.8	41.79	6.84	34.95
8-N	LKP (bone)	RLKP (bone)[1]	60.9	(1.69)	39.2	67.4	37.79	10.04	27.75
8-S	LKP (bone)	RLKP (bone)[2]	65.0	(1.59)	36.0	69.4	37.25	7.64	29.61
9-N	RLKP (bone)	RLKP (bone)[1]	60.9	(2.18)	43.8	75.8	42.63	10.04	32.59
9-S	RLKP (bone)	RLKP (bone)[2]	72.2	(1.65)	41.5	77.8	41.51	7.64	33.87
10-N	RKP (bone)	RKP (bone)[1]	48.2	(1.93)	45.7	56.6	37.32	9.04	28.28
10-S	RKP (bone)	RKP (bone)[2]	51.2	(1.53)	43.0	60.6	35.97	6.64	29.33
11-N	[3]	RP (rock)	70.4	(1.68)	45.3	61.8	39.74	4.25	35.49
11-S	[3]	RP (super)	60.0	(1.78)	44.5	63.0	38.88	3.55	35.33

[1]Bone meal applications resumed in 1924. [2]No bonemeal applied since 1917. [3]New plot added in 1924.

before the present experiments were begun and may therefore have an advantage over the bone meal plot. However this may be, the results as they stand place both rock phosphate and superphosphate ahead of bone meal.

It is interesting to observe that in the three plots giving the very highest net return (Plots 6-S, 11-N, and 11-S) all three forms of phosphate—bone meal, rock phosphate, and superphosphate—are represented in the respective treatments and the differences among the results are so small as to be negligible.

Between rock phosphate and superphosphate four direct comparisons under varying conditions are afforded. On the new plots, 11-N and 11-S, no limestone has been applied and here the difference in the net returns from the two forms of phosphate is insignificant.

In the other comparable tests between rock phosphate and superphosphate (Plots 3, 5, and 7) limestone is used in the combination, and in each case the superphosphate has given the higher net return. Thus, as is so often the case, limestone appears to exert a depressing effect upon the efficiency of rock phosphate. In the final result, however, the simpler system of residues and phosphate appears to be fully as effective, so far as net value of crops per acre is concerned, as the more complex systems in which limestone or limestone and potassium are included.

On the whole, therefore, the data of these four years appear to furnish no conclusive evidence for discriminating among the three forms of phosphate.

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 summarizing the main lessons brought out by the Bloomington experiments, the following statements may be made.

1. The results indicate an outstanding phosphorus hunger.
2. This phosphorus need is satisfied by the application of either bone meal, rock phosphate, or superphosphate.
3. So far as the data from these particular experiments are concerned, there is no indisputable evidence for discrimination among these three carriers.
4. On these plots there is a pronounced residual effect from previous excessive applications of bone meal.

THE ALEDO FIELD

An experiment field on 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.

Experiments on the Major Series

The major system comprizes four series made up of 10 plots each. The plots were handled substantially as described above 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 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 these changes, no residues except cornstalks and the green manure have been returned to the residues plots. The limestone applications were temporarily abandoned in 1923. No more will be applied until there appears to be a need for them. The phosphate applications were evened up to a total of 4 tons an acre in 1924, and no more will be applied on the west halves of these plots for some time at least.

Table 13 presents a summary of the results showing the average annual yields obtained for the period beginning when complete soil treatment came into

TABLE 13.—ALEDO FIELD: SUMMARY OF CROP YIELDS

Average Annual Yields 1912-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat *13 crops*	Corn *21 crops*	Oats *15 crops*	Clover *6 crops*	Soybeans *3 crops*	Stubble clover[1] *1 crop*
1	0	30.0	55.8	57.6	(2.21)	(1.60)	(0.00)
2	M	34.7	69.6	64.7	(2.74)	(1.63)	(0.00)
3	ML	35.0	73.7	67.7	(3.12)	(1.60)	(1.65)
4	MLP	36.7	74.9	68.1	(3.05)	(1.61)	(1.71)
5	0	30.7	58.2	59.7	(2.00)	(1.61)	(0.00)
6	R	31.4	64.3	60.7	(1.91)	(1.65)	(0.00)
7	RL	33.7	71.6	66.1	(1.79)	(1.88)	(1.20)
8	RLP	37.7	74.1	67.4	(2.08)	(2.03)	(1.25)
9	RLPK	37.3	75.4	69.7	(1.73)	(2.09)	(1.57)
10	0	30.1	55.9	58.0	(2.38)	(1.62)	(0.00)
	Crop Increases						
	M over 0	4.7	13.8	7.1	(.53)	(.03)	(0.00)
	R over 0	.7	6.1	1.0	−(.09)	(.04)	(0.00)
	ML over M	.3	4.1	3.0	(.38)	−(.03)	(1.65)
	RL over R	2.3	7.3	5.4	−(.12)	(.23)	(1.20)
	MLP over ML	1.7	1.2	.4	−(.07)	(.01)	(.06)
	RLP over RL	4.0	2.5	1.3	(.29)	(.15)	(.05)
	RLPK over RLP	− .4	1.3	2.3	−(.35)	(.06)	(.32)

[1]Hubam clover was grown on Plots 3 and 4, biennial white sweet clover on Plots 7, 8, and 9.

sway. The lower section of this table gives comparisons in terms of crop increases intended to indicate the effect of the different fertilizing materials applied.

In looking over these results we may observe first the beneficial effect of animal manure on all crops, but especially marked on the corn. This suggests the advisability of carefully conserving and regularly applying all stable manure produced on the farm. Residues alone have been beneficial for corn but have shown little effect on the other crops of the rotation.

Limestone has been more effective applied with residues than with manure. An interesting fact not brought out in these averages is that the beneficial effect has increased in the later years.

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 even here the margin of profit on these crop increases is too narrow to assure the profitable use of rock phosphate applied in the manner of these experiments. However, the economic story has not all been told, for the application of lime and phosphate on these plots has been discontinued in order to observe the residual effects, and the results of the next few years, will be awaited with great interest.

For the effect of potassium treatment (K) Plots 8 and 9 may be compared. No significant response appears as the result of applying potassium, so far as these common field crops show.

A number of problems have arisen out of the experience on this and other experiment fields which call for some revision of the investigations described above, and accordingly certain changes have been made in the conduct of these plots which are intended especially to throw more light upon the problems of liming and applying phosphorus. (See Soil Report No. 29).

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 (acid phosphate) is applied at the yearly rate of 333⅓ pounds per acre. On a third series rock phosphate serves as the source of phosphorus, applied at the rate of 666⅔ pounds per acre yearly, and on the last series, basic slag phosphate is applied at the rate of 250 pounds per acre yearly.

A summary of the yields on these plots is given in Table 14. The differences in crop yields presumed to have resulted from applying the various forms of phosphatic fertilizers will be found in Table 15 for the twelve crops harvested since the beginning of the applications up to 1927. 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.

TABLE 14.—ALEDO FIELD: PHOSPHATE EXPERIMENT
General Summary—Average Annual Yields 1916-1927
Bushels or (tons) per acre

Plot No.	Soil treatment applied	Wheat *2 crops*	Corn *5 crops*	Oats *3 crops*	Clover *1 crop*	Soybeans[1] *1 crop*
501	R	38.2	60.4	66.1	(2.88)	18.9
502	R, bone meal	47.0	72.0	76.2	(3.25)	19.0
503	RL, bone meal	48.8	73.9	72.4	(3.48)	23.2
504	RL	38.8	68.0	64.2	(2.61)	22.6
601	R	38.1	61.1	67.6	(3.17)	19.5
602	R, superphosphate[2]	49.4	69.6	74.9	(3.23)	18.7
603	RL, superphosphate[2]	51.3	72.4	71.3	(3.53)	23.1
604	RL	40.0	66.7	65.3	(3.06)	24.6
701	R	39.5	62.8	67.5	(3.41)	20.8
702	R, rock phosphate	48.0	71.6	72.2	(3.60)	23.3
703	RL, rock phosphate	47.1	72.5	67.4	(3.82)	28.1
704	RL	41.4	68.8	65.6	(3.15)	26.9
801	R	39.8	60.2	57.9	(2.62)	18.0
802	R, slag phosphate	49.1	69.4	73.4	(3.66)	20.6
803	RL, slag phosphate	52.2	72.4	67.5	(3.63)	23.7
804	RL	40.8	65.0	63.7	(2.99)	21.8

[1]No residues were applied for this crop. [2]Acid phosphate.

TABLE 15.—ALEDO FIELD: AVERAGE ANNUAL CROP INCREASES PRODUCED BY THE VARIOUS FORMS OF PHOSPHATE, AND THEIR VALUE, COMPUTED FROM YIELDS IN TABLE 14

Bushels or (tons) per acre

Comparison of treatments	Wheat *2 crops*	Corn *5 crops*	Oats *3 crops*	Clover *1 crop*	Soy-beans *1 crop*	Value of increase *12 crops*	Cost of phos-phate *12 years*	Profit from *12 crops*	Profit per acre per year
Bone meal, residues, *over* residues	8.8	11.6	10.1	(.37)	.1	$78.02	$48	$30.02	$2.50
Bone meal, residues, lime, *over* residues, lime	10.0	5.9	8.2	(.87)	.6	66.97	48	18.98	1.58
Superphosphate[1], residues, *over* residues	11.3	8.5	7.3	(.06)	– .8	64.42	48	16.42	1.37
Superphosphate[1], residues, lime, *over* residues, lime	11.3	5.7	6.0	(.47)	– 1.5	58.03	48	10.03	.84
Rock phosphate, residues, *over* residues	8.5	8.8	4.7	(.19)	2.5	62.37	48	14.37	1.20
Rock phosphate, residues, lime, *over* residues, lime	5.7	3.7	1.8	(.67)	1.2	39.60	48	– 8.40	– .70
Slag phosphate, residues, *over* residues	9.3	9.3	15.5	(1.04)	2.6	91.00	30	61.00	5.08
Slag phosphate, residues, lime, *over* residues, lime	11.4	7.4	3.8	(.64)	1.9	68.89	30	38.89	3.24

[1]Acid phosphate.

Attention has already been called to the difficulties in making exact comparisons of this nature on account of fluctuating prices of both farm products and fertilizer materials. However, a set of arbitrary prices may be assumed and for the present purpose values similar to those used in calculating the results from the Kewanee field will be employed. In the following comparisons, wheat is placed at $1.20 a bushel; corn, at 68 cents; oats, at 40 cents; soybeans, at $1.50; and hay at $14 a ton. For the cost of the phosphatic materials, the following estimates are used: bone meal, $40 a ton; superphosphate (acid phosphate), $24; rock phosphate, $12; and slag phosphate, $20. These values seem to be conservative enough, and furthermore, it may be pointed out that the quantities of phosphatic fertilizer employed in these experiments are, with the possible exception of slag phosphate, greater than ordinarily would be used, or need be used, in good farm practice.

The total value of all crop increases for the twelve years is shown in Table 15, as is also the total cost of the phosphates applied and from these figures are derived the average annual acre profits shown in the last column of the table.

Reckoned on the basis of the above prices, it appears that the slag phosphate has furnished the most profitable returns of the four phosphorus carriers in the test, producing an average profit of $5.08 an acre yearly where applied without limestone, and $3.24 where applied with limestone. Bone meal has given an average profit of $2.50 applied without limestone and $1.58 applied with limestone. Superphosphate (acid phosphate) has returned $1.37 used without limestone and 84 cents used with limestone. Rock phosphate has produced the lowest money returns, giving a profit of $1.20 an acre a year applied without limestone and a loss of 70 cents used with limestone.

No consideration is given here to the relative phosphorus reserves which should have accumulated in the soil. In considering these figures let it be emphasized again that the order of these values might easily be shifted by a relatively small change in commodity prices.

We may next consider the results from the standpoint of limestone, which was applied at the rate of 4 tons an acre to Plots 3 and 4 of the minor series in 1912, when the land was still under alfalfa. Another dressing of 2 tons an acre was added in 1917, after the present experiments were under way. The effect of this limestone, in terms of crop increase, is set forth in Table 16.

In estimating the financial results for the use of limestone, it is to be noted that altho 6 tons an acre have been applied in the last sixteen years, only the last 12 crops are involved in these particular experiments. For the present purpose, therefore, it may be considered that three-quarters of the total amount applied, or 4½ tons, is chargeable to the 12 crops under consideration. At the rate of $2 a ton the cost of the limestone, is therefore $9, to be charged against the value of the total crop increases for the twelve years included in this experiment. Figured in this manner we find a profit of $1.73 an acre a year for limestone applied without phosphate of any kind. Where limestone was applied with bone meal, the limestone profit was 56 cents an acre a year, and with superphosphate (acid phosphate) it was 96 cents. Used with rock phosphate, the crop increases were so small that a loss of 30 cents an acre a year was sustained, and with slag phosphate there was a gain of 48 cents an acre a year.

In view of the possible experimental error which is always involved in plot experiments of this sort, these margins of profit cannot be considered very

TABLE 16.—ALEDO FIELD: AVERAGE ANNUAL CROP INCREASES PRODUCED BY LIMESTONE AND THEIR VALUE, COMPUTED FROM YIELDS IN TABLE 14

Bushels or (tons) per acre

Comparison of treatments	Wheat 2 crops	Corn 5 crops	Oats 3 crops	Clover 1 crop	Soybeans 1 crop	Value of increase 12 crops	Cost of limestone 12 years	Profit from 12 crops	Profit per acre per year
Limestone, residues, *over* residues	1.4	6.0	− .1	−(.07)	4.7	$29.71	$9	$20.71	$1.73
Limestone, residues, bone meal, *over* residues, bone meal	1.8	1.9	− 3.8	(.23)	4.2	15.74	9	6.74	.56
Limestone, residues, superphosphate[1], *over* residues, superphosphate[1]	1.9	2.8	− 3.6	(.30)	4.4	20.54	9	11.54	.96
Limestone, residues, rock phosphate, *over* residues, rock phosphate	− .9	.9	− 4.8	(.22)	4.8	5.42	9	− 3.58	− .30
Limestone, residues, slag phosphate, *over* residues, slag phosphate	3.1	3.0	− 5.9	−(.03)	3.1	14.79	9	5.79	.48

[1]Acid phosphate.

pronounced. The Aledo field, however, represents one of those borderline cases, so to speak, in which the upper soil is only slightly acid and the lime requirement, therefore, is not yet very marked. As time goes on, however, and cropping continues, a greater need of lime may develop. It is planned to discontinue liming on these plots until its need becomes manifest, and in so doing the annual cost of the limestone already applied will become automatically reduced, so that net returns may possibly, sooner or later, become substantially increased.

THE HARTSBURG FIELD

A University soil experiment field representing Black Clay Loam is located in Logan county just east of Hartsburg. This field was established in 1911 and embraces 20 acres. The soil is uniform with the exception of a small area in the northwest part of the field which on the detailed map is identified as of the type Brown Silt Loam On Clay. A thoro system of tile has been installed whereby good drainage has been effected.

The somewhat standard rotation, including alfalfa and the soil treatment methods described on pages 43 and 44, were established on the five series of plots. These methods were followed without change until 1918, when it was planned to remove one hay crop and a seed crop of clover from the residues plots. In 1921 it was decided to harvest all the clover as hay. At that time the return of the oat straw was discontinued. In 1922 the return of the wheat straw was discontinued. The only residues plowed under since that time have been the cornstalks, and the green sweet clover before the corn. On this field the sweet clover has grown

TABLE 17.—HARTSBURG FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1913-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Wheat	Corn	Oats	Clover	Soybeans	Alfalfa	Stubble clover	
		13 crops	*22 crops*	*15 crops*	*7 crops*	*2 crops*	*8 crops*	Hubam *1 crop*	Common sweet clover *1 crop*
1	0	24.9	48.4	46.1	(1.84)	(1.29)	(3.47)	(.83)	......
2	M	29.2	58.0	51.6	(2.16)	(1.64)	(3.67)	(1.15)	......
3	ML	34.0	64.2	57.4	(2.32)	(1.82)	(3.91)	(.91)	......
4	MLP	36.2	63.4	56.8	(2.39)	(1.92)	(4.19)	(1.17)	......
5	0	29.7	53.7	45.4	(1.28)	(2.58)	(3.33)	(.71)	......
6	R	32.7	63.3	53.4	(1.67)	(2.68)	(3.78)	(.75)	(.85)
7	RL	30.1	66.8	51.6	(1.64)	(2.84)	(3.45)	(.68)	(.75)
8	RLP	34.3	66.8	55.1	(1.79)	(2.61)	(4.04)	(.72)	(.90)
9	RLPK	33.4	65.2	54.5	(1.70)	(2.64)	(4.16)	(.80)	(1.00)
10	0	30.5	52.7	47.1	(2.02)	(1.69)	(3.20)	(.75)	......
	Crop Increases								
	M over 0	4.3	9.6	5.5	(.32)	(.35)	(.20)	(.32)	......
	R over 0	3.0	9.6	8.0	(.39)	(.10)	(.45)	(.04)	......
	ML over M	4.8	6.2	5.8	(.16)	(.18)	(.24)	−(.24)	......
	RL over R	− 2.6	3.5	− 1.8	−(.03)	(.16)	−(.33)	−(.07)	−(.10)
	MLP over ML	2.2	− .8	− .6	(.07)	(.10)	(.28)	(.28)	......
	RLP over RL	4.2	0.0	3.5	(.15)	−(.23)	(.59)	(.04)	(.15)
	RLPK over RLP	− .9	− 1.6	− .6	−(.09)	(.03)	(.12)	(.08)	(.10)

satisfactorily on the unlimed plots. The application of limestone was also 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 4 tons an acre on all plots, and no more will be applied for an indefinite period. At that time the rotation on Series 100, 200, 300, and 400 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. On Series 500 the rotation was changed to corn, oats, wheat, and a mixture of alfalfa and red clover for one year.

The outstanding feature of the results of the Hartsburg field is the large increase in yields produced by organic manures, whether they be in form of crop residues (R) or of stable manure (M).

The behavior of limestone (L) on this field presents a peculiarity difficult to explain in that limestone has been much more beneficial where applied with animal manure than where used with residues. With the exception of a single crop, limestone used with manure shows considerable increase and has given profitable returns on the investment, while in the residues system the effect of this material on several of the crops appears as negative and its use in this system has been attended by a financial loss.

Rock phosphate (P) has found its most effective place in these experiments in the production of wheat and of alfalfa, particularly in the residues system, but its effect on the other crops has been so indifferent that, on the whole, the use of this material has not proved profitable on this field.

The addition of potassium (K) in the combinations here employed has likewise been ineffective.

In 1924 these plots were divided and some new treatments designed to furnish further information regarding the effect of phosphorus fertilizers on this soil were introduced. The west halves were continued under the old treatments except that the phosphate applications were discontinued indefinitely after a total of 4 tons an acre of rock phosphate had been applied. These later experiments have scarcely continued long enough, however, to furnish results of sufficient reliability for discussion at this time.

THE VIENNA FIELD

Morgan county, as indicated in the descriptions of certain of its soil types, includes considerable land that is subject to destruction thru erosion or washing. Yellow Silt Loam, which occupies about 80 square miles in the county, is particularly susceptible to this kind of damage. Operators of land in Morgan county will therefore be interested in experiments conducted on the Vienna field, in Johnson county, to test out different methods of reclaiming badly gullied land and preventing further erosion.

The Vienna field is representative of the sloping, erodible land so common in the extreme southern part of the state. When the experiments were started the whole field, with the exception of about three acres, had been abondoned because so much of the surface soil had washed away, and there were so many gullies

FIG. 11.—PROPER SOIL AND CROPPING METHODS WOULD HAVE PREVENTED THIS CONDITION
This abandoned hillside is just over the fence from the field shown in Fig. 12. Yellow Silt Loam is particularly susceptible to this kind of damage.

that further cultivation was unprofitable. For the purpose of the experiments the field was divided into different sections (see Table 18). These were not entirely uniform; some parts were much more washed than others, and portions of the lower-lying land had been affected by soil material washed down from above. The higher land had a very low producing capacity; on many spots little or nothing would grow.

Limestone was applied to the entire field at the rate of 2 tons an acre. Corn, cowpeas, wheat, and clover were grown in a four-year rotation on each section except the one designated as D, which included but three plots.

FIG. 12.—CORN GROWING ON AN IMPROVED HILLSIDE OF THE VIENNA EXPERIMENT FIELD
This land had formerly been badly eroded. It was reclaimed by proper soil treatment and cropping. Compare with Fig. 11.

TABLE 18.—VIENNA FIELD: HANDLING HILLSIDE LAND TO PREVENT EROSION
Average Annual Yields, 1907-1915—Bushels or (tons) per acre

Section	Method	Corn *7 crops*	Wheat *7 crops*	Clover *3 crops*
A	Terrace	31.4	9.0	(.68)
B	Embankments and hillside ditches	32.4	12.7	(.97)
C	Organic matter, deep contour plowing, and contour planting	27.9	11.7	(.80)
D	Check	14.1	4.6	(.21)

Section A included the steepest part of the field and contained many gullies. The land was built up into terraces at vertical intervals of 5 feet. Near the edge of each terrace a small ditch was placed so that the water could be carried to a natural outlet without much washing.

Section B was used to test the so-called embankment method. Ridges were plowed up which were sufficiently high so that when there were heavy falls of rain the water would break over and run in a broad sheet rather than in narrow channels. At the steepest part of the slope, hillside ditches were made for carrying away the run-off.

Section C was washed badly but contained only small gullies. Here the attempt was made to prevent washing by incorporating organic matter in the soil and practicing deep contour plowing and contour planting. With two exceptions, about 8 loads of manure an acre were turned under each year for the corn crop.

Section D was washed to about the same extent as Section C. It was farmed in the most convenient way, without any special effort to prevent washing.

Careful records were kept for nine years. The results, summarized in Table 18 indicate something of the possibilities in improving hillside land by protecting it from erosion. The average yield of corn from the protected series (A, B, and C) was 30.6 bushels an acre, as against 14.1 bushels on the check series (D). Wheat yielded 11.1 bushels on the protected series, in comparison with 4.6 bushels on the check, and clover yielded ⅘ of a ton on the protected series and but ⅕ of a ton on the check.

Figs. 11 and 12 serve further to indicate what may be done with this type of soil even after it has become badly washed and gullied.

Altho these results show in principle the possibility of improving this land, it cannot be said that the experiments as conducted represent directly the most economical system of farming. However, it appears possible that by modifying the cropping plan in some manner, as for example, substituting sweet clover for cowpeas and giving large place in the farming system to hay and pasture crops, production might be substantially increased and thus a system of farming instituted that would represent a profitable enterprise.

THE OQUAWKA FIELD

Since there are considerable areas of Dune Sand, Terrace, in Morgan county, experiments on that type conducted by the University in Henderson county near the Mississippi river, will be of interest. The field was established in 1913. It is divided into six series of plots. Corn, soybeans, wheat, sweet clover, and rye, with a catch crop of sweet clover seeded in the rye on the residues plots, are grown in rotation on five series, while the sixth series is devoted to alfalfa. When sweet clover seeded in the wheat fails, cowpeas are substituted. Table 19

TABLE 19.—OQUAWKA FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1915-1927—Bushels or (tons) per acre

Serial plot No.	Soil treatment applied	Corn *13 crops*	Soy-beans[1] *13 crops*	Wheat *13 crops*	Rye *11 crops*	Sweet clover[2] *9 crops*	Alfalfa *10 crops*
1	0	19.9	10.0	8.7	12.6	0.00	(.44)
2	M	25.4	12.0	12.0	14.5	0.00	(1.16)
3	ML	34.8	16.4	17.1	24.9	1.09	(2.49)
4	MLP	34.2	15.8	17.3	23.8	1.13	(2.57)
5	0	19.4	7.9	10.8	11.2	0.00	(.66)
6	R	21.1	8.3	12.5	11.6	0.00	(.72)
7	RL	36.6	12.0	16.1	24.0	1.43	(2.23)
8	RLP	36.4	12.7	16.6	24.0	1.32	(2.24)
9	RLPK	38.4	12.5	16.0	25.7	1.52	(2.29)
10	0	18.4	7.2	10.0	9.0	0.00	(.48)
	Crop Increases						
	M over 0	5.5	2.0	3.3	1.9	0.00	(.72)
	R over 0	1.7	.4	1.7	.4	0.00	(.06)
	ML over M	9.4	4.4	5.1	10.4	1.09	(1.33)
	RL over R	15.5	3.7	3.6	12.4	1.43	(1.51)
	MLP over ML	− .6	− .6	.2	− 1.1	.04	(.12)
	RLP over RL	− .2	.7	.5	0.0	− .11	(.01)
	RLPK over RLP	2.0	− .2	− .6	1.7	.20	(.05)

[1]Eleven regular crops, together with the extra crop described in the following footnote, averaged as 11 crops. Several crops which were harvested as seed are evaluated in this summary as hay.
[2]Some hay evaluated as seed. In 1918 the sweet clover was killed by early cutting for a hay crop. Soybeans were seeded in July and the ensuing crop is included in the soybean average.

indicates the kinds of treatment applied. The amounts of the materials used were in accord with the standard practice, as explained on pages 43 and 44.

Limestone (L), it will be noted, has had a remarkably beneficial action on this sand soil. Where it has been used in conjunction with crop residues, the yield of corn has been practically doubled. It has also produced good crops of rye and fair crops of sweet clover and alfalfa.

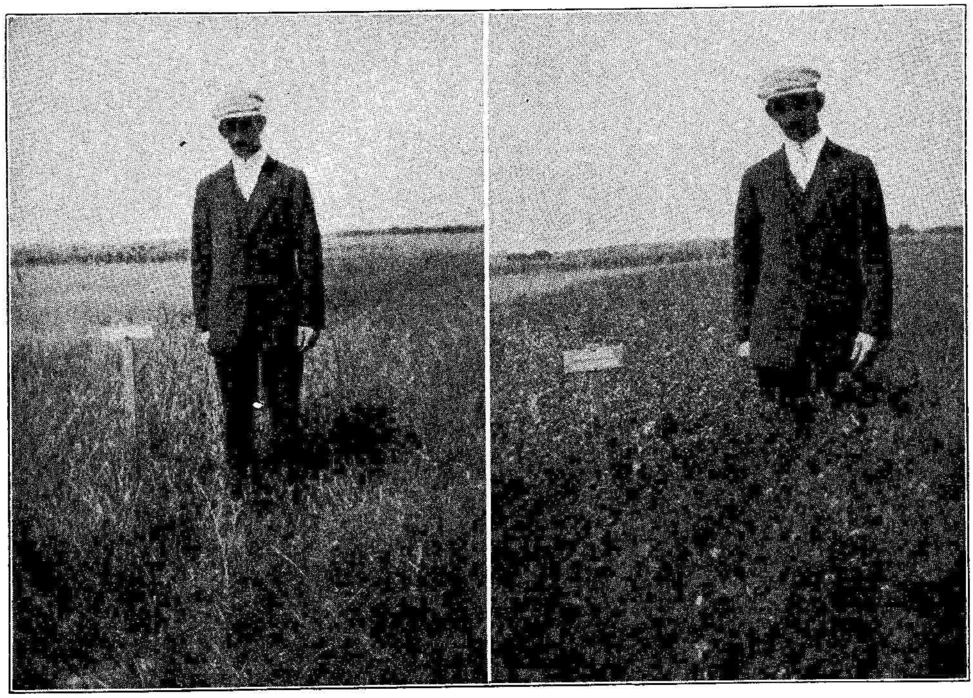
This land appears to be quite indifferent to treatment with rock phosphate (P). The analyses show, however, that the stock of phosphorus in this type of soil is not large; and as time goes on and the supply diminishes under the production of good-sized crops, the application of this element may become profitable. It is also quite possible that a more available form of phosphate could be used to advantage on this very sandy soil.

The slight increases or decreases from the use of potassium (K) can scarcely be considered significant.

A significant fact which the above summary does not bring out is that improvement in crop yields under favorable treatment has been progressive, as evidenced by a marked upward trend in production after the first few years. The yield of corn, for example, under the limestone-residues (RL) treatment, has been 36.6 bushels an acre as an average for the 13 crops since full treatment started, but if we take an average of the last five crops the yield rises to 39.5

bushels. Likewise the wheat under this same treatment gives for the 13-year average 16.1 bushels, but for the last five years has given 22.8 bushels.

Experience thus far shows rye to be better adapted to this land than wheat, and both alfalfa and sweet clover grow better than soybeans. With these two legume crops thriving so well under this simple treatment, we have promise of great possibilities for the profitable culture of this land, which hitherto has been considered as practically worthless.



Manure
Yield: Nothing

Manure and limestone
Yield: 4.43 tons per acre

FIG. 13.—ALFALFA ON THE OQUAWKA EXPERIMENT FIELD

These pictures show the possibility of improving this unproductive sandy land. Both plots were seeded alike to alfalfa. Where manure alone was applied, the crop was a total failure, but where limestone in addition to manure was applied, nearly 4½ tons of alfalfa hay was obtained as the season's yield.

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
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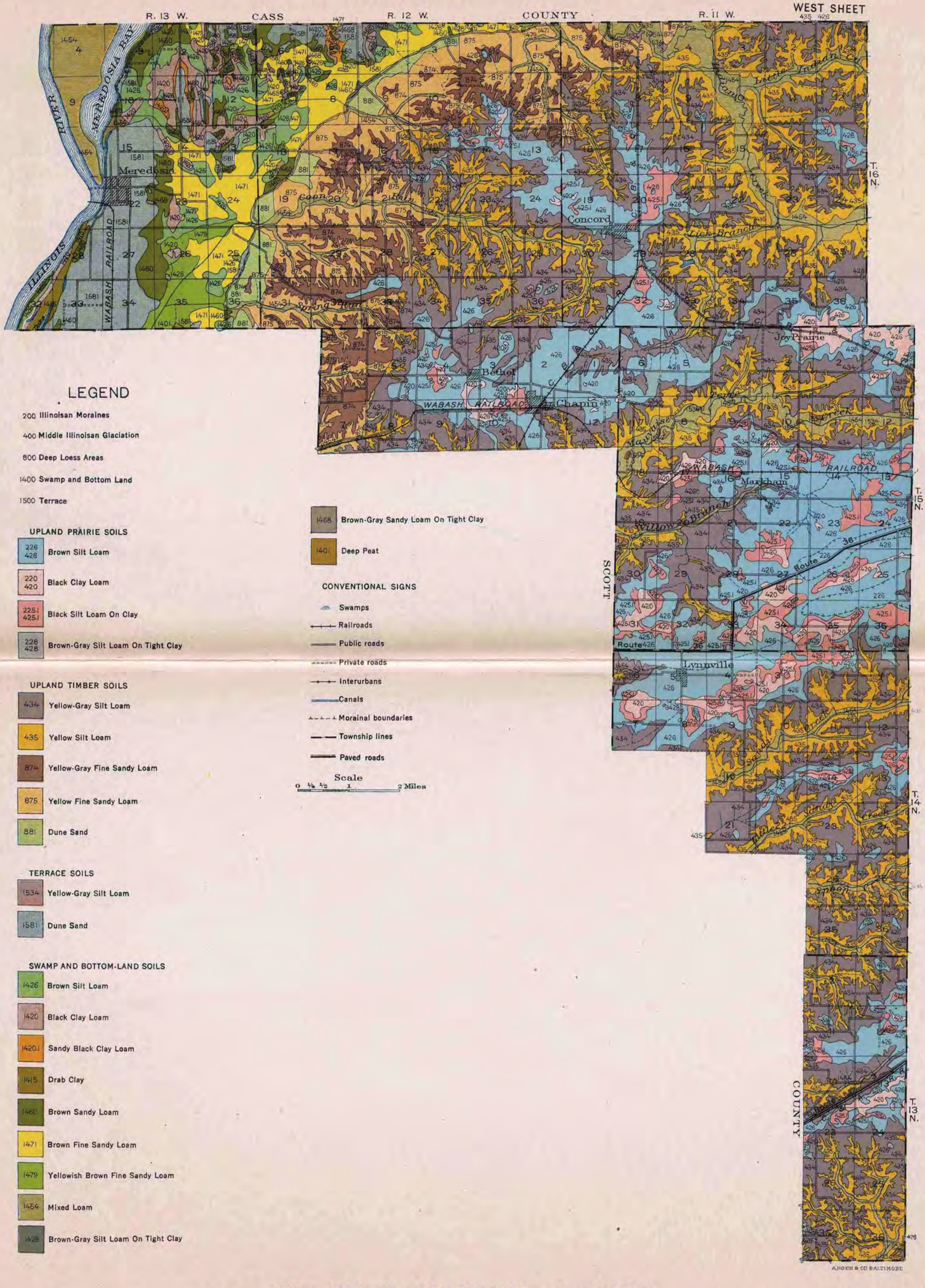
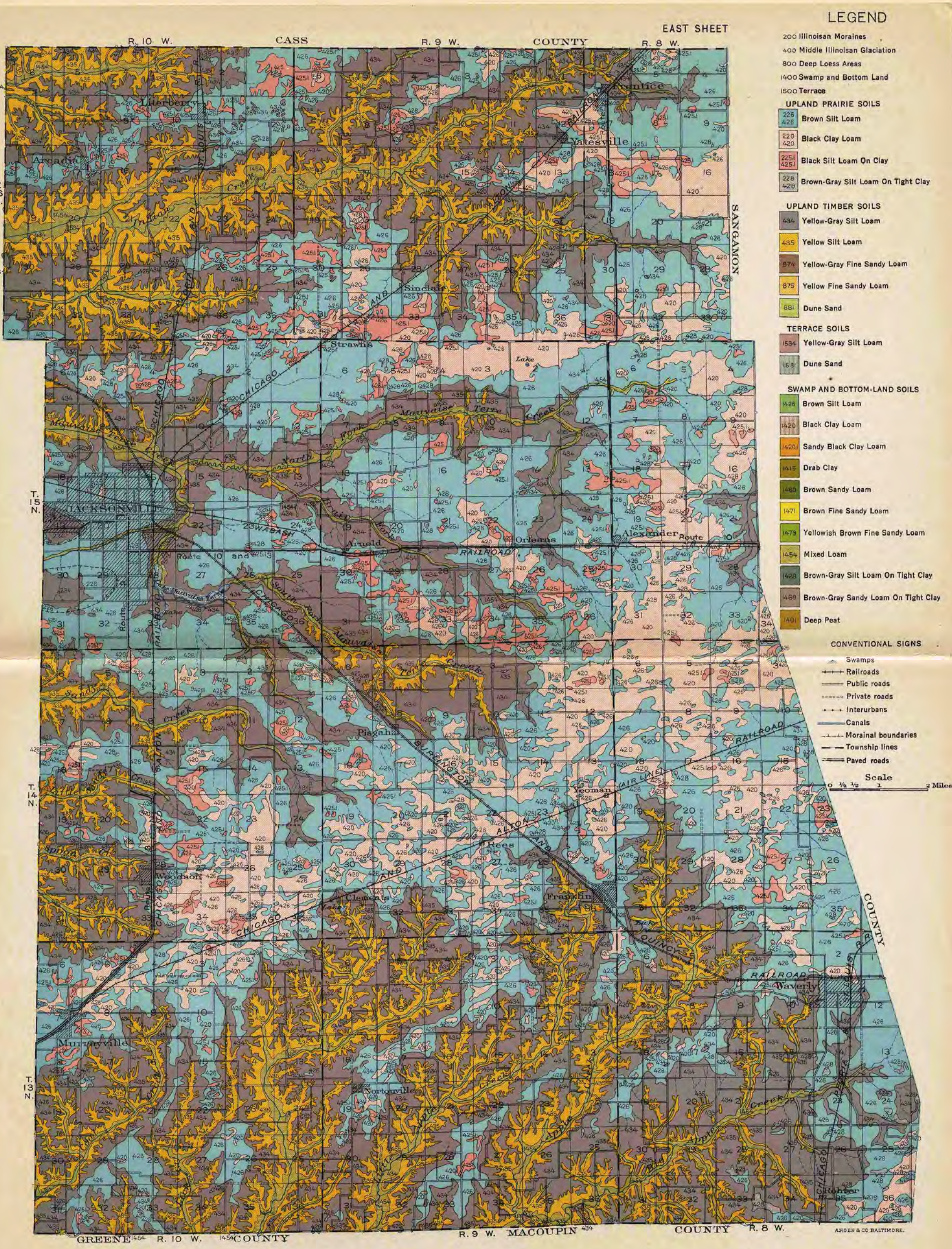


SOIL SURVEY MAP OF MORGAN COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION



SOIL SURVEY MAP OF MORGAN COUNTY
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