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Agricultural Experiment Station

SOIL REPORT No. 50

MACOUPIN COUNTY SOILS

By E. A. NORTON, 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.

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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 management, 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.

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.

CONTENTS

PAGE

GEOGRAPHICAL FEATURES OF MACOUPIN COUNTY 5
Climate 5
Physiography and Drainage 6
Social Development 7
Agricultural Production 8

FORMATION OF MACOUPIN COUNTY SOILS 10
Origin of Soil Material 10
Soil Development 11

THE SOIL MAP 12
Basis of Soil Classification 12
Naming the Soil Types 13

DESCRIPTION OF SOIL TYPES 14
Deep Gray Silt Loam On Tight Clay 14
Gray Silt Loam On Tight Clay 15
Gray Silt Loam On Orange-Mottled Tight Clay 15
Yellowish Gray Silt Loam On Orange-Mottled Tight Clay 16
Eroded Silt Loam 16
Eroded Gravelly Loam 16
Light Gray Silt Loam On Tight Clay 16
Yellow-Gray Silt Loam On Tight Clay 17
Yellow-Gray Silt Loam On Compact Medium-Plastic Clay 17
Reddish Yellow-Gray Silt Loam 18
Reddish Yellow Silt Loam 18
Grayish Brown Silt Loam On Clay 18
Grayish Black Silt Loam On Clay 19
Grayish Drab Silt Loam On Clay 20
Grayish Brown Clay Loam On Clay 20
Black Clay Loam 21
Black Clay Loam On Drab Clay 21
Mixed Loam 21
Deep Brown-Gray Silt Loam On Tight Clay 22
Brown-Gray Silt Loam On Tight Clay 22
Brown-Gray Silt Loam On Reddish Brown Tight Clay 23
Brown-Gray Silt Loam On Compact Medium-Plastic Clay 23
Drabbish Gray Silt Loam On Tight Clay 23
Drabbish Yellow-Gray Silt Loam On Tight Clay 24
Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay 24
Drabbish Yellow-Gray Silt Loam 25
Slick Spots 25
Grayish Brown Silt Loam 26
Grayish Light Brown Silt Loam 27

CHEMICAL COMPOSITION OF MACOUPIN COUNTY SOILS 27
Great Variation in Chemical Composition 28
Nitrogen Closely Associated With Organic Matter 28
Light-Colored Soils Low in Phosphorus 29
The Sulfur Cycle 30
Potassium Content Comparatively Uniform 30
Wide Variations in Calcium and Magnesium 31
Local Tests for Soil Acidity Often Required 33

Character of Chemical Combination Related to Availability 33
Service of Chemical Investigations in Soil Improvement 33

FIELD EXPERIMENTS ON SOIL TYPES SIMILAR TO THOSE IN MACOUPIN COUNTY 35
Carlinville Field 36
Toledo Field 45
Ewing Field 46
Vienna Field 48
Sparta Field 49
Raleigh Field 51

APPENDIX

PRINCIPLES OF SOIL MANAGEMENT 53
Providing Adequate Drainage 54
Protecting Soil From Erosion 55
Applying Limestone to Correct Acidity 57
Maintaining a Well-Planned Crop Rotation 58
Supplying Right Kinds and Amounts of Organic Matter 61
Plant-Food Requirements and Supply 62
Nitrogen Problem 64
Phosphorus Problem 66
Potassium Problem 68
Use of Mixed Commercial Fertilizers 68

MACOUPIN COUNTY SOILS

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

GEOGRAPHICAL FEATURES OF MACOUPIN COUNTY

MACOUPIN COUNTY is located in southwestern Illinois about forty miles northeast of St. Louis, Missouri. It forms a large rectangular area extending 36 miles north and south and 24 miles east and west, and comprizes about 850 square miles. It lies on the southern border of the fertile corn-belt section of the United States. Its soils are dark-colored, rich, and highly productive in the northern part, becoming light-colored, poor, and less productive in the southern part. The climate is favorable for the production of a wide variety of crops. Corn growing and livestock raising predominate in the northern part, and wheat growing and dairying in the southern part.

Climate

The climate of Macoupin county is characterized by a wide range between the extremes of winter and summer and by an abundant rainfall. The average yearly range of temperature is about 100 degrees. The highest temperature recorded at the weather station located at Carlinville during the years 1896 to 1930 was 110° in 1918; the lowest, 23° below zero in 1905. The average date of the last killing frost in spring is April 20; the earliest in autumn is October 12. The latest killing frost in spring on record occurred May 14, 1920; the earliest killing frost in autumn, September 18, 1901. The average length of the growing season is 175 days, which is ample time to mature all the common crops grown in the region. The shortest growing season on record was 143 days in 1918; the longest, 199 days in 1898. Occasionally, when the spring is so wet as to delay corn planting, early frosts produce soft corn. Winter wheat and legume crops are occasionally injured, particularly on flat ground, as a result of sudden temperature changes in winter and early spring.

The prevailing wind direction in spring and summer is south. Spring winds are usually brisk from the southwest, those of summer relatively light except before thunder showers. A series of strong northwesterly gales, which bring cold waves, followed by periods of calm characterize the winter season. Macoupin county lies within the region subject to tornadoes, and a few causing minor destruction have visited the region.

The average annual rainfall, as recorded at Carlinville for the thirteen-year period 1917-1930, was 37.47 inches. This includes the water melted from an average yearly snowfall of nearly 16 inches. The average rainfall during the growing season for this same period was 24.17 inches. The distribution of rainfall during the growing season is fairly good, altho nearly every year there are one or more rainless periods of sufficient length to be harmful to growing

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crops. During the thirteen-year period mentioned above there were six years in which there was a rainless period of 30 days duration or longer, and twelve years in which there was a rainless period of 20 days or longer during the growing season. In several of these twelve years there were two or more 20-day rainless periods. There are a number of factors, however, other than amount and distribution of rainfall which are important in producing drouth conditions. Among these are the character of the rainfall preceding rainless periods and the evaporation during the rainless periods. Then there are also to consider the reaction of the crop toward drouth conditions, its stage of growth, and whether it is a resistant crop or one easily affected by drouth.

On account of the diverse character of the soils in Macoupin county it is impossible to make any general statement as to their drouthiness. The upland soils on flat and intermediate topography in the southeastern quarter of the county have compact, plastic, slowly pervious subsoils which impede water movement. The surface soil of these types is low in organic matter and consequently has a low water-holding capacity. Under these conditions the upper portion of the soil is quickly saturated with water during rainy periods and shallow ponds are formed; then it remains wet until the water evaporates. When the surface soil dries, drouthy conditions result more quickly than in a pervious soil because movement of moisture from below is shut off by the impervious subsoil. Root growth is therefore shallow. The rolling uplands in the southern part of the county have a loose, open subsoil which allows free moisture movement.

Physiography and Drainage

The general elevation of Macoupin county is about 600 feet above sea level. The altitude of a few towns in the county is as follows: Atwater, 652; Brighton, 659; Bunker Hill, 646; Carlinville, 627; Medora, 622; Mt. Olive, 682; Staunton, 625; Virden, 678. The present topography of the region is largely the result of erosion rather than deposition, for the county was extremely smooth and flat before stream cutting took place. Only a few low drift knolls and swells originally existed on the flat drift plain. The streams have now cut back inland dissecting much of the formerly flat upland, and producing a rough and hilly surface over much of the county. Narrow, flat, or tabular divides are a characteristic feature of the physiography of that part of the county most thoroly dissected by water courses. The bottom lands along the streams are narrow, with the exception of those of the larger creeks, and the slopes down from the uplands are generally steep and unsuited to cultivation.

Most of Macoupin county is drained by Macoupin creek and its tributaries. This stream flows in a westerly direction thru the middle of the county and empties into Illinois river. Apple creek, another Illinois river tributary, drains the northwestern part of the county and the southern and southeastern parts drain south toward Mississippi river. Fig. 1 shows the stream courses and other physiographic features of the county. Even tho drainage channels pierce almost every section in the county, some of the flat land is poorly drained because of insufficient slope to carry the excess water away and the impervious character of the subsoil. Drainage has been improved in the central and north-

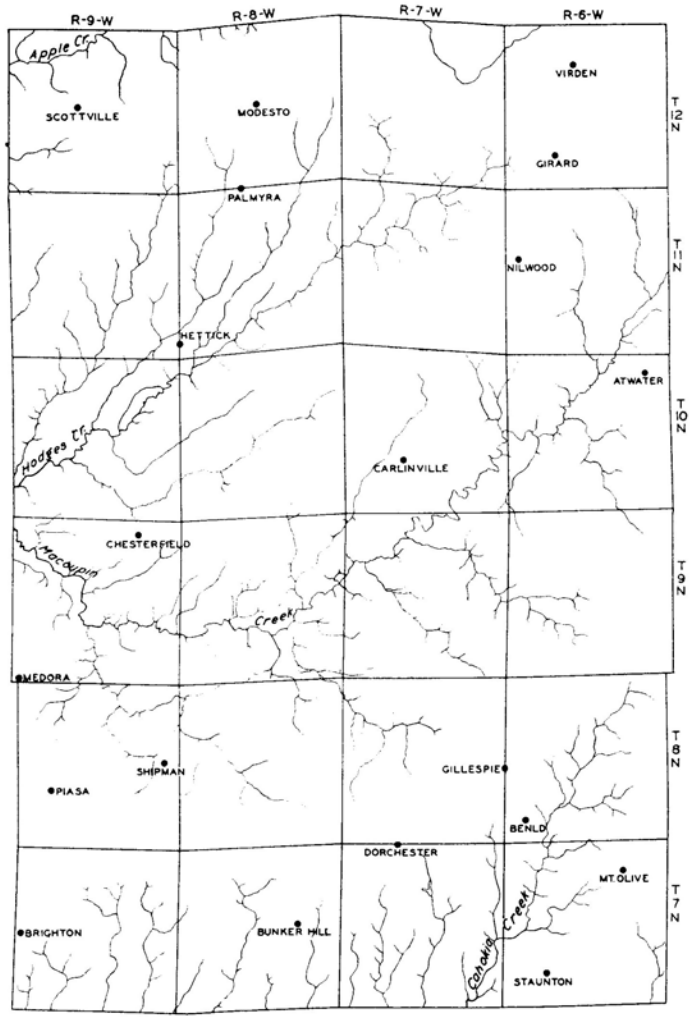

FIG. 1.—DRAINAGE MAP OF MACOUPIN COUNTY SHOWING STREAM COURSES

ern parts of the county by the use of tile and by the construction of surface and dredge ditches.

Social Development

The territory now known as Macoupin county was settled about 1820. At that time wild game was plentiful and Indians roamed over the country. Macoupin is an Indian name which signifies "white potato." The area was originally part of Madison county, and the present boundaries were established and the county organized in 1829. Settlement was rapid from that time on, and the population steadily increased until 1920, as is shown in Fig. 2. After 1920 it declined somewhat, owing probably to the closing of the coal mines. The 1930 Census reports the number of inhabitants of the county as 48,703, less than half of whom were counted as being engaged in farming.

Aside from agriculture the chief industrial interest is coal mining. Transportation facilities are well developed and in general markets are readily available. Rural educational facilities and social life are well developed, and improvements and equipment on farms indicate general prosperity thruout the county.

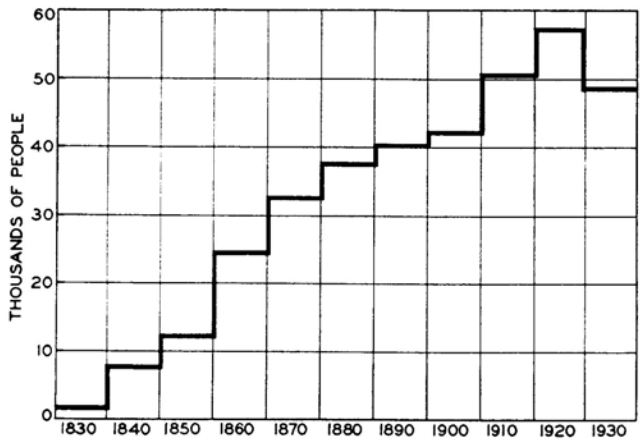

FIG. 2.—GROWTH IN POPULATION OF MACOUPIN COUNTY
Population reached its maximum in 1920. The last Census shows a decline.

Agricultural Production

The early settlers took advantage of the favorable conditions which they found in Macoupin county and rapidly expanded agricultural production. They were hampered somewhat by the lack of transportation facilities before the completion of a railroad thru the county in 1852. Prior to that time most of the grain was fed to livestock, and the livestock were either driven or hauled overland to the St. Louis market.

Fig. 3 shows the acreage of corn, oats, and wheat in the county in certain years from 1880 to 1930. The corn acreage has always been the largest and, except in 1920, when the wheat acreage expanded to meet the demand brought on by the World War, has usually exceeded the combined acreage of the other two crops. The decrease in corn acreage since 1900 does not mean a falling off in total production, but rather that more of the acreage is being utilized for other crops, particularly legumes.

Other crops that have been given more or less attention in recent years are alfalfa, of which some 3,000 acres were grown in Macoupin county in 1930, and sweet clover, of which there were 14,000 acres in 1930. The soybean is another crop that has come rapidly into prominence within the last decade. In 1922 a total of 3,500 acres was recorded as planted to soybeans alone; in 1930, 44,000 acres were so grown. The practice of planting soybeans with corn has also increased until last year 10,000 acres were reported as used in this way.

Altho the proportion of legumes to other field crops is gradually increasing, the acreage devoted to such crops, particularly the clovers and alfalfa, is far

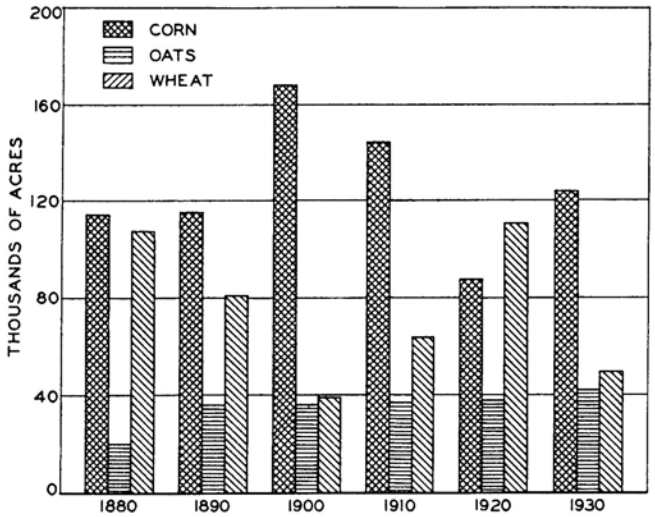

FIG. 3.—ACREAGES OF CORN, OATS, AND WHEAT IN MACOUPIN COUNTY
The diagram shows the relative acreage devoted to the three principal grain crops at periodic intervals since 1880. (Figures from U. S. Census)

short of what it should be from the standpoint of soil unkeep. At least 25 percent of the cropped area should be planted to legumes every year.

The following figures (compiled from reports made by the U. S. Department of Agriculture and Illinois State Department of Agriculture in cooperation) show the average acre-yields of the principal crops. For the past ten years: corn, 31.4 bushels; oats, 27.7; winter wheat, 13.6; tame hay, 1.28 tons. A five-year average for spring wheat shows 13.6 bushels an acre.

Fruit and vegetable crops are not of great commercial importance in Macoupin county. A number of apple and a few peach orchards are being de-

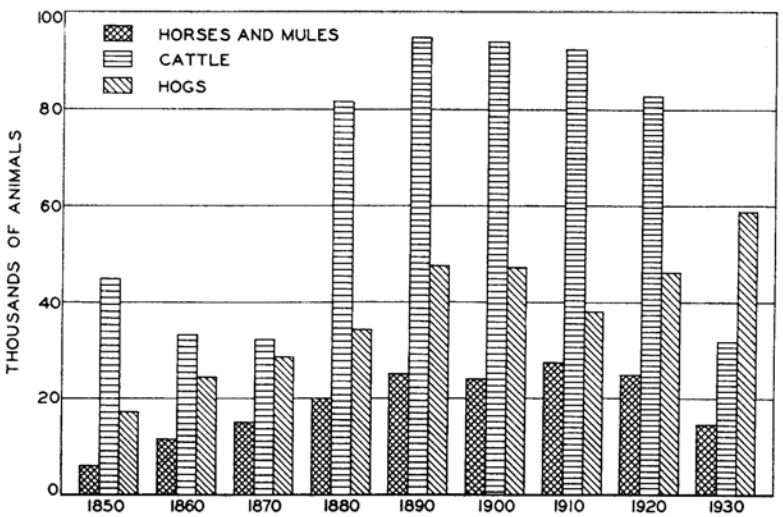

FIG 4.—NUMBER OF HORSES AND MULES, CATTLE, AND HOGS IN MACOUPIN COUNTY
The diagram shows the relative numbers of the principal classes of livestock at periodic intervals since 1850. (Figures from U. S. Census)

veloped in the southwestern part. Some of these have come into production and are proving profitable. Practically all vegetables raised are consumed locally.

The importance of the livestock industry in Macoupin county is indicated by Fig. 4, which shows the trend in livestock production since 1850. It is of interest to note that the total number of animals increased rapidly, reaching a maximum between 1900 and 1910, and have since shown a decided decrease.

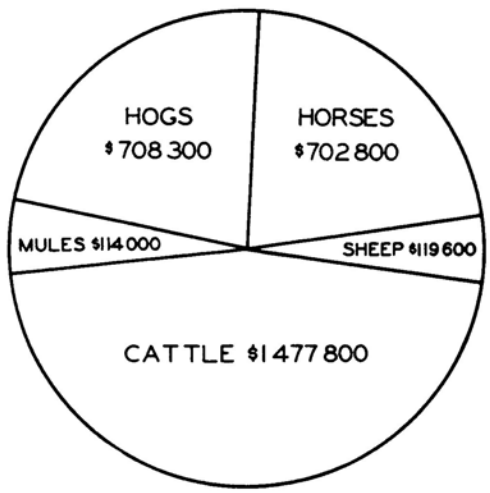

FIG. 5.—RELATIVE VALUE OF THE MORE IMPORTANT CLASSES OF FARM ANIMALS IN MACOUPIN COUNTY IN 1929
(Data from Illinois Crop and Live Stock Statistics, Circular 409)

An idea of the relative value of the more important classes of farm animals is brought out in Fig. 5. The total value of these animals is placed at $3,149,900. About half this amount represents the value of all cattle, while the bulk of the remainder represents hogs and horses, almost equally.

FORMATION OF MACOUPIN COUNTY SOILS

Origin of Soil Material

The land surface of Macoupin county, once rough, was leveled off during the Glacial period by one and perhaps two enormous ice sheets that moved down from the north and left over the county a deposit of clay, sand, gravel, and boulders. This glacial drift does not form a part of the present soils, being buried under a cover of fine wind-blown material called "loess," but the glaciers, by producing a flat-lying surface, nevertheless exerted a marked influence on the character of the present soils.

The loess covering Macoupin county came very largely from the Illinois and Mississippi river bottoms. The water flowing away from the melting glaciers carried immense quantities of finely ground rock particles in suspension. These were deposited along the stream courses. Later, as the stream courses became dry, this fine material was picked up by the wind and carried to the upland, where it was redeposited as a vast dust blanket.

The thickness of the loess deposit in this county varies from about 4 to more than 30 feet. It is thickest in the western part of the county nearest the river bottom lands, becoming gradually thinner toward the east. Not all the loess was deposited at the same time; some was laid down much earlier than that in other parts of the county. This difference in the age of the loess is one of the causes for the differences in the character of the soils and in their productivity.

Soil Development

Soils are not formed all at once; they develop gradually as the result of many forces acting on such parent material as loess, drift, or solid rock. When first deposited, the composition of the soil material, especially of loess, is rather uniform thruout. As times goes on, however, the weathering forces, such as freezing and thawing and wetting and drying, serve to break down the rock particles into finer particles; chemical action renders certain substances soluble; and leaching translocates these substances from one depth to another or else washes them out of the soil altogether. Finer particles are also carried downward by water and, under certain circumstances, they accumulate in the subsoil to such an extent as to form an almost impervious stratum.

Organic life, both plant and animal, plays a highly important role in these soil-forming processes. As the elements of plant food become available, the simpler forms of vegetation, followed by the higher plants, gradually spread over the land.

In Macoupin county conditions were favorable for the development of a grass vegetation, the decay of which added much organic matter to the soil. As the weathering processes continued, the soils became acid and somewhat impoverished thru the loss of lime and other substances. These soils no longer support the luxuriant vegetative growth that they once did, and the originally dark-colored soils have become gray.

Near the streams, where good drainage has been maintained, forest vegetation has developed, and the trees have been instrumental in reducing the amount of organic matter in the soil. The surface soil under timber vegetation is even lighter colored than prairie soil.

Thus soils are constantly changing in their characteristics; in other words, they undergo an aging process, in a sense similar to that of living beings. Hence soils are spoken of as *youthful*, *immature*, and *mature*, according to the stage of development at which they have arrived. Thus in Macoupin county, soils in the southeastern part have reached maturity; that is to say, they have been exposed to the weathering process so long that certain characteristics are clearly and definitely expressed. Those in the central part are approaching maturity, while those in the northern part are clearly immature. In the bottom land and in eroded areas youthful soils are found, the soil materials having been either deposited or uncovered so recently that the transforming processes have had little time to act.

As a soil matures, the leaching of the carbonates (including lime) downward is of particular importance. Dissolved by the rain, they gradually pass out in solution with the drainage water; and with their loss soil acidity de-

velops. All the soil material in Macoupin county originally contained an abundance of lime; that is to say, it was sweet. As time went on, however, much of the soil gradually became acid and somewhat impoverished, vegetative growth became less vigorous, and the destruction of organic matter began to overtake its accumulation. These changes reduced the dark brown or black of the surface soil to a gray. Many different stages in the accumulation and destruction of organic matter are represented in the surface stratum of these prairies soils.

One of the most pronounced effects of the process of soil development is the gradual stratification of the material into layers, or "horizons." Differences in the arrangement, thickness, and nature of these horizons constitutes one of

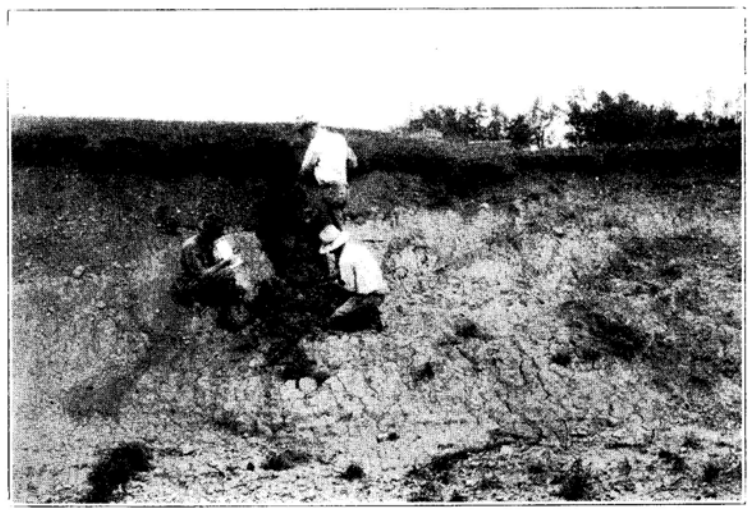

FIG. 6.—STUDYING THE SOIL PROFILE
Deep natural exposures are made use of in studying the soil profile.

the chief characteristics for separating soils into types. For the purposes of this report soil types will usually be described according to the outstanding characteristics of their strata designated as *surface*, *subsurface*, and *subsoil*. The surface layer is the upper 3 to 10 inches; it is that part of the soil that is cultivated and in which the most roots are found. The subsurface lies just below the surface and usually is lighter in color than the surface. The subsoil begins at depths varying from 12 to 24 inches; it has two divisions, the upper one being more compact and plastic than any other layer. The lower subsoil is the more friable and the yellowish tinge is more pronounced.

THE SOIL MAP

Basis of Soil Classification

In the soil survey the "type" is the unit of classification. Each soil 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 these characteristics may be mentioned color, structure, texture, and chemical composition. The topography and

TABLE 1.—SOIL TYPES OF MACOUPIN COUNTY, ILLINOIS

Type No.	Name of type	Area in square miles	Area in acres	Percent of total area
1	Deep Gray Silt Loam On Tight Clay	.15	96	.02
2	Gray Silt Loam On Tight Clay	10.71	6 854	1.26
3	Gray Silt Loam On Orange-Mottled Tight Clay	9.59	6 138	1.13
4	Yellowish Gray Silt Loam On Orange-Mottled Tight Clay	.70	448	.08
5	Eroded Silt Loam	31.66	20 262	3.73
8	Eroded Gravelly Loam	120.73	77 267	14.21
11	Light Gray Silt Loam On Tight Clay	.61	390	.07
12	Yellow-Gray Silt Loam On Tight Clay	7.75	4 960	.91
13	Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	132.47	84 781	15.59
14	Reddish Yellow-Gray Silt Loam	1.32	845	.16
15	Reddish Yellow Silt Loam	2.11	1 350	.25
46	Grayish Brown Silt Loam On Clay	35.08	22 451	4.13
47	Grayish Black Silt Loam On Clay	3.38	2 163	.40
48	Grayish Drab Silt Loam On Clay	44.93	28 755	5.29
50	Grayish Brown Clay Loam on Clay	2.79	1 786	.33
65	Black Clay Loam	2.81	1 798	.33
66	Black Clay Loam On Drab Clay	2.65	1 696	.31
72	Mixed Loam	64.44	41 242	7.58
111	Deep Brown-Gray Silt Loam On Tight Clay	4.47	2 861	.52
112	Brown-Gray Silt Loam On Tight Clay	51.84	33 178	6.10
113	Brown-Gray Silt Loam On Reddish Brown Tight Clay	62.66	40 102	7.38
114	Brown-Gray Silt Loam On Compact Medium-Plastic Clay	7.21	4 614	.85
115	Drabbish Gray Silt Loam On Tight Clay	.20	128	.02
116	Drabbish Yellow-Gray Silt Loam On Tight Clay	2.32	1 485	.27
117	Drabbish Yellow-Gray Silt Loam on Compact Medium-Plastic Clay	108.45	69 408	12.76
118	Drabbish Yellow-Gray Silt Loam	1.63	1 043	.19
120	Slick Spots	4.63	2 963	.54
127	Grayish Brown Silt Loam	129.95	83 168	15.29
128	Grayish Light Brown Silt Loam	1.67	1 069	.20
MD	Mine Dumps	.21	134	.03
	Ponds	.63	403	.07
	Total	849.75	543 840	100.00

the kind and character of the vegetation are easily observed features of the landscape which are very useful indicators of soil character. A knowledge of the geological origin and formation of the soil material of the region being mapped often makes possible an understanding of the soil conditions which occur.

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.

Naming the 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 somewhat 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; on the contrary, the profile of mature soils is usually made up of more than one stratum and it is impossible to describe each stratum 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.

To assist in designating soil types, a number is assigned to each type. These numbers are not only a convenience in referring to the respective types but they are especially useful in designating very small areas on the map and as a check in reading the map colors.

Table 1 gives the list of the soil types as mapped in Macoupin county, the area of each in square miles as well as in acres, and also the percentage that each type constitutes of the total area of the county.

The accompanying colored map, shown in three sections, gives the location and boundary of each soil type and indicates the position of streams, roads, railroads, and town sites.

DESCRIPTION OF SOIL TYPES

Soil types must serve as a basis in working out a soil-management program. For example, the underdrainage of a soil developed on a flat surface in the southeastern part of Macoupin county, is so different from that of a soil developed on a rolling slope in the northern part that the management programs must be radically different. In the improvement of the former the first consideration is the removal of excess water, while in the improvement of the latter the rate of surface run-off must be retarded in order to reduce erosion.

On the basis of the principles explained in the preceding pages, the soils of Macoupin county have been differentiated into twenty-nine types. A brief description of the outstanding characters of each type, together with a few suggestions for its practical management, are given in the following pages. For a more complete discussion of the principles of soil fertility and soil management, the reader is referred to the accompanying Appendix, pages 53 to 71.

Deep Gray Silt Loam On Tight Clay (1)

Deep Gray Silt Loam On Tight Clay is found in the depressions at the heads of drainage in the southeastern part of the county. The area of this type in Macoupin county is of very limited extent, occupying all told only 96 acres. The soil material was derived very largely from sediment washed in from surrounding higher land. The type is naturally poorly drained.

The surface soil varies from 8 to 10 inches in thickness and is a brownish gray, friable, silt loam. The subsurface is light gray, and is ashy in the lower part. The subsoil begins at 22 to 28 inches and is a compact, plastic, pale yellowish gray clay. Small, black, rounded concretions of iron are numerous thru-

out the soil. Slick spots, identified by their lighter color in the surface soil, are numerous in this type.

Management.—Drainage should be provided to keep the water running off from surrounding higher land from spreading over this type and to remove excess surface water from rains. This can best be done by well-distributed open surface ditches. The organic-matter content should be increased by applications of animal manure or by plowing under green manuring crops. The soil is acid and should be tested and limestone applied as needed. Following the building up of the organic-matter content a trial application of a potassium fertilizer is suggested. The test for available phosphate in the soil should be made and phosphate applied if needed.

This soil should return fair crop yields if properly managed.

Gray Silt Loam On Tight Clay (2)

Gray Silt Loam On Tight Clay is found on the poorly drained, flat to undulating land in the southeastern part of the county. It occupies about 10 square miles. It is an old prairie soil and is characterized by an almost impervious subsoil, making it wet in spring and drouthy in summer. It is difficult to drain because of its flatness and the impossibility of underdrainage.

The surface soil is 6 to 8 inches thick and is a friable gray silt loam. The upper subsurface is lighter in color than the surface, and the lower subsurface is an ashy light gray silt loam. The subsoil begins at 18 to 21 inches and is a very compact and plastic pale yellowish gray clay. Numerous small, hard, rounded pellets are scattered on the surface and thru the soil. The subsoil remains compact to a depth of nearly 6 feet. Slick spots are very numerous.

Management.—It is questionable just how far to proceed with treatment to increase production on this type because of the practical impossibility of securing good drainage and the presence of so many unproductive slick spots. Where drainage can be obtained, treatment similar to that suggested for Deep Gray Silt Loam On Tight Clay (page 14) should be used.

Only a moderate return in crop yields can be expected even under the best management. The use of this soil largely for hay and meadow crops, particularly redtop, is suggested at this time.

Gray Silt Loam On Orange-Mottled Tight Clay (3)

Gray Silt Loam On Orange-Mottled Tight Clay occurs on the undulating prairie land in the southeastern part of the county. It occupies only 9.59 square miles. It has fair surface drainage but poor underdrainage.

The surface soil is 6 to 7 inches thick, and is a friable gray silt loam. The upper subsurface is yellowish gray and friable. The lower subsurface is gray with orange-colored mottling and is ashy. The subsoil begins at 15 to 18 inches and is a very compact and plastic yellowish gray clay heavily orange-mottled. The lower subsoil below 32 to 34 inches is less compact.

Management.—Artificial drainage should be provided by shallow open surface ditches. The excess surface water can be readily removed from this type because it lies on sloping land. The organic-matter deficiency should be cor-

rected and further treatment given as suggested under the management of Deep Gray Silt Loam On Tight Clay (page 14).

This type will produce fair crop yields under good management, but the impervious nature of the subsoil limits returns in all but the most favorable years.

Yellowish Gray Silt Loam On Orange-Mottled Tight Clay (4)

Yellowish Gray Silt Loam On Orange-Mottled Tight Clay is mapped on the drift knolls and on the rolling land along the streams in the southeastern part of the county. It occupies only a small acreage. It has good surface drainage because of the slopes on which it lies. Most of the type was originally covered with a growth of brush and scattering trees such as locust and wild cherry.

The surface soil is 4 to 5 inches thick and is a yellowish gray silt loam. The subsurface is yellow with dull red or orange-colored splotches. The subsoil begins at 11 to 13 inches and is a medium-compact clay loam, somewhat plastic of reddish yellow color splotched with dull red. The lower subsoil is friable and is yellow in color.

Management.—In cultivating this land precaution must be taken to prevent erosion. The more rolling slopes should be terraced and vegetation kept on the land as much as possible, and particularly thru the winter and early spring months. The soil should be tested for its need of limestone and for available phosphorus. The organic-matter content should be built up by applying animal manure or by growing and plowing under green manuring crops such as sweet clover. This type makes good orchard land and is well adapted to small fruits and vegetables. Alfalfa can be successfully grown after proper soil treatment.

Eroded Silt Loam (5)

Eroded Silt Loam occupies about 30 square miles on the very rolling and steep land adjacent to streams in the southwestern part of the county. This type is subject to serious and destructive erosion. The soil shows little or no horizon development and is a friable, yellow silt loam. The less steep slopes can be used for orcharding and permanent pasture. The remainder of the area should be kept in timber. This soil should not be cultivated.

Eroded Gravelly Loam (8)

Eroded Gravelly Loam, occupying 120.73 square miles in Macoupin county, is mapped on the steep, gullied hillsides adjacent to streams. It differs from Eroded Silt Loam in being composed of a sandy, gravelly material rather than silty material. The sandy, gravelly material is glacial drift which has been exposed following the removal of the silty loess cap by erosion.

This soil should be managed in a manner similar to that suggested for Eroded Silt Loam.

Light Gray Silt Loam On Tight Clay (11)

Light Gray Silt Loam On Tight Clay occupies the very flat, exceptionally poorly drained areas in the upland in the southeastern part of the county. It

is the poorest soil in the county but fortunately is very limited in extent, occupying a total of only 390 acres. The areas of this type are now, or were formerly, covered with post oak and hickory timber.

The surface soil is a thin, light gray silt loam. The subsurface is a thick, very light gray, ashy silt loam. The subsoil begins at 21 to 22 inches below the surface and is a very compact, very plastic, pale yellowish gray clay.

Management.—The practical impossibility of draining this soil makes it doubtful if any sort of treatment involving a money outlay should be attempted. The land can be kept in grass such as redtop and used for pasture. It might also be replanted to timber.

Yellow-Gray Silt Loam On Tight Clay (12)

Yellow-Gray Silt Loam On Tight Clay occurs on the flat to very gently sloping land which is now, or was formerly, covered with timber. It occurs in the southern and southeastern parts of the county and occupies 7.75 square miles. Both surface drainage and underdrainage on this type are poor but not so bad as on Light Gray Silt Loam On Tight Clay. Small slick spots frequently occur.

The surface soil is 4 to 5 inches thick and is a friable yellowish gray silt loam. The subsurface is light gray, and is ashy in the lower part. The subsoil is a thick, compact, plastic, yellowish gray clay.

Management.—The reader is referred to the management of Gray Silt Loam On Tight Clay (2) for suggestions regarding the soil treatment for this type. Artificial drainage should be more easily provided on this type than on Gray Silt Loam On Tight Clay, because it is usually easier to obtain a good outlet. Special attention should be given to increasing the organic-matter content, as this important soil constituent is very low.

Yellow-Gray Silt Loam On Compact Medium-Plastic Clay (13)

Yellow-Gray Silt Loam On Compact Medium-Plastic Clay is found on the gently rolling to rolling upland in the central and southern parts of the county which is now, or was formerly, timbered. It occupies 132.47 square miles, or 15.59 percent of the total area of the county. It occurs on the intermediate slopes between the prairie and the steep, gullied land along streams. It is moderately well drained.

The surface soil is about 6 inches thick and is a yellowish gray, friable, silt loam. The subsurface is a grayish yellow silt loam, the lower part of which is gray and somewhat ashy. The subsoil begins at 15 to 18 inches and is a medium-compact, somewhat plastic clay loam yellow in color and splotched with gray. Below 32 to 36 inches the material is less compact and less plastic.

Management.—Provision should be made to carry off the excess water in order to prevent sheet erosion and to enable the soil to dry out earlier in spring. Tile will work in this type if laid shallow and placed close together. Open surface ditches are practical if care is observed to prevent gully formation. The land should have a protective covering of vegetation during winter and early spring months. Terracing on the more rolling land would effectively check erosion. The organic-matter content should be increased by the application of

animal manure, or by the growing and turning under of green manuring crops. Sweet clover is an excellent crop for this purpose and it will make a good growth on this soil after the acidity is corrected. Test the soil and apply limestone as needed. Trial applications of both a phosphorus and a potassium fertilizer are suggested following the correction of any drainage and erosion difficulties and the addition of fresh organic matter.

This soil responds well to good farming and under proper management should produce satisfactory yields of grain, alfalfa, vegetables, and fruits.

Reddish Yellow-Gray Silt Loam (14)

Reddish Yellow-Gray Silt Loam is found on the rolling upland that is now, or was formerly, timbered. It occupies a position on the smooth slopes of the glacial knolls which rise above the surrounding flat upland and on the uneroded slopes between the upland and the bottom land. It covers only 1.32 square miles and is confined to the southern part of the county.

The surface soil is 4 to 5 inches thick and is a very friable brownish yellow silt loam. The subsurface is yellow with a reddish cast. The subsoil begins at 12 to 14 inches and is a reddish yellow, slightly compact clay loam. The soil material becomes very friable below 26 to 28 inches and is a yellow silt loam streaked with gray.

Management.—Every precaution must be used to check erosion on this type if it is to be cultivated. The land should be terraced and vegetation kept on it as much as possible. The organic-matter content should be increased and a phosphate fertilizer should be tried out. Add limestone to correct acidity.

This soil will grow good alfalfa, and it can also be used for small grains, fruits, and vegetables.

Reddish Yellow Silt Loam (15)

Reddish Yellow Silt Loam occupies about 2 square miles on the very rolling to steep, but uneroded, areas occurring in conjunction with Reddish Yellow-Gray Silt Loam. In cultivating this soil great care should be observed, as it slopes are so steep that erosion, once started, is difficult to control.

The surface soil is about 4 inches thick and is a yellow silt loam. The subsurface and subsoil are reddish yellow in color and friable in texture. Some sand and gravel occur on the steeper slopes where erosion has removed most of the overlying loess.

Management.—This type is similar to Reddish Yellow-Gray Silt Loam, Type 14, in its management requirements. Extreme care must be observed to avoid erosion if the land is to be plowed and cultivated. Because of this fact it is better adapted to orcharding or permanent pasture than to general farming.

Grayish Brown Silt Loam On Clay (46)

Grayish Brown Silt Loam On Clay is scattered in irregular areas on the flat, low-lying prairie land in the central and northern parts of the county. It occupies practically 35 square miles, or about 4 percent of the total area of the

county. The areas of this soil type were swampy and originally poorly drained but have since been tiled. In seasons of excessive rainfall water still accumulates over the surface because it cannot be removed fast enough.

The surface soil is about 8 inches thick and is a medium brown silt loam. When the soil is dry it appears to contain gray specks. The subsurface is darker brown and somewhat heavier in texture than the surface. The lower portion of the subsurface is grayish brown and is lighter in texture. The subsoil begins at 18 to 20 inches and is a drabbish brown splotched with yellow, medium-compact and plastic clay. Below 36 to 38 inches the soil material becomes friable and has a drabbish gray color which is splotched with yellow.

Management.—Tile drainage should be provided on this soil type. The tile should be large and should be placed close together. The organic-matter content should be maintained by applying animal manure or by growing and plowing under green manuring crops. Red clover will grow on this soil without lime unless it has been farmed too exhaustively. Sweet clover requires the presence of limestone for growth. The soil should be tested and limestone applied as needed. The soil should also be tested for available phosphate; if little or none is present, indications are that the application of some phosphate carrier would pay.

Grayish Black Silt Loam On Clay (47)

Grayish Black Silt Loam On Clay is found in the depressions on the upland prairie in the central southern part of the county. Its topographic position is similar to that of Grayish Brown Silt Loam On Clay. It differs from that type in having a darker colored and heavier textured surface soil and a more grayish subsoil. Small, rounded, grayish pellets of lime frequently occur in the subsoil of this type. Undoubtedly the depressions in which this type is found were much more swampy prior to being artificially drained than the depressions in which Grayish Brown Silt Loam On Clay is mapped. It occupies 3.38 square miles in the county.

The surface soil of this type is 8 to 10 inches thick and is a heavy, dark brown to black silt loam. When it is dry the dark-colored soil particles appear grayish from the gray specking on them. The subsurface is a drabbish brown to drabbish black clay loam. The gray specking becomes more prominent near the base of the subsurface and can be observed even when the soil is wet. The subsoil begins at 17 to 21 inches. It has a drabbish gray color heavily splotched with pale yellow. In texture it is a compact and plastic clay loam. Below 32 to 34 inches the subsoil color is a light drabbish gray splotched with pale yellow and the texture becomes less compact.

Management.—The recommendations for Grayish Brown Silt Loam On Clay, given above, apply in general to this type also. However, more care must be observed in securing adequate drainage on this type than on the former, and somewhat less attention need be paid to the organic-matter content. Most areas of this type will grow sweet clover without lime. Fields should be tested for acidity, however, before they are seeded.

This is a very productive soil when adequately drained and properly managed.

Grayish Drab Silt Loam On Clay (48)

Grayish Drab Silt Loam On Clay is found on the flat prairie land in the central part of the county. It occupies nearly 45 square miles, or 5.29 percent of the total area of the county. It was naturally poorly drained, but installation of tile and the construction of ditches have improved drainage considerably. It resembles the two types just described, Nos. 46 and 47, but differs from them chiefly in being lighter in color thruout the soil strata, in having a fairly well developed ashy, gray layer and a more compact, plastic, and impervious subsoil. This type is somewhat less productive than either of the above mentioned types and is more difficult to drain.

The surface soil is about 7 inches thick and is a grayish drab, friable silt loam. The subsurface is lighter in both color and texture than the surface. The lower 2 or 3 inches of the subsurface is gray and ashy. The subsoil begins at 18 to 19 inches and is a compact and plastic, drabbish gray clay splotched with pale yellow. Small slick spots are very numerous thruout the area of this type, and they reduce its productivity considerably.

Management.—Drainage should be provided on this type by means of tile, and by surface and dredge ditches. Tile lines must be placed close together, and surface ditches should be provided to carry off the excess surface water. Dredge ditches often are the only means of furnishing a proper outlet. The organic-matter content should be increased by the application of animal manure or the growing and plowing under of green manuring crops. Legumes should be grown and plowed under frequently. The soil is somewhat acid except in the slick spots. It should be tested for acidity and limestone applied as needed. It would be well to make a trial application of a potassium fertilizer, as potassium may or may not give response in crop yields. A test for available phosphorus should be made also and phosphate applied if needed.

This type of soil will give satisfactory returns if it is adequately drained and carefully managed.

Grayish Brown Clay Loam On Clay (50)

Grayish Brown Clay Loam On Clay is found in conjunction with Grayish Drab Silt Loam On Clay, just described, and occurs on very flat topography. It occupies 2.79 square miles. It is very poorly drained naturally and is distinctly heavier in texture than the above type.

The surface soil is a grayish drab plastic clay loam about 8 or 9 inches thick. The subsurface is lighter in color than the surface but somewhat heavier in texture. The subsoil begins at 16 to 19 inches and is a drabbish gray clay splotched with pale yellow. It is compact and very plastic. Numerous slick spots occur thruout this type.

Management.—For suggestions regarding the treatment of this type the reader is referred to the management of Grayish Drab Silt Loam On Clay, given above. Naturally this clay loam is more difficult to drain and cultivate than the silt loam type and it should have frequent applications of either stable or green manure to increase the active organic-matter content.

Unless properly managed, this soil is not very productive and in unfavorable seasons crops fail, but with good management it is a very productive soil.

Black Clay Loam (65)

Black Clay Loam occurs on the flat, originally poorly drained prairie areas in the northern part of the county. It occupies somewhat less than 3 square miles.

The surface soil is about 9 inches thick and is a dark brown to black clay loam. When dry the surface soil has a slightly gray cast. The subsurface is a drabbish black clay loam. The subsoil begins at 18 to 20 inches. It is a drabbish brown color splotched with yellow in the upper part and becomes drabbish gray below 28 to 30 inches.

Management.—Black Clay Loam is a very productive soil if it is properly drained and well managed. It is sometimes difficult to secure a good outlet for tile, but the soil can be thoroly drained when an outlet is established. This type seldom needs limestone to grow sweet clover. It should be tested for available phosphorus and phosphate added if needed. Fresh organic matter should be added frequently to keep the soil in good physical condition.

Black Clay Loam On Drab Clay (66)

Black Clay Loam On Drab Clay occurs in the depressions on the prairie in the northern part of the county. This type was formed under swampy conditions. In fact, during wet seasons water still collects on the surface of many of these areas.

The surface soil is 10 to 11 inches thick and is a heavy drabbish black clay loam. The subsurface is more plastic and drabbish in color than the surface. The subsoil begins at 18 to 20 inches and is a drabbish gray plastic clay. A few small pale yellow splotches appear below 38 to 40 inches, but the material is gray down to 50 inches.

Management.—Adequate drainage must be provided before the areas of this type can be profitably cultivated. Large tile should be used and a good outlet established. Frequent additions of organic matter and a good crop rotation is all the treatment suggested. The soil is sweet and a few small spots may contain sufficient alkali to be harmful. The alkali spots will show up when planted to corn; they should have an application of potash when the next crop of corn is planted.

Mixed Loam (72)

Mixed Loam occurs in the stream bottom lands thruout the county. This type is variable both in color and texture. The small-stream bottom lands are yellowish in color and have some sand and gravel mixed with the silt loam. Those in the northern part of the county are brownish, whereas in the southern part gray predominates. The large-stream bottom lands are silty and are yellowish gray in color. All the bottom lands are subject to intermittent overflow, but they usually are dry long enough in summer to produce a corn crop. This type of soil occupies 64.44 square miles, or 7.58 percent of the total area of the county.

Management.—Most of this land drains well if opportunity for drainage is afforded. Surface ditches frequently aid in removing the excess surface water. No treatment is suggested because the land is subject to frequent overflow, which results in constant renewal of the soil material. Winter and early spring crops are often lost because of flooding but summer crops, such as corn and soybeans, usually yield well. Less than half the total area of this type is cultivated.

Deep Brown-Gray Silt Loam On Tight Clay (111)

Deep Brown-Gray Silt Loam On Tight Clay is mapped in depressions on the flat prairie upland and at the heads of stream drainage in the central southern parts of the county. It occupies 4.47 square miles. The soil material was derived largely from sediment washed in from surrounding higher land. This type is poorly drained.

The surface soil is 8 to 9 inches thick and is a grayish brown silt loam. The subsurface is thick and varies from a brownish gray near the top to a gray silt loam just above the subsoil. The subsoil is not always developed and seldom is over 4 to 8 inches thick. Where it is developed, it begins at 22 to 26 inches and is a pale yellowish gray, compact and plastic clay. Slick spots are numerous.

Management.—Drainage should be established by the use of open ditches and tile. Tile must be placed close together. Excess surface water is best removed by a system of shallow ditches. The organic-matter content should be increased by the frequent addition of animal or green manure. The soil should be tested for its need of limestone and phosphate. Limestone must be added to grow clovers. A trial application of a potassium fertilizer is also suggested.

This type of soil should give moderate returns in crop yields if properly drained and managed.

Brown-Gray Silt Loam On Tight Clay (112)

Brown-Gray Silt Loam On Tight Clay occurs on the flat, poorly drained prairie land in the central and southern-parts of the county. It occupies over 50 square miles, or about 6 percent of the total area of the county. This type is characterized by an impervious subsoil which makes underdrainage very poor.

The surface soil is about 7 inches thick. It is a silt loam, appearing brown when wet but grayish brown when dry. The subsurface is brownish gray with a gray ashy layer in its lower part. The subsoil begins at 17 to 20 inches and is a pale drabbish gray, compact and plastic clay heavily splotched with yellow. The upper subsoil has drabbish brown coatings over the soil particles. Soft reddish yellow concretions are also present. Slick spots which are too small to be shown on the map are numerous.

Management.—For suggestions regarding the treatment of this soil the reader is referred to the management of Gray Silt Loam On Tight Clay, page 15. Much better response should be obtained from this type than from the former, but even under the best treatment only moderate yields can be expected because of the drainage handicap.

Brown-Gray Silt Loam On Reddish Brown Tight Clay (113)

Brown-Gray Silt Loam On Reddish Brown Tight Clay occurs on the gently sloping prairie land thruout the county. It occupies nearly 63 square miles, or more than 7 percent of the total area of the county. Surface drainage is fair to good but underdrainage is poor owing to the impervious nature of the subsoil.

The surface soil is about 7 inches thick and is brown when wet but grayish brown when dry. The subsurface is a yellowish gray silt loam, the lower part of which is ashy gray and splotched with orange or dull red. The subsoil begins at 14 to 17 inches and is a compact and plastic drabbish yellow clay heavily splotched with reddish yellow. Below 34 to 36 inches the subsoil is more friable. Some small slick spots are to be found.

Management.—Drainage should be provided by means of a system of surface ditching which will quickly remove the excess water accumulated from rains. The organic-matter content must be built up and maintained by frequent additions of manure. The soil should be tested for its need of limestone and also for available phosphorus. Limestone and phosphate should be applied as needed. After the soil has been treated as suggested above, a trial application of potassium should be made and a potassium fertilizer applied if the trial indicates sufficient benefit.

This soil will return moderate yields if properly managed but it will not stand poor management.

Brown-Gray Silt Loam On Compact Medium-Plastic Clay (114)

Brown-Gray Silt Loam On Compact Medium-Plastic Clay occurs on the rolling prairie land in the central southern part of the county. It occupies 7.21 square miles. It has good surface drainage and fair underdrainage but is subject to erosion when continuously cultivated.

The surface soil is about 6 inches thick and is a yellowish brown silt loam. The subsurface is yellow and appears gray specked when dry. The subsoil begins at 11 to 13 inches and is a yellow, compact, somewhat plastic clay loam splotched with reddish yellow. The subsoil becomes friable below 26 to 28 inches.

Management.—If this soil is to be cultivated it should be protected from erosion by terracing or by keeping a vegetative covering on it thruout the winter and spring months. The organic-matter content should be built up and maintained by frequent additions of stable or green manure. The soil should be tested for its need of limestone and for available phosphorus. Limestone and phosphate should be applied as needed. This soil will grow alfalfa following liming and is an excellent orchard soil.

Drabbish Gray Silt Loam On Tight Clay (115)

The descriptive name Drabbish Gray Silt Loam On Tight Clay misrepresents the soil type as mapped because it is found on very rolling topography, is well drained, and has a rather friable subsoil. Only 128 acres of this type occur in the county, all of which is in the southern part.

The surface soil is a thin brownish yellow silt loam. The subsurface is yellow splotched with dull red. The subsoil begins at 9 to 11 inches and is a reddish yellow, slightly compacted, somewhat plastic clay loam. The subsoil becomes friable below 16 to 18 inches and is yellow in color.

Management.—For suggestions regarding the management of this type the reader is referred to Type 114, Brown-Gray Silt Loam On Compact Medium-Plastic Clay, page 23. Greater precaution, however, must be used in protecting this soil from erosion; it should be kept under a vegetative cover as much as is possible.

Drabbish Yellow-Gray Silt Loam On Tight Clay (116)

Drabbish Yellow-Gray Silt Loam On Tight Clay occurs on the flat, poorly drained land in the central and northern parts of the county. The areas of this type are now, or were formerly, covered with oak and hickory timber. This type occupies only 2.32 square miles in the county. An impervious subtratum underlies this soil, making underdrainage very poor.

The surface soil is 6 to 7 inches thick and is a drabbish gray friable silt loam. The subsurface is gray and is ashy in the lower part. The subsoil begins at 17 to 20 inches and is a pale drabbish gray, compact, plastic clay, splotched with pale yellow. Slick spots occur on this type.

Management.—Drainage should be established thru the use of open ditches. The organic-matter content should be increased and maintained by the frequent application of stable or green manure. The soil is acid excepting in the slick spots and should be tested and lime applied as needed. Following the correction of drainage, the application of lime, and the plowing under of manure, trial applications of phosphate and potassium fertilizers should be made. Some form of these fertilizers should be used if the trial indicates sufficient benefit to justify the expense.

Even under full treatment and the best of management this soil will return only moderate crop yields.

Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay (117)

Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay is mapped on intermediate sloping land in the central and northern parts of the county. This type is now, or was formerly, covered by timber. It occupies over 108 square miles, or about one-eighth of the total area of the county. The soil has good surface drainage and fair to good underdrainage.

The surface soil is about 7 inches thick and is a dark drabbish yellow, friable, silt loam. The subsurface is yellow and somewhat grayish in the lower part. The subsoil begins at 15 to 18 inches and is a medium-compact, plastic, drabbish yellow clay loam. Below 30 to 32 inches the material is more friable.

Management.—The drainage of this soil can be improved by tile and, on the more level portions, by shallow surface ditches. The organic-matter content should be built up and maintained by frequent additions of animal manure or by plowing under green manuring crops. Sweet clover is a good crop to use

for this purpose. It will make a good growth on this soil after the acidity is corrected. The soil should be tested and limestone applied as indicated by the test. Following the improvement of drainage and the addition of organic matter, a phosphate fertilizer should be applied either on clover or wheat, on a trial basis.

This soil should return fairly good crop yields under good management. Some precaution must be taken to keep erosion from destroying those areas that lie adjacent to present eroded areas. This can usually be accomplished by installing permanent or temporary dams.

Drabbish Yellow-Gray Silt Loam (118)

Drabbish Yellow-Gray Silt Loam occurs on the rolling land that is now, or was formerly, timbered. It occupies only 1.63 square miles and is found in the western part of the county. It is a well-drained soil but is subject to some erosion, chiefly sheet washing.

The surface soil is about 6 inches thick, and is a brownish yellow, very friable, silt loam. Erosion has in many places removed a portion of the surface soil, leaving it thin. The subsurface is yellow with a reddish cast. The subsoil begins at 10 to 14 inches and is a slightly compacted, non-plastic, reddish yellow, silty clay loam. It becomes very friable below 24 to 26 inches and has a grayish cast.

Management.—Some precautions must be observed to stop erosion on this soil. If it is to be continuously cultivated, the land should be terraced and the crop rotation so arranged as to maintain a vegetative cover during winter and early spring months. The same management is suggested for this type as was given for Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay (page 24). Following liming, this soil will grow good legume crops, including alfalfa. It also makes a good orchard soil.

Slick Spots (120)

Slick Spots are found on the flat to gently rolling land thruout the county. They occupy 4.63 square miles as mapped, but they also occur in spots, too small to map, in conjunction with all soil types found on flat to gently rolling land. They can be recognized by their lighter colored surface soil, and by their difference in moisture. When once dry, slick spots do not take up water easily and they remain much drier than the surrounding soil. The very compact nature of their subsoil forces the plow to the surface and makes it draw very hard. In roadside cuts and ditches the subsoil stands out in characteristic columns over which a white salty material accumulates on drying. Slick Spots are thought to have formed by the accumulation of bases, which are continually going into solution as the soil material weathers. The accumulation of bases is caused by the presence of an impervious layer in the substratum, that stops underdrainage. Slick Spots have a very high alkaline reaction in the subsoil altho the surface soil is often acid.

The surface soil, when present, is an ashy gray silt loam. Oftentimes the subsoil is developed up to the surface so that there is no true surface soil present.

The subsurface soil, when present, is an ashy white silt loam. The subsoil begins at depths varying from the surface down to 26 or 30 inches. When wet it is a soft, mushy, greenish yellow clay, but when dry it is a very hard, pale yellowish gray clay.

Management.—Enough drainage should be provided, wherever possible, so that the water table is never above 36 inches. This can be done only by ditches, for tile will not draw. Unless drainage can be provided, no attempt should be made to treat the soil. The surface and subsoil should be tested for their re-

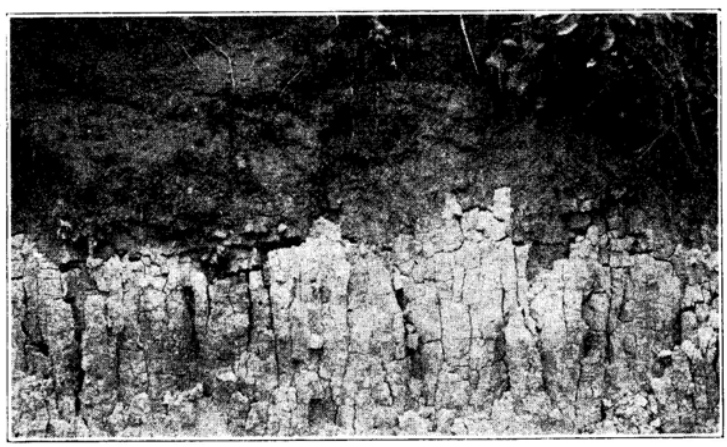

FIG. 7.—COLUMNAR STRUCTURE IN SUBSOIL OF SLICK SPOT
This distinctly columnar formation occurs just beneath the surface in Slick Spot areas.

action. If the surface is acid, enough limestone should be applied to correct the acidity and then sweet clover should be seeded. Sweet clover may be allowed to reseed itself for a number of years before being plowed under. Practical experience has shown that animal manure is of less value on Slick Spots than on other soil types.

Crop yields on this soil vary from nothing in unfavorable years to a small yield in years of favorable moisture conditions. Small grains and clover grow better than corn.

Grayish Brown Silt Loam (127)

Grayish Brown Silt Loam occurs on the gently rolling prairie land in the western and northern parts of the county. It occupies about 130 square miles, or nearly one-sixth of the total area. It has good surface drainage and underdrainage. It is one of the best general-purpose soils in the county.

The surface soil is about 8 inches thick and when moist is a friable brown silt loam. When it is dry it has a gray coat due to the presence of gray specks on the brown soil particles. The subsurface is yellowish brown and is also decidedly grayish when dry. The subsoil begins at 15 to 18 inches and is a medium-

compact and plastic brownish yellow clay loam. Gray coatings appear in the subsoil when it is dry.

Management.—Altho natural drainage is fairly good on this soil, improvement can be made by tiling, especially on the flatter areas. The organic-matter content should be maintained by frequent additions of animal or green manure. The soil should be tested for its need of limestone and limestone applied as required. One of the clovers, preferably sweet clover, should be grown in the rotation once every three or four years. The soil should be tested for available phosphorus and phosphate applied if needed. In addition to these treatments a trial application of some potassium fertilizer is suggested.

Profitable returns can be expected from this soil if it is properly managed.

Grayish Light Brown Silt Loam (128)

Grayish Light Brown Silt Loam occurs on the rolling prairie upland in the northern part of the county. The slopes on which this type is found were produced either by erosion along drainage lines or as a result of glacial deposition forming knolls. This type occupies only 1.67 square miles in the county.

The surface soil is a shallow light brown silt loam. It has a gray cast when dry. The subsurface soil is light brownish yellow, also with a gray cast when dry. The subsoil begins at 12 to 15 inches and is a slightly compacted, nonplastic reddish yellow clay loam. Below 24 to 28 inches it becomes very friable and is grayish yellow in color.

Management.—The slope on which this soil occurs makes it subject to erosion, particularly sheet erosion. If the land is to be continuously cultivated it should be terraced and vegetation kept growing on it during the winter and early spring months. Limestone should be added as indicated by the test. The organic-matter content should be built up and maintained by frequent additions of animal or green manure. A test for available phosphorus should be made and phosphate applied if needed.

This soil is excellent for the growing of alfalfa, orchard and small fruits. It will return a profit in crop yields but must be carefully managed. It will not endure poor farming.

CHEMICAL COMPOSITION OF MACOUPIN COUNTY SOILS

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 discus-

sion is mostly concerned, for it includes the soil that is ordinarily turned with the plow and is the part with which the farm manure, limestone, phosphate, or other fertilizing material is incorporated. Furthermore it is the only stratum which can be greatly changed in composition by adding fertilizing materials.

For convenience in making application of the chemical analyses, the results presented in Tables 2, 3, and 4 are given in terms of pounds per acre. It is a simple matter to convert these figures to a percentage basis in case one desires to consider the information in that form. In comparing the 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.

Great Variation in Chemical Composition

Lying in the border region between the darker colored soils of the northern two-thirds of Illinois and the light-colored soils of the southern portion, there are found in Macoupin county not only soils representing these general groups but also types representing gradations between them. These wide variations are reflected in the chemical composition of the various soil types summarized in Tables 2, 3, 4. Only the upland soils are included in these tables because the bottom-land soils are not only extremely variable within a given type, but also subject to sudden change from time to time as a result of overflow.

While all the chemical elements studied, with the exception of potassium, vary within wide limits, it may be observed that the nonmetallic elements—carbon, nitrogen, phosphorus, and sulfur—all vary more or less in a parallel relationship. The reason for this is that all these elements are associated to a greater or less extent with the organic matter of the soil.

Nitrogen Closely Associated With Organic Matter

Being approximately half carbon, the organic matter of the soil is measured by the organic carbon. Soil nitrogen is practically all combined in the organic form, constituting about one-twentieth of the organic matter. In fresh organic materials the proportion of nitrogen is much less than in older materials, in which decay has taken place, for in the process of decay the carbon is oxidized and lost much more rapidly than is the nitrogen and so the ratio of nitrogen to carbon gradually narrows. The nitrogen-carbon ratio tends also to become much more narrow with increasing depth of soil, particularly in the more mature soil types. This is to be expected in view of the fact that the organic matter in the deeper levels is older and is replenished with fresh plant residues to a less extent than is that nearer the surface. In the soils of Macoupin county the nitrogen-carbon ratio drops from an average of 1:11.3 in the surface soil to 1:8.9 in the lower stratum. If only the more mature types be considered, the narrowing of this ratio will be seen to be even more pronounced.

In addition to the change in the chemical character of the organic matter with increasing depth, as shown by the nitrogen-carbon ratios, there is a very

TABLE 2.—MACOUPIN COUNTY SOILS[1]: 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 potassium	Total magnesium	Total calcium
1	Deep Gray Silt Loam On Tight Clay	36 400	3 640	720	29 780	6 320	7 500
2	Gray Silt Loam On Tight Clay	24 710	2 670	800	28 660	4 940	5 300
3	Gray Silt Loam On Orange-Mottled Tight Clay	37 260	3 730	660	30 290	6 120	10 960
11	Light Gray Silt Loam On Tight Clay	18 550	1 650	740	(2)	5 010	6 130
12	Yellow-Gray Silt Loam On Tight Clay	15 320	1 390	710	(2)	3 700	4 920
13	Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	20 590	2 380	1 440	33 230	4 760	4 360
14	Reddish Yellow-Gray Silt Loam	24 800	2 740	1 120	39 240	5 700	7 280
15	Reddish Yellow Silt Loam	31 580	2 680	920	38 340	6 720	9 480
46	Grayish Brown Silt Loam On Clay	47 840	3 860	880	31 690	6 470	11 340
47	Grayish Black Silt Loam On Clay	66 670	4 550	1 230	31 810	9 540	14 550
48	Grayish Drab Silt Loam On Clay	36 440	3 040	890	30 940	6 650	10 190
50	Grayish Brown Clay Loam On Clay	36 560	3 160	1 380	35 820	10 300	15 460
65	Black Clay Loam	65 710	5 140	1 460	28 970	9 250	14 550
66	Black Clay Loam On Drab Clay	73 380	6 820	1 340	32 360	13 500	20 640
111	Deep Brown-Gray Silt Loam On Tight Clay	25 680	2 320	780	28 620	9 080	4 540
112	Brown-Gray Silt Loam On Tight Clay	33 010	2 830	770	32 440	5 680	8 150
113	Brown-Gray Silt Loam On Reddish Brown Tight Clay	37 130	3 130	1 040	36 230	6 240	9 950
114	Brown-Gray Silt Loam On Compact Medium-Plastic Clay	27 380	2 860	1 390	36 420	6 640	6 690
115	Drabbish Gray Silt Loam On Tight Clay	19 040	1 880	720	33 000	5 280	6 740
116	Drabbish Yellow-Gray Silt Loam On Tight Clay	28 850	2 410	910	32 670	4 660	6 250
117	Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	20 480	2 000	820	37 980	7 460	5 760
118	Drabbish Yellow-Gray Silt Loam	37 900	3 480	1 020	37 980	8 100	10 320
120	Slick Spot	20 680	1 420	580	29 600	3 780	6 600
120A	Slick Spot	23 800	2 160	680	(2)	3 360	9 420
120B	Slick Spot	27 250	2 440	710	30 260	4 460	9 490
120C	Slick Spot	25 810	2 130	560	29 600	4 620	7 750
127	Grayish Brown Silt Loam	48 520	3 500	890	33 860	7 050	9 160
128	Grayish Light Brown Silt Loam	20 100	1 880	640	34 440	9 100	7 140

[1]Samples from neighboring counties are included. [2]No total potassium analyses available.

definite decrease in the *total amount* of organic matter present with increasing depth. This falling off in amount of organic matter is observable to some extent in the middle sampling stratum but is much more striking in the lower stratum.

Light-Colored Soils Low in Phosphorus

In contrast to nitrogen, only one-fourth to one-third of the phosphorus in most soils exists in various organic forms. Hence variations in the amounts of phosphorus in the different soils are more nearly independent of the organic matter than is the case with nitrogen, especially in the lower levels, where the organic matter is not abundant and most of the phosphorus exists in mineral combinations. Among the soils poorest in total phosphorus content are the lightest colored soils, such as Types 1, 2, 3, 11, and 12, and the Slick Spots. These types are rather well supplied, however, in the lower stratum.

TABLE 3.—MACOUPIN COUNTY SOILS[1]: 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 potassium	Total magnesium	Total calcium
1	Deep Gray Silt Loam On Tight Clay	43 400	4 160	2 040	61 560	12 120	15 800
2	Gray Silt Loam On Tight Clay	22 580	2 800	1 360	60 560	9 860	8 960
3	Gray Silt Loam On Orange-Mottled Tight Clay	39 340	3 940	1 270	63 820	16 720	16 980
11	Light Gray Silt Loam On Tight Clay	14 300	1 590	1 480	(2)	13 800	13 070
12	Yellow-Gray Silt Loam On Tight Clay	12 000	1 460	1 410	(2)	12 110	10 510
13	Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	15 210	1 980	2 140	70 630	17 960	8 900
14	Reddish Yellow-Gray Silt Loam	23 040	2 920	1 920	82 960	14 880	11 440
15	Reddish Yellow Silt Loam	20 720	2 680	1 440	77 760	21 320	11 920
46	Grayish Brown Silt Loam On Clay	65 830	5 170	1 520	64 220	17 340	21 980
47	Grayish Black Silt Loam On Clay	93 000	6 200	1 960	63 840	20 920	27 260
48	Grayish Drab Silt Loam On Clay	41 880	3 560	1 460	63 560	16 520	19 620
50	Grayish Brown Clay Loam On Clay	60 800	4 660	2 490	65 350	21 340	30 850
65	Black Clay Loam	78 150	6 260	2 260	59 890	18 770	27 140
66	Black Clay Loam On Drab Clay	61 160	6 000	2 200	66 080	29 640	37 480
111	Deep Brown-Gray Silt Loam On Tight Clay	44 520	3 600	1 440	58 000	26 240	10 480
112	Brown-Gray Silt Loam On Tight Clay	43 120	3 700	1 390	66 620	12 660	17 120
113	Brown-Gray Silt Loam On Reddish Brown Tight Clay	47 870	4 290	1 960	72 010	17 130	18 210
114	Brown-Gray Silt Loam On Compact Medium-Plastic Clay	22 720	2 530	1 890	68 470	21 890	12 500
115	Drabbish Gray Silt Loam On Tight Clay	12 000	2 040	1 280	64 440	12 640	10 000
116	Drabbish Yellow-Gray Silt Loam On Tight Clay	22 000	2 090	1 390	67 930	14 040	11 410
117	Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	14 160	1 680	1 840	76 000	22 640	8 640
118	Drabbish Yellow-Gray Silt Loam	33 960	3 440	1 600	76 640	19 480	16 880
120	Slick Spot	19 920	1 320	960	62 000	14 840	11 160
120A	Slick Spot	29 200	3 160	1 520	(2)	15 800	25 760
120B	Slick Spot	32 300	2 990	1 330	58 920	17 310	25 840
120C	Slick Spot	28 720	2 470	990	60 340	12 640	16 360
127	Grayish Brown Silt Loam	60 930	4 630	1 640	67 140	16 990	18 070
128	Grayish Light Brown Silt Loam	26 280	2 480	1 160	65 440	25 120	13 560

[1]Samples from neighboring counties are included. [2]No total potassium analyses available.

The Sulfur Cycle

Less is known of the state in which sulfur is combined in soils. The amounts present, however, tend in general to be much lower than those of phosphorus. While crops take as much sulfur as phosphorus from the soil, or even more, sulfur deficiencies do not ordinarily develop because of the supply of this element in the atmosphere. The sulfur dioxid which escapes into the air in the burning of wood and coal is brought to the earth dissolved in rain water, the amount thus recovered by the soil ranging in different parts of Illinois from one to three or more pounds of sulfur an acre a month. This is more than enough to supply the requirements of maximum crops.

Potassium Content Comparatively Uniform

The potassium content of Macoupin county soils shows relatively less variation from type to type than any other element studied. The average amount in

TABLE 4.—MACOUPIN COUNTY SOILS[1]: PLANT-FOOD ELEMENTS IN LOWER SAMPLING STRATUM, 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 potassium	Total magnesium	Total calcium
1	Deep Gray Silt Loam On Tight Clay	36 060	3 720	3 180	89 580	27 300	22 860
2	Gray Silt Loam On Tight Clay	34 110	3 960	3 420	83 940	36 150	19 740
3	Gray Silt Loam On Orange Mottled Tight Clay	19 010	2 710	2 960	101 880	39 420	30 160
11	Light Gray Silt Loam On Tight Clay	14 550	2 070	2 790	(2)	28 510	18 310
12	Yellow-Gray Silt Loam On Tight Clay	13 080	1 810	2 470	(2)	30 820	20 630
13	Yellow-Gray Silt Loam On Compact Medium-Plastic Clay	14 320	2 190	3 610	106 630	33 880	17 670
14	Reddish Yellow-Gray Silt Loam	26 460	3 660	3 420	123 060	36 540	17 280
15	Reddish Yellow Silt Loam	18 900	2 820	2 220	106 020	33 360	18 600
46	Grayish Brown Silt Loam On Clay	41 040	3 960	2 210	92 490	38 800	34 240
47	Grayish Black Silt Loam On Clay	46 980	3 300	2 580	92 970	44 400	40 470
48	Grayish Drab Silt Loam On Clay	33 120	3 060	2 280	94 650	41 520	37 350
50	Grayish Brown Clay Loam On Clay	39 940	3 280	3 030	96 030	33 060	40 140
65	Black Clay Loam	30 070	3 280	2 990	85 940	34 080	46 900
66	Black Clay Loam On Drab Clay	22 200	2 700	2 700	103 160	47 580	87 120
111	Deep Brown-Gray Silt Loam On Tight Clay	25 440	2 160	2 640	117 240	40 080	28 320
112	Brown-Gray Silt Loam On Tight Clay	31 580	3 450	2 560	96 770	38 670	31 400
113	Brown-Gray Silt Loam On Reddish Brown Tight Clay	31 930	3 720	3 000	105 720	38 700	30 760
114	Brown-Gray Silt Loam On Compact Medium-Plastic Clay	20 000	2 380	3 100	101 560	34 610	25 610
115	Drabbish Gray Silt Loam On Tight Clay	28 500	3 300	2 220	100 740	40 020	18 540
116	Drabbish Yellow-Gray Silt Loam On Tight Clay	25 720	2 760	2 440	100 720	39 060	18 940
117	Drabbish Yellow-Gray Silt Loam On Medium-Plastic Clay	14 280	1 800	2 760	114 540	43 020	18 420
118	Drabbish Yellow-Gray Silt Loam	24 360	3 120	2 460	115 080	38 760	25 560
120	Slick Spot	32 160	2 400	2 340	93 540	45 180	26 760
120A	Slick Spot	19 200	2 280	3 540	(2)	35 520	49 140
120B	Slick Spot	24 440	2 770	2 960	96 360	36 160	53 410
120C	Slick Spot	26 060	2 800	2 220	85 680	40 540	52 420
127	Grayish Brown Silt Loam	35 050	3 760	2 310	97 900	40 490	34 530
128	Grayish Light Brown Silt Loam	25 980	2 760	1 560	87 240	33 300	21 900

[1]Samples from neighboring counties are included. [2]No total potassium analyses available.

the surface soil is approximately 33,000 pounds an acre, and the entire range thru all the types in the county is from a minimum of 28,620 pounds up to 39,240 pounds an acre. The potassium concentration in the soil at different depths likewise shows very little variation, averaging about 33,300 pounds an acre in the middle stratum, and 33,200 pounds in the lower, after correcting for the varying thickness of the different strata.

Wide Variations in Calcium and Magnesium

The soils of Macoupin county vary widely in their calcium and magnesium contents. These variations are related to the intensity of leaching and other weathering processes involved in soil development.

Aside from the calcium that may be in solution in the soil water, soil calcium exists primarily in three forms. *Calcium-aluminum silicates* are complex soil minerals which decompose but slowly and furnish but scant amounts of

soluble calcium for plant growth. This is the form which predominates in most soils, particularly in those which are highly acid. Calcium may be deficient for plant growth in such soils, so that the supplying of this element in readily available form may be one of the benefits of liming. Calcium also occurs in association with the soil colloids (the finest of the clay particles) by which it is absorbed; this is known as *replaceable calcium,* and is much more easily obtained by growing plants than the mineral form above mentioned. It is found more abundantly in the soils which are nonacid or only slightly acid. Types are occasionally found that grow sweet clover luxuriantly, because of the high degree of saturation of their colloids with replaceable calcium, even tho they may actually be somewhat acid. *Calcium carbonate,* the form contained in limestone, is the third form of calcium in soils. It occurs only in alkaline (sweet) soils. Of the three forms of calcium this is the one most readily dissolved in the soil water and leached to lower and lower levels as weathering proceeds, much of it eventually being removed entirely in the drainage water. This weathering and leaching process has continued to such an extent in Macoupin county that probably all the surface soils in the county are free from carbonates and the majority of the types are found to contain no calcium or magnesium in this form within the upper 40 inches. These statements concerning soil calcium apply in general also to the magnesium compounds in the soil.

Even after the carbonates have disappeared there continues a gradual release of the replaceable calcium and magnesium, which are taken up in part by growing plants and thus removed in harvested crops, but which are also continually being carried down by the soil water. This removal goes on at very different rates for calcium and magnesium. Either because of the more rapid loss of replaceable calcium or because of the greater reabsorption of part of the magnesium by soil colloids, the proportionate amount of magnesium as compared with calcium increases with increasing depth.

This changing ratio of magnesium to calcium in the lower levels is a function of the aging or approaching maturity of the soil. It is very pronounced in mature types but has proceeded to only a slight extent, or not at all, in young or immature soils. For example, it may be computed from the calcium and magnesium data in Tables 2, 3, and 4 that in Type 11, one of the mature types, the magnesium-calcium ratios are, for the upper, middle, and lower strata, respectively, .82, 1.06, and 1.55. That is, in the surface soil there is present .82, or about four-fifths, as much magnesium as calcium; in the middle stratum these two elements are about equal; while in the lower stratum the magnesium is more than one and one-half times as great as the calcium. In a typically immature or youthful soil such as Black Clay Loam, Type 65, these ratios are low and about equal in all three strata—.64, .69, and .73 respectively. While these figures all refer to the *total* calcium and magnesium, it has been definitely shown by other investigations that it is the more mobile, or *replaceable,* portion of these elements which is chiefly concerned in the shifting that results from leaching.

It is obvious, therefore, that some of the processes involved in soil development are definitely reflected in the chemical properties of the soil itself. These, in turn, may be related to agricultural utilization and to fertility requirements.

Local Tests for Soil Acidity Often Required

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

The qualitative field tests made during the process of the soil survey are much more numerous than the chemical analyses made in the laboratory, and they 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 the respective types on pages 14 to 27. To have a sound basis for the application of limestone, the owner or operator of a farm will, however, usually find it desirable to determine individually the lime requirements of his different fields. The section in the Appendix dealing with the application of limestone (page 57) is pertinent and should be read in this connection.

Character of Chemical Combination Related to Availability

It has been seen that a given plant-food element exists in the soil in various forms, or chemical combinations. Thus soil phosphorus is found partly in organic form and partly in inorganic, or mineral, combinations. These forms differ from each other, not only in the rates at which they become available to growing crops, but also in the way in which their availability to crops is affected by soil conditions. Calcium has been observed to be present sometimes as *calcium carbonate,* a form that is quickly available to crops; sometimes as *replaceable calcium,* a form somewhat less active than calcium carbonate; and also as *calcium-alumino-silicates,* minerals that decompose very slowly. Statements of similar import might be made concerning nitrogen, sulfur, and other elements. Moreover, the proportions in which the different forms of an element occur vary in different soils.

Thus, the rate at which plant-food elements become available is extremely important; a knowledge of merely the total amounts of these various elements present in a soil does not furnish sufficient information for complete guidance for the application of fertilizers.

Service of Chemical Investigations in Soil Improvement

While the chemical studies made in connection with the soil survey (of which the analyses here reported are a part) may not all serve directly as a complete guide in the use of fertilizers, they are nevertheless of value in two ways.

In the first place such investigations reveal at once any *outstanding* deficiences in the amounts of the various plant-food elements present—deficiencies so large that soil productivity would be affected regardless of other conditions. For instance, peat soils usually lack sufficient potassium to grow crops. This condition is revealed at once by the chemical analysis and the proper corrective measure is obvious. Small differences in the amount of a plant-food element, however, do not necessarily indicate corresponding differences in fertilizer need. Differences in phosphorus content as small as 100 or 200 pounds an acre, for example, should not be considered as indicating similar differences in the need for phosphate fertilization. In the case of nitrogen ordinary chemical analysis does not distinguish between active and inactive forms. One hundred pounds of active nitrogen added by plowing down a clover crop may be of more importance to the succeeding crop than 1,000 pounds of soil nitrogen if only a small part of it happens to be in a form that plants can use. As examples of the direct use of chemical analysis in soil improvement may be cited the tests for soil acidity, for carbonate, and for available phosphorus.

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

FIELD EXPERIMENTS ON SOIL TYPES SIMILAR TO THOSE IN MACOUPIN COUNTY

The University of Illinois has conducted altogether about fifty soil experiment fields in different sections of the state and on various soil types. Altho some of these fields have been discontinued, the majority are still in operation. It is the present purpose to report the results from certain of these fields located on soil types described in the accompanying soil report. For further discussion of these fields reference is made to Bulletin 362, "Response of Illinois Soils to Systems of Soil Treatment."

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

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

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

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

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

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

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

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

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

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

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

Explanation of Symbols Used. In the presentation of the data much use is made of the following symbols:

0 = Untreated land or check plots

M = Manure (animal)

R = Residues (from crops, and includes legumes used as green manure)

L = Limestone

P = Phosphorus, in the form of rock phosphate unless otherwise designated, (sP = superphosphate, bP = bone meal, rP = rock phosphate, slP = slag phosphate)

K = Potassium (usually in the form of kainit)

( ) = Parentheses enclosing figures, signifying tons of hay, as distinguished from bushels of seed

CARLINVILLE FIELD

The University has maintained a soil experiment field in Macoupin county for more than twenty years, the land having been donated for the purpose by Blackburn College. This field of 20 acres is located just north of the city of Carlinville.

Inasmuch as a detailed examination of the soil has disclosed five distinguishable types within its borders, this field cannot be said to represent an individual soil type in the sense of the soil survey. It does, however, represent a kind of land which, in a grouping of types, has been designated as "dark soils with impervious, non-calcareous subsoils of mature development." Moreover, this non-uniformity of land with respect to soil type is characteristic of the prevailing upland thruout this region, and the work on the Carlinville field is therefore of considerable practical interest to farmers of this general region.

The names of the individual soil types and their distribution over the field are shown in the accompanying diagram (Fig. 8). This same chart indicates, by means of contour lines, the topography or slope of the land and it also shows the arrangement of the experiment plots.

The field is laid out into three systems of plots which might be considered as constituting a major and two minor systems.

Major Series

The soil treatments and cropping practices on Series 100 to 400, which constitute the major series, have, with a few modifications, conformed to the general plan described on pages 35 and 36. In the earlier years a rotation of corn, oats, clover or soybeans, and wheat was practiced, but in 1924 this rotation was changed to corn, oats with Hubam clover seeding, wheat, and hay. This hay is a mixture of clover and alfalfa, the last growth of which is plowed down as a green manure

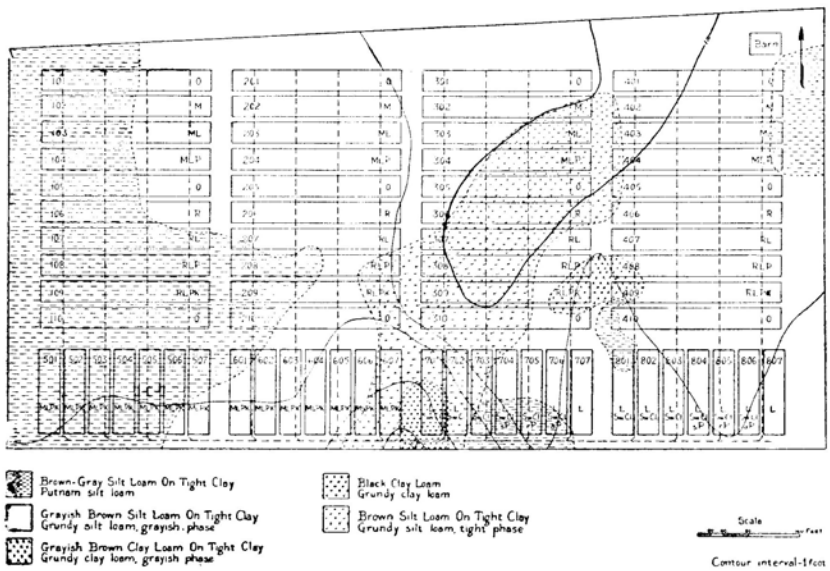

FIG. 8.—DIAGRAM OF THE CARLINVILLE SOIL EXPERIMENT FIELD

This diagram shows the arrangement of plots, the soil treatments applied, the location of the soil types and, by means of contour lines, the natural drainage of the field.

on the residues plots. In 1921 the return of oat straw was discontinued. The following year the return of wheat straw was discontinued. The regular application of limestone was discontinued in 1923 after 8½ to 10 tons had been received by the various plots. Rock phosphate was also discontinued after enough had been added to each phosphate plot to bring the total application to 4 tons an acre. In 1930 the phosphate applications were resumed by adding 400 pounds an acre to the wheat ground.

As a matter of record, the yields of all crops grown are given in Table 5, but for ready inspection the summarized results shown in Table 6 will be more convenient. The average annual yields of the several kinds of crops, including the years since the complete soil treatments have been in effect, are given in the latter table.

A study of the financial returns of the last crop rotation (ending in 1930), recently reported in Bulletin 370 of this Station, are brought together here in Table 7. For prices of crops and cost of treatments employed, the reader is referred to the above-mentioned bulletin.

TABLE 5.—CARLINVILLE FIELD: SERIES 100, 200, 300, 400
Annual crop yields—bushels or (tons) per acre

Plot No.	Soil treatment	1910 Wheat[1]	1911 Corn	1912 Oats	1913 Soy-beans	1914 Wheat	1915 Corn	1916 Oats	1917 Sweet clover	1918 Wheat	1919 Corn	1920 Oats	1921 Soy-beans	1922 Wheat	1923 Corn	1924 Corn	1925 Oats	1926 Wheat	1927 Clover-Alfalfa	1928 Corn	1929 Oats	1930 Wheat
101	0	8.1	36.3	19.1	(1.45)	7.8	36.4	31.6	(0.00)	26.5	28.4	33.3	22.3	15.5	17.2	18.6	28.9	13.6	(2.00)	32.5	12.2	10.5
102	M	9.3	42.9	23.8	(1.54)	10.4	47.7	40.6	(.05)	36.3	36.1	37.2	25.8	23.2	32.4	25.1	39.5	21.0	(1.99)	42.9	33.0	17.7
103	ML	10.4	50.7	29.7	(1.79)	17.8	56.9	48.3	(1.76)	48.0	48.0	63.3	29.1	32.1	44.8	36.2	47.0	22.7	(4.21)	60.2	39.7	33.2
104	MLP	12.9	52.7	32.2	(1.83)	19.6	58.6	50.5	(1.91)	48.5	47.2	57.2	30.6	33.8	45.4	37.2	44.8	21.3	(4.58)	61.5	40.3	31.4
105	0	9.1	38.0	20.3	13.6	8.4	36.6	30.6	...[3]	34.5	23.4	38.4	22.9	13.4	20.1	18.1	27.0	9.2	(1.79)	22.0	20.5	12.3
106	R	8.4	37.3	19.2	13.2	7.4	49.1	32.0	...[3]	34.8	29.3	35.6	22.5	8.7	45.3	22.8	33.9	10.8	(.92)	22.7	17.0	12.9
107	RL	8.8	45.7	26.9	15.8	12.8	68.0	49.5	...[3]	43.4	43.3	54.7	30.4	21.5	53.8	51.1	55.9	18.8	(3.23)	46.1	33.1	25.8
108	RLP	10.3	49.4	27.5	17.8	17.2	71.8	55.0	...[3]	47.3	45.9	52.0	33.2	30.2	55.1	54.3	57.0	21.8	(3.20)	48.7	32.0	28.8
109	RLPK	9.3	53.6	28.3	15.3	15.6	75.2	46.1	...[3]	50.6	46.8	48.2	33.4	32.3	55.3	57.1	51.3	25.8	(3.50)	59.1	32.0	28.0
110	0	6.8	40.8	19.1	(1.23)	7.3	38.4	27.0	(.17)	36.8	27.8	36.1	20.4	9.7	22.7	16.7	27.5	7.9	(1.85)	26.9	17.3	7.5
		Cow-peas[1]	Wheat[2]	Corn	Oats	Soy-beans	Wheat	Corn	Oats	Sweet clover	Wheat	Corn	Oats	Clover	Wheat	Oats	Wheat	Clover-Alfalfa	Corn	Oats	Wheat	Clover-Alfalfa
201	0	(.65)	21.3	30.6	5.1	(1.20)	14.2	28.4	46.1	(1.70)	27.3	9.3	33.3	(1.30)	25.2	36.7	18.1	(1.65)	34.8	30.2	19.7	(.61)
202	M	(.62)	23.6	41.4	2.3	(1.27)	19.7	39.9	62.2	(1.90)	27.7	15.9	47.7	(1.83)	31.9	52.2	28.6	(2.33)	52.9	40.8	25.5	(.87)
203	ML	(.74)	26.1	52.1	3.0	(1.50)	30.0	47.0	75.8	(1.65)	26.8	23.2	44.2	(1.92)	38.1	67.0	34.3	(3.09)	56.7	43.1	25.8	(1.95)
204	MLP	(.80)	27.8	46.0	2.8	(1.50)	28.0	49.3	76.2	(2.01)	26.4	27.8	44.2	(1.87)	40.0	65.5	34.9	(3.16)	56.5	44.2	28.4	(2.24)
205	0	(.65)	22.1	25.4	1.9	10.2	14.4	28.7	45.0	5.17	31.6	10.0	36.4	(1.57)	29.8	41.4	22.9	(1.80)	30.8	31.7	19.9	(.81)
206	R	.....	20.4	28.7	1.9	10.4	16.7	30.8	51.9	4.50	26.2	7.7	30.5	(1.63)	31.4	45.9	22.6	(1.67)	29.7	25.6	19.5	(.91)
207	RL	.....	28.6	35.6	2.0	13.9	28.8	37.4	72.3	6.42	28.5	11.7	59.2	(1.88)	36.0	63.4	27.3	(2.09)	32.5	35.0	23.4	(1.58)
208	RLP	.....	30.3	39.6	2.3	14.8	36.0	37.8	77.0	4.67	31.1	15.9	43.1	(1.97)	40.7	63.4	34.5	(2.44)	38.9	38.0	22.7	(1.89)
209	RLPK	.....	32.7	44.7	3.8	12.9	27.1	43.2	81.2	3.83	28.7	17.1	52.7	(2.15)	42.8	65.5	36.4	(2.93)	62.2	41.1	21.8	(2.37)
210	0	(.64)	28.2	35.1	5.5	(1.37)	18.6	32.8	46.2	(1.70)	17.8	6.8	41.6	(1.36)	28.2	40.8	19.9	(1.91)	39.9	34.1	16.2	(1.05)

[1]No manure or residues. [2]No manure. [3]No seed produced in 1917.

TABLE 5.—*Concluded*

Bushels or (tons) per acre

Plot No.	Soil treatment applied	1910 Oats[1]	1911 Clover[2]	1912 Wheat[2]	1913 Corn	1914 Oats	1915 Clover	1916 Wheat	1917 Corn	1918 Oats	1919 Sweet clover	1920 Wheat	1921 Corn	1922 Oats	1923 Soy-beans	1924 Oats[3]	1925 Clover-Alfalfa	1926 Corn	1927 Oats	1928 Oats[3]	1929 Clover-Alfalfa	1930 Corn
301	O	32.5	(.82)	7.3	21.1	1.9	(2.31)	5.0	39.2	44.5	(.25)	15.9	38.3	9.4	14.3	46.9	(1.04)	24.8	11.7	39.5	(1.27)	18.8
302	M	32.8	(.79)	7.6	24.7	2.2	(2.45)	5.8	63.8	53.4	(.25)	19.5	43.0	17.8	19.3	53.6	(2.12)	41.3	14.7	51.3	(1.78)	31.1
303	ML	46.4	(1.00)	10.0	32.4	4.1	(2.97)	9.4	72.2	62.5	(1.86)	39.4	56.2	26.4	23.6	62.5	(5.11)	52.3	21.6	60.5	(3.76)	30.6
304	MLP	45.6	(1.30)	12.3	33.2	3.9	(2.12)	11.7	71.3	64.5	(1.96)	39.1	59.4	27.8	22.1	63.9	(6.43)	52.3	21.1	59.5	(4.40)	35.0
305	O	45.6	(1.51)	9.8	23.2	3.4	.50	9.0	60.1	48.8	(.31)	18.4	53.3	16.1	19.2	58.1	(2.49)	36.7	17.3	52.0	(2.27)	30.7
306	R	47.0	.17	8.2	16.4	3.9	.58	8.0	65.3	56.9	(.63)	15.0	53.0	17.7	24.1	65.5	(2.39)	37.6	13.8	53.6	(3.11)	32.1
307	RL	46.6	.33	12.7	18.7	3.9	.50	11.4	63.7	58.3	(1.85)	34.3	55.6	23.8	31.0	65.8	(4.54)	50.7	16.7	60.5	(3.47)	30.3
308	RLP	45.0	.33	14.3	18.3	4.5	.50	13.7	66.6	63.3	(1.68)	37.8	58.2	23.4	29.8	67.7	(5.64)	57.5	17.0	59.2	(3.86)	27.3
309	RLPK	40.6	.33	19.0	17.7	4.4	.25	18.2	71.8	48.4	(1.84)	36.7	66.2	24.5	30.3	68.0	(6.28)	52.5	17.0	60.9	(3.87)	31.9
310	O	38.8	(.97)	18.8	25.0	3.1	(1.95)	9.0	48.6	47.7	(.58)	14.0	55.6	11.4	16.8	55.2	(2.24)	42.0	16.7	47.5	(2.23)	30.8
		Corn[1]	Oats[2]	Soy-beans[2]	Wheat[2]	Corn	Oats	Clover	Wheat	Corn	Oats	Sweet clover and soybeans[4]	Wheat	Corn	Oats	Clover	Corn	Oats	Wheat	Clover-Alfalfa	Corn	Oats
401	O	48.7	30.6	(1.11)	10.9	3.3	71.7	(1.17)	13.2	9.4	35.6	(.09) 2.88	19.9	37.7	38.8	(1.94)	58.1	32.3	20.4	(1.51)	36.7	40.6
402	M	49.6	21.1	(1.19)	7.2	6.6	74.7	(1.48)	15.8	18.7	52.2	(.28) 3.16	25.5	51.4	55.6	(2.83)	71.6	38.8	25.8	(2.27)	48.8	59.8
403	ML	48.3	32.9	(1.29)	7.7	6.8	70.5	(1.71)	23.4	35.4	47.0	(2.32)	28.0	58.4	56.4	(4.03)	75.2	46.1	27.4	(3.94)	54.2	78.0
404	MLP	52.0	34.7	(1.37)	9.6	7.2	70.2	(1.58)	25.7	40.9	46.7	(2.39)	26.2	56.9	51.1	(3.73)	71.0	43.3	27.8	(4.28)	54.3	79.4
405	O	49.5	38.4	11.3	7.7	2.5	68.8	2.75	19.8	14.0	29.1	(.28) 5.09	23.3	39.5	42.5	(2.39)	57.6	33.6	19.0	(1.92)	38.8	47.3
406	R	43.7	30.3	12.6	15.3	3.0	71.1	2.75	9.7	28.5	54.1	(.19) 4.62	25.7	45.1	47.3	(2.34)	60.6	36.3	21.8	(1.99)	41.0	46.2
407	RL	38.1	31.7	13.2	7.2	5.5	69.1	3.17	14.8	35.0	40.3	(1.76)	28.0	53.4	51.4	(3.61)	59.8	40.6	25.1	(3.29)	43.0	60.5
408	RLP	48.5	33.3	15.2	5.3	6.6	70.2	3.00	13.8	42.9	42.7	(1.78)	27.2	55.1	51.3	(3.93)	59.9	43.8	25.1	(3.85)	44.1	71.6
409	RLPK	47.1	34.4	14.3	8.5	6.2	66.7	2.42	10.6	45.7	37.5	(1.83)	29.7	59.3	49.2	(4.06)	76.1	62.5	28.4	(4.69)	47.0	76.1
410	O	45.6	33.8	11.5	8.7	3.5	69.1	(1.20)	15.6	13.3	35.0	(.19) 3.72	19.2	37.8	43.1	(1.83)	60.5	32.2	19.9	(1.87)	35.7	57.0

[1]No manure or residues. [2]No manure. [3]Wheat winterkilled; oats grown as a substitute crop. [4]Hay yields are of combined sweet clover and soybean crops; seed yields are of sweet clover only.

TABLE 6.—CARLINVILLE FIELD: SERIES 100, 200, 300, AND 400, SUMMARY OF CROP YIELDS
Average annual yields 1911-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Corn *20 crops*	Oats *21 crops*	Wheat *15 crops*	Clover[1] *4 crops*	Clover-alfalfa *6 crops*	Sweet clover[2] *4 crops*	Soy-beans[2] *4 crops*
1	0	28.5	30.9	16.8	(1.68)	(1.35)	1.23	15.8
2	M	39.0	40.6	22.3	(2.15)	(1.89)	1.41	18.3
3	ML	47.5	47.5	29.0	(2.66)	(3.68)	1.90	21.4
4	MLP	48.2	47.2	29.5	(2.32)	(4.18)	2.05	21.5
5	0	30.5	33.8	19.1	(1.80)	(1.85)	2.71	16.3
6	R	34.3	36.3	18.1	(1.82)	(1.83)	2.49	17.6
7	RL	42.0	44.9	25.3	(2.29)	(3.03)	2.51	22.8
8	RLP	44.7	45.8	28.1	(2.35)	(3.48)	2.03	23.9
9	RLPK	49.4	46.0	28.8	(2.22)	(3.94)	1.88	23.0
10	0	32.0	34.0	16.5	(1.59)	(1.86)	1.59	15.8

[1]Some seed evaluated as hay. [2]Some hay evaluated as seed.

Looking over these data one may observe first the rather moderate productiveness of the untreated land as indicated by the returns on the check plots. Twenty crops of corn, for example, have yielded on the average about 30 bushels an acre, and the average production of wheat is around 17 bushels. The average acre-value of all crops produced in the last rotation period was $17.71 a year.

The value of animal manure on this land is well demonstrated in the increases in yields on the manure plots. Used alone, this material has produced increases in crop yields during the last rotation worth $6.29 an acre a year.

Crop residues without supplementary treatment have been practically without effect. The 38 cents, representing the value of the increases in yield ascribed to the residues treatment, does not cover the cost, which is estimated at 75 cents an acre.

TABLE 7.—CARLINVILLE FIELD: SOME FINANCIAL RESULTS BASED ON CROP YIELDS FOR THE ROTATION PERIOD ENDING IN 1930
Figures indicate average annual acre-values

Untreated land, acre-value of *all crops*	$ 17.71
Acre-value of *crop increases* from—	
Manure, alone	$ 6.29
Residues, alone	.38
Limestone, used with manure	8.85
Limestone, used with residues	7.13
Rock phosphate, used with manure and limestone	1.77
Rock phosphate, used with residues and limestone	1.76
Potash, used with residues, limestone, and rock phosphate	3.48
Net acre-value of *crop increases* under most profitable treatment—	
In livestock system (manure, limestone)	$ 11.57
In grain system (residues, limestone)	5.94
Net acre-value of *total crops* under most profitable treatment—	
In livestock system (manure, limestone)	$ 27.85
In grain system (residues, limestone)	23.73

Limestone has been used with pronounced effect both in the livestock and the grain systems. All crops show more or less benefit from it. The money value of the additional yields for the last rotation period amounts to $8.85 where limestone was used with manure and $7.13 where used with crop residues.

The use of rock phosphate as applied in these experiments has not been profitable. The small gains in yield, as measured by the acre-value of crop increase, are scarcely significant. In fact these values, $1.77 and $1.76 in the livestock and grain systems respectively, are too small to cover the expense of application with the cost of rock phosphate figured at $15 a ton.

Potash is used here only in combination with residues, limestone, and rock phosphate. In the earlier years of the experiments there was little response to

FIG. 9.—EFFECT OF SOIL TREATMENT ON THE CORN CROP ON THE CARLINVILLE FIELD

The plot at the left, under complete treatment (RLPK), has yielded on the average at the rate of almost 50 bushels an acre. At the right, without treatment, the yield has been 32 bushels.

the potassium treatment and the kainit used as the potassium fertilizer was applied at a financial loss. But as the work progressed, a need for potassium gradually developed so that during the last rotation period kainit not only returned its cost but also some profit in addition. This behavior with respect to a growing potassium requirement is in accordance with the experience on several of the experiment fields. The beneficial effect appears mainly in the improved corn crops.

The most profitable of the eight different systems of management, as measured by the effects produced during the last crop rotation, has been manure with limestone and residues with limestone. Taking into account cost of treatment, the manure system has produced crop increases having a net valuation of $11.57 an acre a year; the grain system, increases valued at $5.94 an acre a year.

In this connection it should be pointed out that response to systems of soil treatment is subject to change as time goes on, so that in the future other systems may supplant those of the present as being most profitable.

Series 500 and 600

Series 500 and 600 constitute a minor system used for miscellaneous purposes. The land received only one fertilizer combination—manure, limestone, phosphate, and potash—until 1929, when the series were subdivided in order to furnish a basis for comparing different fertilizer treatments. Until 1924 a cropping system that included wheat, clover, and alfalfa had been used mainly, as shown in Table 8. In 1925 this land was given over to variety-testing experiments, the details of which are indicated in Table 9.

TABLE 8.—CARLINVILLE FIELD: SERIES 500 and 600
Annual crop yields 1911-1924—bushels or (tons) per acre

Series[1]	Soil treatment	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
500	MLPK	Alfalfa (5.00)	Alfalfa (0)	Alfalfa (2.93)	Alfalfa (3.22)	Alfalfa (3.99)	Soybeans (2.06)	Wheat 40.0	Clover (2.87)	Wheat 26.3	Clover (1.74)	Wheat 31.8	Soybeans 26.4	Wheat 22.1	Corn 60.9
600	MLPK	Wheat 39.9	Soy-beans 14.4	Wheat 9.6	Soy-beans 18.7	Wheat 19.9[2]	Clover (1.26)	Alfalfa (3.87)	Alfalfa (4.61)	Alfalfa (4.71)	Alfalfa (4.28)	Alfalfa (0)	Corn 51.4	Corn 43.9	Soy-beans (2.73)

[1]Formerly designated as Plots A and B. [2]1.92 tons stubble clover also harvested.

The annual yields are recorded in the two tables mentioned. Altho no attempt is made to summarize them, these data are, nevertheless, of considerable practical interest. For example, it is of interest to note the good crops of alfalfa produced on this land under favorable treatment. Several excellent wheat crops have been obtained. As is the case on all farms, every season is not favorable for high yields. Carlinville is in the chinch-bug section, and this pest has frequently been the cause of severe disturbance to these experiments.

In the variety tests (Table 9) the Chilean clover exhibits its inferiority as compared with other sorts. Among the alfalfas tested, the Argentine proved to be distinctly lower in yield than any of the others. In the commercial fertilizer trials with corn and wheat (1929 and 1930) the results display little consistency.

Series 700 and 800

Series 700 and 800 form another minor system on the Carlinville field. These series were left unplotted and untreated until 1920, altho a systematic plan of cropping was practiced as follows. A six-year stand of timothy alternated with a wheat-clover rotation, shifting from one series to the other every six years as indicated by the records given in Table 10. In 1921 these series were subdivided into plots for soil-treatment experiments and the crop rotation was changed to corn and wheat with sweet-clover seeding for green manure except on Plot 7. The soil treatments included different amounts of limestone and different forms of phosphate, as indicated in Table 11.

Because of the various angles involved in a problem of this kind where commercial values are constantly changing from year to year, it is difficult to state anything like final conclusions regarding economic results. A few points

TABLE 9.—CARLINVILLE FIELD: SERIES 500 and 600, MISCELLANEOUS TESTS
Annual yields 1925-1930—bushels or (tons) per acre

Plot No.	1925 Oat varieties	1926 Clover varieties	1927 Corn	1928 Spring grains	1929 Clover varieties	1930 Corn (fertilizer tests)
501	Iowar 40.9	Ohio 2471 (1.87)	40.6	Barley planted on north half, oats on south half; yields not recorded	French 14459 (2.30)	None 28.4
502	Iowa 103 50.6	Roumanian (1.55)	41.6		Imported (2.50)	9-27-9 41.8
503	Big Four 56.6	Italian (1.01)	47.4		French 2584 (2.62)	0-21-9 48.8
504	Silvermine 63.4	Hungarian (1.48)	37.0		Illinois (2.80)	None 36.6
505	Big Four 55.0	French (1.70)	37.4		Roumanian (2.38)	9-27-9 43.8
506	Iowa 103 44.0	Chilean (.98)	33.0		Roumanian (2.15)	0-21-9 30.0
507	Iowar 44.4	Ohio 2471 (1.55)	32.6		Polish (1.86)	None 33.8
	Oat varieties	Alfalfa varieties	Alfalfa varieties	Alfalfa varieties	Corn (fertilizer tests)	Wheat (fertilizer tests)
601	Iowar 47.2	So. Dakota 12 (3.25)	So. Dakota 12 (2.22)	So. Dakota 12 (2.82)	None 31.0	None 36.3
602	Iowa 103 51.6	Grimm (2.76)	Grimm (2.18)	Grimm (2.80)	9-27-9 29.6	9-27-9 44.2
603	Big Four 62.5	Cossack (2.29)	Cossack (2.20)	Cossack (2.28)	0-21-9 31.0	0-21-9 37.2
604	Silvermine 62.5	So. Dakota 12 (2.73)	So. Dakota 12 (2.15)	So. Dakota 12 (2.67)	None 29.6	None 37.3
605	Big Four 60.6	Argentine (.93)	Argentine (1.60)	Argentine (1.10)	9-27-9 30.4	9-27-9 36.8
606	Iowa 103 40.6	Utah Common (2.18)	Utah Common (2.05)	Utah Common (2.38)	0-21-9 31.6	0-21-9 36.0
607	Iowar 56.6	So. Dakota 12 (3.06)	So. Dakota 12 (2.55)	So. Dakota 12 (2.59)	None 27.8	None 34.7

TABLE 10.—CARLINVILLE FIELD: SERIES 700 and 800
Annual crop yields 1911-1920—bushels or (tons) per acre

Series[1]	Soil treatment	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
700	None	Timothy (1.84)	Timothy (1.57)	Timothy (.41)	Timothy (.63)	Timothy (1.67)	Timothy (.85)	Wheat 12.9	Clover (1.71)	Wheat 20.2	Clover (1.81)
800	None	Wheat 30.9	Soybeans[2] 10.9	Wheat 5.6	Soybeans[2] 14.8	Wheat 17.6	Clover (.97)	Timothy (.54)	Timothy (1.62)	Timothy (2.42)	Timothy (1.25)

[1]Formerly designated as Plots C and D. [2]Soybeans substituted for clover.

of interest, however, may be observed as to what seems to be developing on these plots.

In order to make comparisons possible, the annual yields given in Table 11 are summarized in the last column in terms of money value per acre at prices prevailing during the past four years. Based upon these comparisons it appears that:

With the light applications of limestone made on Series 700, little effect is produced by varying the quantity. In the heavy applications made to Series 800, the medium quantity (5 tons an acre) appears to have been more effective than either half or double this amount.

As to the three carriers of phosphorus, superphosphate is in the lead on both series.

The effectiveness of legumes in connection with these treatments is very apparent in the acre-returns. Under the heavier liming on Series 800, the benefit from legumes is the more pronounced.

TABLE 11.—CARLINVILLE FIELD: SERIES 700 and 800
Annual crop yields 1921-1930—bushels or (tons) per acre

Plot No.	Soil treatment[1]	1921 Wheat[2]	1922 Wheat[2]	1923 Corn	1924 Oats[3]	1925 Corn	1926 Wheat	1927 Corn	1928 Oats[3]	1929 Corn	1930 Wheat	Average annual value per acre
701	LeL (1,000)	24.3	13.2	34.2	40.3	52.6	13.5	36.8	40.9	26.6	6.2	$19.42
702	LeL (4,000)	21.5	15.7	30.8	39.7	51.4	13.7	39.0	40.9	25.2	12.6	19.97
703	LeL (2,000)	24.5	16.7	37.6	42.8	51.2	14.2	40.2	39.1	29.2	11.2	20.93
704	LeL (2,000), treble superphosphate	26.0	21.3	28.0	45.6	64.2	24.8	40.0	47.5	26.0	25.7	24.90
705	LeL (2,000), superphosphate	25.7	20.3	44.8	46.9	65.2	23.8	45.0	47.8	28.8	24.7	26.90
706	LeL (2,000), rock phosphate	26.0	17.5	38.2	48.8	57.4	21.5	40.2	46.3	27.0	24.2	24.73
707	L (2,000)	25.7	15.2	36.0	45.0	46.6	13.5	30.6	37.2	23.8	16.5	19.74
		Corn[4]	Wheat[2]	Corn	Oats[3]	Corn	Wheat	Corn	Oats[3]	Corn	Wheat	
801	LeL (5,000)	42.6	12.7	36.8	42.5	60.0	2.2	33.2	43.1	17.0	23.4	$20.16
802	LeL (20,000)	38.2	7.5	33.2	49.4	54.6	6.3	32.2	53.4	25.6	35.8	23.10
803	LeL (10,000)	39.2	9.7	50.4	46.3	56.2	12.2	51.4	57.5	35.8	31.6	27.57
804	LeL (10,000), treble superphosphate	39.0	28.0	28.0	50.9	60.0	19.8	50.8	59.1	32.2	51.0	29.57
805	LeL (10,000), superphosphate	38.0	25.3	40.6	53.1	60.2	18.3	48.4	62.5	33.6	52.0	31.78
806	LeL (10,000), rock phosphate	36.8	16.7	34.0	50.6	60.0	14.3	47.2	60.3	29.6	41.1	27.48
807	L (10,000)	36.2	8.3	36.0	46.3	43.6	6.3	26.8	54.1	24.4	14.8	18.83

[1]The figures in parentheses denote total amounts of limestone applied per acre since 1921. [2]Limestone and phosphate only [3]Oats substituted for wheat, which winter-killed. [4]No soil treatment.

TOLEDO FIELD

The Toledo experiment field is located on Gray Silt Loam On Tight Clay immediately south of Toledo in Cumberland county. It was established in 1913. This field of 17 acres is laid out into two separate systems of plots, one including four series of 10 plots each, and the other containing four series of 4 plots each, and designated as the major and the minor series respectively.

Major Series

The system of plots made up of Series 100 to 400 is under a crop rotation of wheat, corn, oats, and clover. Cowpeas were seeded in the corn at the last cultivation until 1921, when this practice was abandoned. In 1922 sweet clover was introduced as the regular clover crop, but since 1926 a mixture of clovers, alfalfa, and timothy has been used. In 1922, also, the application of limestone was suspended, the limestone plots having received up to this date a total of 6½ to 8 tons an acre of this material. About this time the return of oat and wheat straw on the residues plots was discontinued.

TABLE 12.—TOLEDO FIELD: SERIES 100, 200, 300, AND 400, SUMMARY OF CROP YIELDS
Average annual yields 1914-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Corn *17 crops*	Oats *16 crops*	Wheat *13 crops*	Clover[1] *4 crops*	Sweet clover *3 crops*	Mixed hay *5 crops*	Soybeans *3 crops*
1	0.....	20.4	14.9	11.0	(.06)	.11	(.39)	(.70)
2	M.....	26.8	18.6	12.3	(.18)	.24	(.59)	(.72)
3	ML....	38.8	29.9	24.1	(.89)	2.45	(1.73)	(1.27)
4	MLP...	38.2	30.5	24.8	(.97)	2.42	(1.69)	(1.21)
5	0.....	16.2	14.3	9.2	(.05)	.26	(.29)	(.38)
6	R.....	18.4	15.1	10.7	(.22)	.53	(.40)	(.47)
7	RL....	26.4	32.1	22.0	(1.19)	1.84	(1.50)	(.94)
8	RLP...	26.9	31.1	24.9	(1.48)	1.77	(1.58)	(1.05)
9	RLPK .	39.2	35.1	29.4	(1.57)	2.48	(2.17)	(1.18)
10	0.....	14.4	15.4	8.2	(.17)	.19	(.28)	(.53)

[1]Some seed evaluated as hay on Plots 6, 7, 8, 9.

Table 12 presents a summary of the crop yields for the years in which the complete plot treatments have been in effect. The results confirm those of other fields located on similar soil; briefly stated, they show:

1. Low yields on untreated land.

2. Only a slight response to organic manures without limestone.

3. A very decided response to the use of limestone in connection with organic manures.

4. No material effect from rock phosphate applied with organic manures and limestone.

5. A general response to potassium fertilizer, the response becoming very marked in the case of corn. In fact, kainit, which supplies the potassium, is being used with good profit.

Minor Series

The second set of plots on the Toledo field, comprizing Series 500 to 800, has been devoted mainly to an investigation in soil tillage, the purpose being to compare the effects of subsoiling, deep tilling, and dynamiting with that of ordinary plowing. A crop rotation of corn, soybeans, wheat, and sweet clover was adopted, second-year sweet-clover stubble being plowed late in the fall for corn. An application of 4 tons of limestone an acre was made on all plots in 1913; 3 tons were applied for the 1917 crop, and 2 tons for the 1921 crop. One ton of rock phosphate was applied in the fall of 1914 and again in the fall of 1918.

TABLE 13.—TOLEDO FIELD: TILLAGE EXPERIMENTS
Average annual yields 1913-1922—bushels per acre

Tillage treatment	Corn *9 crops*	Soybeans *7 crops*	Wheat *6 crops*	Sweet-clover seed *6 crops*
Plowed 7 inches deep	40.2	16.3	13.5	3.68
Subsoiled 14 inches deep	41.9	16.2	12.9	3.65
Deep-tilled 14 inches	37.4	15.2	10.8	3.18
Dynamited	40.3	16.4	11.7	4.25

A summary of the crop yields is given in Table 13. For a detailed account of these experiments the reader is referred to Bulletin 258 of this Station, "Experiments with Subsoiling, Deep Tilling, and Dynamiting."

The conclusions reached from the results of these experiments is that none of the special tillage treatments had any superior beneficial effect on crop yields. Deep tilling apparently decreased yields, probably because of the mixing of subsurface and subsoil with the surface soil.

EWING FIELD

As representing the soil type Gray Silt Loam On Orange-Mottled Tight Clay, experimental results from a portion of the Ewing field are presented.

The Ewing Field is located in Franklin county about a mile northeast of Ewing. It was established in 1910. Altho four distinguishable soil types have been identified on this field, the 100 and 200 series of plots lie wholly on Gray Silt Loam On Orange-Mottled Tight Clay. This land is nearly level, the drainage is poor, and the soil is strongly acid. These two series, together with Series 300 and 400, constitute a plot system farmed under a crop rotation of wheat, corn, oats, and clover; but because Series 300 and 400 lie mainly on another soil type, results from these plots will not enter into the present consideration.

The handling of the crops and the soil treatments have been in the main according to the somewhat standard plan described above. Until 1920 cowpeas were seeded in the corn as a catch crop on the residues plots. In 1921 sweet clover was substituted as the regular legume in the rotation in addition to its seeding in the wheat for use as a green-manure crop. Seed was harvested from

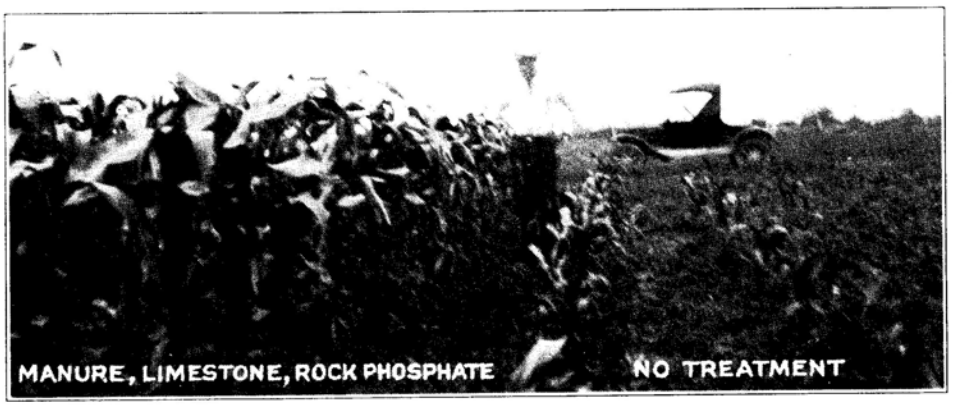

FIG. 10.—CORN GROWING ON NEIGHBORING PLOTS ON THE EWING FIELD IN 1924
At the right is a check plot which produced, as an average of eight years, only 15 bushels of corn an acre. The plot at the left, treated with manure, limestone, and rock phosphate, produced 49 bushels.

all the regular sweet-clover plots and the straw returned to the residues plots. In 1922 the limestone applications were discontinued after they had reached a total quantity of 8½ to 10 tons an acre on the different series. No more limestone will be applied until the need for it appears. The return of oat and wheat straw as a residue was also discontinued about this time. In 1923 the rock phosphate was evened up on all phosphorus plots to 8,500 pounds an acre in total applications and no more will be applied for an indefinite period.

A summary of the results is presented in Table 14, showing the average annual crop yields obtained for the years the plots have been under their complete treatments. The extremely poor yields on the untreated land are characteristic of this soil. About 2.5 bushels of wheat an acre has been the average production on the check plots.

The use of manure alone increases the crop yields somewhat, but not sufficiently to put this kind of farming on a profitable basis. Residues alone are practically without effect.

TABLE 14.—EWING FIELD: SERIES 100 AND 200, SUMMARY OF CROP YIELDS
Average annual yields 1911-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Corn *10 crops*	Oats *10 crops*	Wheat *9 crops*	Clover *1 crop*	Sweet clover *2 crops*	Mixed hay *2 crops*	Soy-beans *4 crops*
1	0	12.9	8.4	2.1	(.20)	0	(.31)	(.46)
2	M	27.1	14.2	5.2	(.24)	0	(.39)	(.54)
3	ML	49.6	30.6	17.9	(.40)	2.23	(1.64)	(1.08)
4	MLP	50.1	32.8	22.9	(.81)	2.25	(2.06)	(1.23)
5	0	12.2	9.0	2.0	0	0	(.40)	(.34)
6	R	12.3	9.2	1.8	0	0	(.48)	(.36)
7	RL	29.8	27.0	17.2	.50	2.46	(1.36)	(.86)
8	RLP	27.6	27.9	19.5	1.08	2.07	(1.33)	(.93)
9	RLPK	47.6	35.4	28.0	.75	2.09	(1.80)	(1.11)
10	0	16.7	9.9	3.3	(0)	0	(.45)	(.56)

Limestone produces a very decided increase in yields used either with manure or with residues, the large increase with the latter being due mainly to the successful growth of legumes following the application of limestone. A financial study of these treatments covering the last rotation period reveals the fact that manure and limestone is now the most effective combination of the various treatment systems under test. At the prices assumed in the estimate, manure and limestone are returning $16.16 an acre a year in value of crop increases after deducting the cost of the treatment.

The results for rock phosphate are rather peculiar in that they are more favorable in the manure system than in the residues system. This unusual behavior may perhaps be explained by the fact that potassium has become a limiting element on this field and that the manure furnishes a certain amount of this substance.

Potassium fertilizer as used in these experiments has had a very beneficial effect on all the grain crops. In fact, within the last few years, in the corn crop under the residues system, the need for potassium has become decidedly acute. Thus the average yield of corn for the last five crops under the lime, residues, and phosphorus treatment was 17.9 bushels an acre, while on the adjoining plot where potassium is included in the treatment, the yield was 48.1 bushels an acre. One year the yield without potassium was 5 bushels an acre while with potassium it was 52.3 bushels.

As mentioned above, manure and limestone is proving the most remunerative treatment on the Ewing field. But unfortunately manure is not abundant. The next best paying system is the combination residues, limestone, phosphate, and potash, which returned a net value of $16.31 an acre a year in crop increases produced.

The recommendation, therefore, for improving land of this type is to apply limestone, use all available farm manure, plow under sweet clover, and return unused crop residues to the soil. Then to this basal program add potassium and phosphorus as the need for these materials develops.

VIENNA FIELD

Macoupin county, as indicated in the descriptions of certain of its soil types, includes considerable land that is subject to destruction thru erosion or washing. Operators of land of this kind 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 abandoned because so much of the surface soil had washed away, and there were so many gullies that further cultivation was unprofitable. For the purpose of the experiments the field was divided into different sections (see Table 15). 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.

TABLE 15.—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.

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.

Careful records were kept for nine years. The results, summarized in Table 15 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 4/5 of a ton on the protected series and but 1/5 of a ton on the check.

Figs. 12 and 13 shown in the Appendix on page 56 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.

SPARTA FIELD

As representative of experimental results on the soil type Light Gray Silt Loam On Tight Clay, data from certain plots on the Sparta experiment field are introduced here.

The Sparta field was established in Randolph county immediately north of the town of Sparta in 1916. The four series of plots designated as 100, 200, 300, and 400, with the exception of parts of two plots, are all on the soil type mapped as Light Gray Silt Loam On Tight Clay. They are under a crop rotation of corn, soybeans, wheat, and clover (chiefly sweet clover). Until 1921 it was the practice to seed cowpeas as a cover crop in the corn on the residues plots. The soil treatments are as indicated in the accompanying table, and they have been applied in the manner previously described (pages 35 and 36) with the exception that the initial application of limestone was 5 tons an acre. In 1922 the application of this material was discontinued until its further need should become apparent. Table 16 gives a summary of the results showing the average annual yields for the different kinds of crops, including the years that the complete soil treatments have been in effect.

TABLE 16.—SPARTA FIELD: SERIES 100, 200, 300, AND 400, SUMMARY OF CROP YIELDS
Average annual yields 1917-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Corn *14 crops*	Soy-beans *13 crops*	Wheat *10 crops*	Oats *3 crops*	Clover *1 crop*	Sweet clover *8 crops*
1	0	13.9	5.6	4.7	15.6	(0)	0
2	M	18.1	7.1	8.2	17.8	(0)	0
3	ML	28.9	14.0	17.2	30.6	(1.66)	1.87
4	MLP	30.1	14.2	18.3	31.9	(1.73)	1.50
5	0	11.6	4.2	5.0	8.7	0	0
6	R	15.2	5.0	5.0	12.2	0	0
7	RL	24.3	12.1	15.8	25.3	1.50	1.40
8	RLP	23.8	12.5	16.7	24.9	1.87	1.48
9	RLPK	30.4	13.2	18.1	27.0	1.69	2.27
10	0	10.4	4.1	4.0	13.4	(0)	0

The low yields on the untreated plots testify to the natural poverty of this soil, altho this particular piece of land, on account of its favorable location with respect to drainage, is rather more productive than the general run of the type that it represents.

Neither manure nor residues, used alone, has much effect toward crop improvement. A sharp increase, however, follows the application of limestone used with either manure or residues. Without limestone, clover refuses to grow; with limestone, fair crops of clover have been obtained. Rock phosphate in addition to limestone has produced no significant effect, used either with manure or with residues.

Potassium has been of considerable benefit to the corn and sweet clover but not so much to the other crops. This suggests a possibility of a more profitable use of kainit (which furnishes the potassium) by cutting down the quantity used and applying directly for the benefit of the corn and sweet-clover crops, thereby effecting considerable saving in the cost of material.

FIG. 11.—CORN ON THE RALEIGH FIELD
At the right no treatment has been applied. At the left, while manure, limestone, and phosphate have been used, the major effect has been produced by the limestone and manure.

RALEIGH FIELD

As representing the soil type Yellow-Gray Silt Loam On Tight Clay the results from a portion of the University experiment field located at Raleigh in Saline county are presented here. Series 200 and 300, which lie on this soil type, form a part of a plot system kept under a crop rotation of wheat, corn, oats, and clover. When clover fails soybeans are substituted.

The general management and soil treatments are as described above, pages 35 and 36. In 1922 the regular applications of limestone were suspended until such time as lime appears to be needed again. In 1923 the rock phosphate was evened up on all phosphate plots to a total application of 4¼ tons an acre and the applications were discontinued for an indefinite period. About this time the practice of returning oat and wheat straw in the residues system was discontinued. The results in terms of average annual yields of the respective kinds of crops are summarized in Table 17.

A study of these data brings out the following comments concerning the effects of the various treatments on the Raleigh field:

1. The untreated plots are conspicuous in their low yields.
2. All the different kinds of grain crops show some response to the application of stable manure, altho the beneficial effect varies greatly.
3. Crop residues used alone have been of very little effect.
4. Limestone in combination either with manure or with crop residues stands out in its effect as the most prominent agency in soil improvement.

5. The application of rock phosphate has produced little effect, so that on the whole the use of this material in the manner of these experiments has been attended by a financial loss.

6. Potassium in the form of kainit has increased the yield of all crops, particularly the corn, wheat, and clover. At current prices the value of the increase is just about offset by the cost of the kainit applied.

Regarding the cropping system employed on this field, it may be said that altho it serves for experimental purposes in determining the needs of the soil, for farming practice it doubtless could be improved either by substituting a more profitable crop for the oats, or by rearranging the crop sequence and omitting the oats. Doubtless other cropping plans could be devised to advantage.

TABLE 17.—RALEIGH FIELD: SERIES 200 AND 300, SUMMARY OF CROP YIELDS
Average annual yields 1911-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *5 crops*	Corn *10 crops*	Oats *11 crops*	Clover[1] *3 crops*	Soybeans *6 crops*
1	0	2.2	11.4	11.1	(.09)	4.8
2	M	4.5	23.4	15.9	(.04)	8.3
3	ML	12.8	40.0	25.6	(.79)	12.9
4	MLP	14.6	41.9	25.5	(.81)	14.2
5	0	2.6	12.1	10.1	(0)	4.6
6	R	3.9	16.4	12.9	(0)	5.1
7	RL	10.0	34.8	23.2	(.28)	10.0
8	RLP	11.5	40.0	26.1	(.35)	11.2
9	RLPK	14.5	47.3	26.4	(.86)	12.1
10	0	4.5	19.7	13.7	(.04)	8.3

[1]One crop red clover and two crops alfalfa-clover-timothy mixture.

APPENDIX

PRINCIPLES OF SOIL MANAGEMENT

Clear thinking on the complex problems of soil management must start with a realization that there are many different kinds of soils, each differing from the others in soil characters. The fertilizer, management, and cropping requirements of each kind of soil are not yet fully worked out, altho knowledge regarding the agricultural significance of the various soil types recognized in the soil survey is rapidly accumulating.

Soils are dynamic, exceedingly complex, natural bodies made up of organic and inorganic materials and teeming with life in the form of microorganisms. Because of these characteristics, soils cannot be considered as reservoirs into which given quantities of an element or elements of plant food can be poured with the assurance that they can be expected to respond uniformly 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 to favor the growth of higher plants and of beneficial microorganisms.

It is obvious that in order to fulfill these conditions no single system of soil treatment can be laid down for all situations. The long-time records from numerous soil experiment fields scattered over Illinois demonstrate strikingly that different soils require different management practices. Some soils are naturally so productive that no fertilizer treatment yet tried has succeeded, on a paying basis, in raising the crop yields over their natural capacity. On the other hand, there are other soils so poor that altho under proper treatment the yield can be increased many fold, the plane of production under the best management known is still so low that it is questionable whether it pays to farm the land at all. Between these two extremes all grades of productivity are found. A further significant fact brought out in a study of these experiment fields is that a given piece of land seldom responds to soil treatments in the same manner thruout its history. The most efficient treatment during one rotation period does not necessarily remain the most efficient in another period.

Thus it appears that soil management is a complex matter even when considered from only one side of the problem, namely, that of producing crops. In addition to these complexities connected with production, however, are those having to do with the everchanging economic conditions by which market prices are affected. Whether a certain yield produced by a given soil treatment will be profitable depends directly upon the price of produce as well as upon the cost of the treatment, and every farmer knows only too well something of the violent fluctuations in market prices that have taken place in recent years. Furthermore, costs of fertilizing materials change from time to time, and these changes do not necessarily run parallel with the fluctuations in value of farm products.

With these facts in mind it is not difficult to understand that, from the standpoint of financial profits, a soil-management practice perfectly recommendable this year may become wholly unprofitable in another year and, vice versa, a practice that is unprofitable under present conditions may become highly profitable at another time.

The above remarks suggest something of the difficulty of prescribing definite recommendations for specific soil treatments and of the futility of making blanket recommendations to cover the requirements of all soils and all crops at all times. In mentioning these difficulties there is no intention to discourage efforts at planning programs of soil improvement; the purpose, rather, is to set forth some of the uncertainties involved and, in particular, to warn against hasty conclusions based upon scanty experience or superficial observation.

In spite of the many complexities involved in the problem of soil improvement, there are certain broad, underlying principles that are basic and that must be taken into consideration in laying out any improvement program. Underlying the permanent and profitable productivity of the soil is the maintenance of good physical condition, favorable biological activity, a suitable soil reaction, and an adequate supply of available plant-food elements during the growing season. The chief practices which accomplish these ends are—

1. Adequate drainage
2. Protection from erosion
3. Application of limestone where necessary
4. A good cropping system, including suitable legumes for soil improvement
5. Provision for active organic matter by returning regularly animal and plant manures
6. Purchase of mineral plant-food elements to supply deficiencies

PROVIDING ADEQUATE DRAINAGE

Adequate drainage is recognized as essential for the consistent production of satisfactory crops. Crops vary, however, in their ability to endure poor drainage. Alsike clover, for example, is better adapted to wet land than is red clover. Some bottom lands produce excellent summer crops but cannot be used for winter crops because of flooding. Altho such lands may not be well drained, it is often possible to raise good crops of corn on them year after year, because, as a result of frequent overflow, they receive periodically a fresh deposit of soil material. Such a practice on poorly drained upland would not be feasible. Upland soils, with few if any exceptions, require a well-planned cropping system if they are to be utilized most efficiently, and such a system is difficult to follow unless adequate drainage is provided.

Soils differ in permeability and consequently in their response to the installation of tile. There are soils in the southern and southwestern parts of Illinois, occupying a large total area, which cannot be drained successfully with tile because they have an impervious, clay-pan subsoil. In the east-central part of the state there is a soil occupying a considerable area which does not underdrain well because of an impervious glacial drift which comes to within 30 inches or less of the surface.

The soils of Illinois may well be artificially underdrained with the exception of those noted above. The soils which cannot be underdrained must be drained by means of open ditches and furrows or by means of a combination of open ditches, furrows, and tile provided with manholes thru which the water may enter the tile. In some soils the efficiency of the tile may be greatly increased by starting to fill the tile ditches with top-soil instead of with the more impervious material taken from the bottom of the ditches.

There are some soils in Illinois that cannot be satisfactorily drained either by tile or by open ditches. There should be no attempt to utilize such soils for general farming purposes.

PROTECTING SOIL FROM EROSION

The erosion problem is a serious one in Illinois. We are accustomed to think of erosion as being harmful only on rough and strongly rolling land. This seems, however, to be far from the truth.

The land surface subject to erosion in Illinois might be considered to include three groups of soils based on steepness of slope. The first group might be characterized as being subject to destructive erosion. Land of this character is located, for the most part, adjacent to streams and comprizes a total area in the state of some 7,000 square miles. Land subject to destructive erosion, is for the most part unsuited to general farming. If used for this purpose, erosion is so difficult to control that the returns do not justify the expense involved. Some of the land of this character may be used for orcharding and some of it may be used for permanent pasture but a large proportion of it is suitable only for timber.

A second group of erodible soils may be considered to include land suitable, under proper protection, for permanent pasture and orcharding but unsuited to general farming because of the steepness of the slopes resulting in destructive erosion if tilled. Land of this general character includes some 8,000 square miles. Terracing is recommendable on land of this character as affording a relatively inexpensive and an effective means of reducing erosion. There will be times however, when erosion will be severe on land of this general character even on fields where the best known methods of control are being used.

Generally speaking the two groups mentioned above comprize land of relatively low agricultural value, as this term is commonly understood. If, however, certain of these soils are used for purposes for which they are adapted, they may be of considerable or, in some cases, of high value.

A third group comprizes the gently rolling to rolling land thruout the northern two-thirds of the state. Some 25,000 square miles may be included in this group. This land has a high value for general farming but is subject to harmful erosion and much of it is being seriously damaged thru the removal of surface soil by running water. The erosion problem presented by this third group is probably of more serious concern than that presented by either of the other two because of the high value of the land involved. Erosion can be controlled on a large proportion of this land by means of a good cropping system. Provision should be made for a protecting cover of vegetation particularly in the fall and spring. Cornstalks rolled down at a right angle to the slope are very effective in

FIG. 12.—PROPER SOIL TREATMENT AND CROPPING WOULD HAVE PREVENTED THIS CONDITION
This abondoned hillside is just over the fence from the field shown in Fig. 13.

reducing erosion on this gently sloping land. Long shallow draws may often be kept in permanent sod to great advantage. Broad base terraces may be effectively used where the slope is a little too steep for effective control to be secured with a good cropping system only. It is surprising however how effective a good cropping system is in decreasing washing. Experimental results indicate that on relatively gentle slopes of about 4 percent the surface seven inches of soil may be washed off in about twenty-five years where a poor cropping system is used, and that the use of a good cropping system alone will extend the time for the removal of the same amount of soil to some 350 years.

The method or combination of methods suitable for the control of erosion on any given area depends on many factors; that is to say, no generally applicable,

FIG. 13.—CORN GROWING ON 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. 12.

detailed directions for controlling erosion can be given because such important factors as steepness of slope, length of slope, and permeability of the soil must be taken into consideration.

A detailed discussion of methods of controlling erosion will be found in Bulletin 207, "Washing of Soils and Methods of Prevention," and Circular 290. "Saving Soil by Use of Mangum Terraces," published by this Station.

APPLYING LIMESTONE TO CORRECT ACIDITY

The maintenance of a favorable soil reaction has been mentioned as one of the essentials in a rational system of soil management, and in contemplating a soil-improvement program one of the first steps for consideration is the application of limestone.

In considering the use of limestone 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, a plant-food element for which certain crops have a high requirement. 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 bacteria. It plays an essential role in the chemical transformation of nitrogen. It helps to check 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. Most important of all its properties is its power to neutralize soil acidity, thus making possible thru the growing of legumes the reclamation of millions of unproductive acres as well as the improvement of land of moderate or even high productive capacity.

Soils vary tremendously with respect to acidity, and the question arises as to how the farmer is to know whether his land needs limestone. Much information on this subject, as it pertains to Illinois land, is to be found in connection with the soil survey. Some soil types are uniformly acid, and therefore in their description attention is called to the necessity of applying limestone; other types being alkaline thruout, do not need lime, and in the discussion this fact is recorded. There are, however, extensive soil types in which the lime requirement is not uniform. It may vary from field to field on the same farm. It may even change on a given field with the passing of time, especially under heavy cropping. Obviously in such cases a definite recommendation in regard to liming cannot be given, and under these circumstances the farmer is advised to resort to a test which he himself can learn to make.

Any citizen of the state may obtain from the county farm adviser or from the Experiment Station instructions for making a systematic limestone map of his fields, showing not only the areas that need liming but also approximately the amount of limestone to apply. Such a test made on soils where the lime requirement is decidedly variable is saving many hundreds of dollars in expenditures for limestone where limestone is not needed, as well as preventing the waste of clover seed on soils too acid to grow clover. For a description of this test see Circular 346 of this Station, "Test Your Soil for Acidity."

A good indication as to whether a soil needs limestone is the character of the growth of certain legumes, particularly sweet clover. This crop does not thrive on acid soils and its thrifty growth therefore indicates that the soil is not acid, at least in a harmful degree. Some legumes, for example red clover, will grow fairly well on soil of moderate acidity provided conditions are otherwise favorable. Too much reliance therefore should not be placed on the behavior of

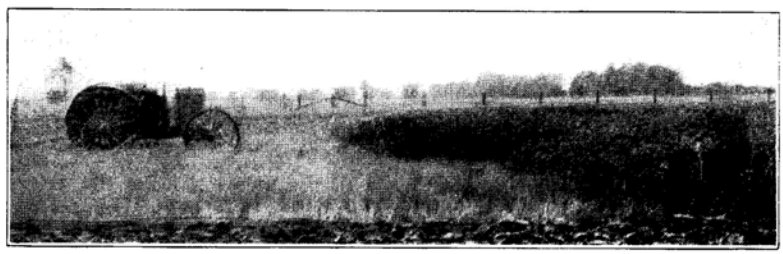

FIG. 14.—SWEET CLOVER AS AN INDICATOR OF THE NEED FOR LIMESTONE
Left, no limestone; right, limestone. Sweet clover is one of the crops most sensitive to soil acidity. This crop will not grow on acid soils until limestone has been applied.

legumes as an indicator of the need of liming, for it frequently happens that fair stands are mistaken for good stands and even good yields can often be greatly increased by the use of limestone. Therefore it is well to be definitely informed regarding the condition of the soil with respect to acidity, using, where necessary, a reliable test such as that mentioned above.

MAINTAINING A WELL-PLANNED CROP ROTATION

In any program of permanent soil improvement one should adopt at the outset a good system of crop rotation, including a liberal use of legumes. It is impossible to prescribe the best rotation for every individual case because what will prove to be the most advantageous system to follow depends upon a number of different factors. Of primary importance among these factors is the location of the farm with respect to soil, to climate, and to market. The particular rotation to be followed will be determined further by the type of farming—whether grain, livestock, orcharding, or other kind of enterprise. Finally, not the least important to be considered are the personal interests and inclinations of the farmer himself.

Following are a few suggested rotations, applicable mainly to the corn belt, which are intended to serve merely as patterns or outlines, to be modified according to special circumstances. In these suggested rotation programs the more common crops are mentioned merely as types, for which other crops of similar nature may be substituted as desired. In the following lists, for example, oats may be replaced by barley or spring wheat, and likewise winter rye might take the place of winter wheat. Or it may be advisable in some cases to divide the acreage of small grain and raise different kinds; for example, plant a part of the land to oats and a part to barley. The word "clover" in the following lists of rotations is used in a general sense to designate red, alsike, or sweet clover, or even a clover-grass mixture to serve either as pasture or meadow. In the event

of clover failure soybeans may be substituted. The value of sweet clover, especially as a green manure, for building up depleted soils is becoming thoroly established, and its importance in a crop-rotation program may well be emphasized. In the following lists the word "clover" in parentheses signifies that clover is seeded in the grain crop.

Numberless different cropping systems might be enumerated, ranging thru various long-term and short-term rotations, but it will suffice for the present purpose to mention only a few systems as suggestive of types of rotations.

Six-Year Rotations

Among the longer type of rotations the following six-year systems are suggested as being good practical rotations adaptable under many circumstances. Two such programs are presented, one in which corn predominates and the other in which wheat is the major crop. Following are the crop sequences:

System A	*System B*
Corn	Corn
Corn	Oats
Oats (clover)	Wheat (clover)
Clover	Clover
Wheat (clover)	Wheat (clover)
Clover	Clover

In grain farming most of the crop residues are returned to the soil and the clover may be left on the land or returned after threshing out the seed. In livestock farming the clover may be mixed with alfalfa or with timothy, the crop being used for pasture or for meadow as desired. Soybeans, a crop that is rapidly coming into favor, can be introduced into System A by replacing either the first or the second corn crop or the last clover crop. In System B perhaps the best place for soybeans would be following the second wheat crop, altho it is possible to grow them in place of the oats.

An objection sometimes arises to wheat following clover on account of the wheat lodging. This lodging is not so likely to happen when the clover is cut as hay and removed from the land.

Five-Year Rotations

A five-year rotation system offers one of the most convenient cropping plans that can be devised for general farming. It is flexible, it provides diversification, and it can be made to give large place to legumes.

Here, three different basal systems are presented. Systems C and E are designed for corn as the major crop while System D is intended to give large place to wheat growing.

System C	*System D*	*System E*
Corn	Corn	Corn
Corn	Oats	Corn
Oats (clover)	Wheat (clover)	Soybeans
Clover	Clover	Oats (hubam)
Wheat (clover)	Wheat (clover)	Wheat (sweet clover)

It is of interest to observe in System C that if soybeans were to replace second-year corn, and the clover catch crop were allowed to grow awhile in the

spring before corn planting, then a legume crop would appear on every acre every year. The same provision could be effected in System D by replacing the oats with soybeans.

A growing problem on many farms where little livestock is fed is the economical disposal of the clover crop. A farmer can ill afford to give up a considerable portion of his land every year to clover production when he can neither feed nor sell the crop. In order to solve this problem the rotation mentioned as System E is proposed. The hubam is an annual sweet clover which seeded in the oats makes a heavy growth to plow down in preparation for the wheat and this, together with the biennial sweet clover grown in the wheat the following year, should furnish plenty of leguminous growth to maintain the rotation, leaving all the land free every year for a cash crop.

Four-Year Rotations

The four-year rotation represents a rather common cropping system. Among the several possibilities the following are suggested as practical programs for a four-year rotation:

System F	*System G*	*System H*
Corn	Corn	Corn
Corn	Oats	Corn
Oats (clover)	Wheat (clover)	Oats (hubam)
Clover	Clover	Wheat (sweet clover)

System F which calls for half the land to be in corn, requires a productive soil. However, half the land is under legumes and this is also true of System G. Soybeans might take the place of one of the corn crops in Systems F and H. In System G they might take the place of the oats provided the bean crop is removed early in order to make way for the fall seeding of the wheat.

System H is proposed in order to accomplish the same purpose in a four-year rotation as System E in the five-year program, namely, to provide for a salable crop on all fields every year.

Three-Year Rotations

One of the most common rotations practiced in the corn belt is the three-year crop succession of corn, oats, and clover (System I). From the standpoint of soil maintenance this is a good rotation. Legumes appear on the land two years out of three. It is also advantageous from the standpoint of labor economy, for plowing is required only once in three years. Its main disadvantage perhaps lies in the restricted crop diversification.

System I	*System J*
Corn	Wheat (clover)
Oats (clover)	Corn
Clover	Soybeans

An opportunity to introduce wheat into a three-year cropping plan is offered in System J. It is of interest to note that by seeding a catch crop of sweet clover in the wheat, to be plowed under the following spring just before corn planting, the land is under legumes some portion of the season every year. It will be necessary to harvest the soybeans early either by using an early variety

or by cutting for hay in order to prepare the land for winter wheat. In some regions it may be desirable to substitute cowpeas for the soybeans.

Two-Year Rotation

The well-known practice of alternating corn and oats has long been pointed out as an example of a bad rotation under which thousands of corn-belt farms are headed toward ruination. However, with the advent of sweet clover, that great soil restorer, a corn-oats rotation becomes a practical possibility.

System K

Corn
Oats (sweet clover)

In this system sweet clover is sown in the oats, pastured in the fall and the following spring if desired, and then plowed down in preparation for corn. From the standpoint of soil upkeep, this cropping plan, which may fit well in certain situations, is offered as an interesting possibility, altho from the general farm-management point of view it may lack some of the advantages of the longer rotations described above.

Altho oats are mentioned as the spring grain crop, as a matter of fact, by dividing the land devoted to small grain and introducing barley, these two crops can be grown simultaneously, thus providing a three-crop system in a two-year cycle.

Alfalfa and Pasture in Rotation

Alfalfa is a highly desirable crop to grow, especially in livestock farming. Its use as a biennial legume in the rotation may well be recommended. It is often desirable, however, to include alfalfa as a perennial stand in the cropping system. This can be done by providing one extra field. The alfalfa occupies a field during a complete rotation period of the other crops plus one year extra. The alfalfa is then shifted to another field while the other crops rotate, and so on around the entire field system.

It may be observed that this same plan for alfalfa in rotation will provide for continuous pasture of any kind, either of perennial grass—redtop, for example, in southern Illinois—or of grass and clover mixture.

SUPPLYING RIGHT KINDS AND AMOUNTS OF ORGANIC MATTER

Organic matter acts beneficially chiefly in two ways: it helps to maintain favorable physical conditions in the soil; and it supplies food material for the microscopic organisms which inhabit the soil and which in turn, thru their life processes, effect many of the necessary chemical transformations that render plant food available for the growing crops.

The main sources of supply for organic matter are stable manure, crop residues, and green manures.

A recent study of the results from the soil experiment fields located in many different parts of Illinois reveals the fact that the system of treatment that has most frequently returned the greatest profit is manure with limestone. Of the eight systems compared, this proved to be the winning treatment on more than

half the fields. This fact indicates the very great value of stable manure and suggests the importance of its careful conservation and use on every farm where this material is available. On most farms, however, there is not sufficient animal manure produced to cover the land, and thus it becomes necessary to resort to some other supply of organic matter. The alternative here lies in the so-called "crop-residues" system, in which unused materials such as stalks, straw, and chaff are returned to the land and plowed under along with leguminous green-manure crops.

In connection with the application of organic matter, an important distinction between kinds of organic matter with respect to chemical make-up has come to be recognized within the last few years. It is commonly observed that an excessive application of straw or similar material is likely to produce a depression in crop growth which may result in lowering the yield. In addition to the unfavorable physical effect of plowing down a mass of decay-resistant material, particularly if dry weather ensues, a detrimental chemical effect may also follow. The large quantity of cellulose contained in straw stimulates the activities of a certain set of microscopic organisms. These may become so active as actually to compete with the growing plants for nitrate and so under certain circumstances to cause nitrogen hunger. Good judgment must therefore be exercised in applying strawy material. Heavy applications should ordinarily be avoided unless they can be plowed under with a good growth of legumes or else applied at such a time as not to interfere with a crop having a large nitrate requirement.

PLANT-FOOD REQUIREMENTS AND SUPPLY

Ten chemical elements have long been accepted as being essential for the growth of the higher plants. These are carbon, hydrogen, oxygen, nitrogen,

TABLE 18.—PLANT-FOOD ELEMENTS IN COMMON FARM CROPS[1]

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

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

phosphorus, sulfur, potassium, calcium, magnesium, and iron. To this list certain other elements have been added from time to time as being either necessary in the physiological processes or else present merely on account of absorption from the soil solution.

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 indirectly from the air by the class of plants known as legumes, in case the amount liberated from the soil is insufficient.

Table 18 shows the average content 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 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.

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. It has been found, for example, that the nitrogen in the surface 6⅔ inches, which represents the plowed stratum, varies in amount from 180 pounds an 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. In presenting these figures it is not intended

TABLE 19.—PLANT-FOOD ELEMENTS IN MANURE, ROUGH FEEDS, AND FERTILIZERS[1]

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

[1]See footnote to Table 10. [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.

to imply that plants are restricted in their feeding to the surface stratum, nor that the total quantities of the various plant-food elements give a reliable indication of the immediate fertilizer requirements of a soil except in extreme cases. Such extreme cases, however, are relatively rare and there are the great middle classes in which chemical composition varies so little as to furnish no clue whatever to the probable effect of a particular fertilizer treatment. Much depends

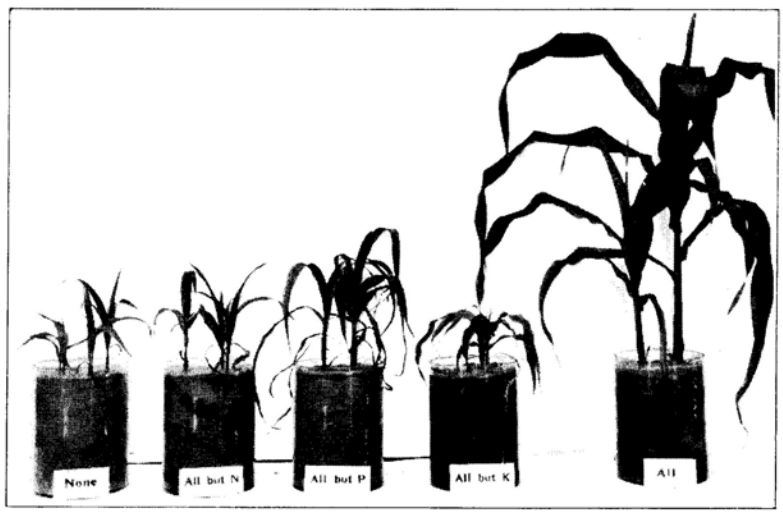

FIG. 15—ALL ESSENTIAL PLANT-FOOD ELEMENTS MUST BE PRESENT
The jars in which these corn plants are growing contain pure sand to which have been added various combinations of the essential plant-food elements. If a single one of these elements is omitted, the plants cannot develop; they die after the small supply stored in the seed becomes exhausted.

upon the ability of the crops grown to utilize plant-food material, and much depends upon the solubility of the plant-food substances themselves. When an element becomes so reduced, either in total quantity or in available form, as to become a limiting factor of production, then we must look for some outside source of supply. Table 19 shows the approximate quantities of some of the more important plant-food elements contained in materials most commonly used as fertilizers.

Nitrogen Problem

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

An inexhaustible supply of nitrogen is present in the air. Above each acre of the earth's surface there are about 69 million pounds of atmospheric nitrogen.

Leguminous plants such as the clovers are able, with the aid of certain bacteria, to draw upon this supply of air nitrogen, utilizing it in their food requirements. In so doing, these leguminous plants if returned to the land add to the soil a part of the nitrogen which has been taken from the air and transformed into food material that can be assimilated by other kinds of crops that follow. By taking advantage of this fact and introducing periodically into the rotation system a crop of legumes, the farmer may draw upon this cheapest source of nitrogen for soil improvement. Therefore, in general farming, that is, in the production of such crops as corn, oats, wheat, and hay, legumes should furnish the main stock of nitrogen, this stock to be supplemented, of course, by all available manure and by other farm waste materials containing nitrogen.

In addition to these home sources of nitrogen supply, there are various commercial products containing nitrogen offered on the market. These materials formerly consisted largely of sodium nitrate, a mineral imported from South America; ammonium sulfate, produced in the manufacture of coal gas and coke; and certain waste and by-product materials mainly of organic composition. Within very recent time, however, tremendous developments in the synthetic production of nitrogen compounds from air nitrogen have taken place. Among these new fertilizer materials may be mentioned cyanamid, calcium nitrate, sodium nitrate, ammonium nitrate, and urea.

These developments in the artificial fixation of nitrogen will doubtless have a far-reaching effect in reducing the cost of commercial nitrogenous fertilizers.

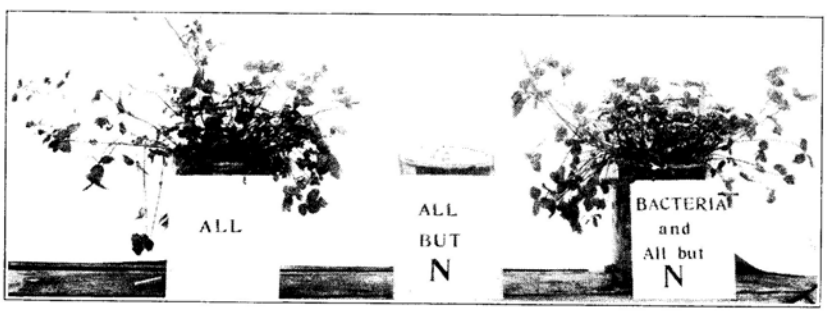

FIG. 16.—LEGUMES CAN OBTAIN THEIR NITROGEN FROM THE AIR

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 certain bacteria are supplied that enable the clover to secure nitrogen from the air.

What the limits may be in this direction one dare not predict. Whether these manufactured nitrogen compounds will become so cheap some day as actually to compete with legume nitrogen is problematical, especially when the other advantages offered by legumes are considered. However, the day has not yet arrived when we can afford to dispense with legumes as a green manuring crop in the production of grain and hay.

Accepting, then, this principle that legumes and farm wastes must constitute the main source of nitrogen supply, the question arises—can these home-grown materials be supplemented to advantage by the use of commercial carriers of nitrogen?

The impossibility of making blanket recommendations has already been pointed out. The question finally resolves itself into a matter of expense and profit for each individual case. Sodium nitrate is purchased on the market at present at about $65 a ton. If a farmer applies 100 pounds an acre, he provides about two-fifths of an ounce to a hill of corn. A ton would cover 20 acres and the cost would be about $3.25 an acre. Under present prices an increase of about four to five bushels of corn or wheat would be required in order to cover the cost before any profit could be realized.

Under what circumstances might such increases in yield be reasonably expected? It is possible that in many cases where manure or legumes have not been used, such an application of nitrogen would return a profit, but such usage should be regarded as a temporary expedient rather than a permanent practice in soil management. Under adverse weather conditions, when soil nitrates are formed too slowly or are washed away by excessive rain, an application of nitrogen fertilizer may prove highly beneficial to wheat and corn.

A peculiar hazard accompanies the application of nitrogen that does not obtain in applying phosphate or potash. Nitrates are readily washed away, and if circumstances are such that the first crop fails to utilize the nitrogen, little or no residual effect on the following crops can be expected. For this reason special caution should be used against applying excessive amounts of nitrogen. Usually it is well to divide the application of a quickly soluble nitrogen fertilizer such as sodium nitrate, using a portion at planting time and distributing the remainder at a later date. Nitrogenous fertilizers are often made up of a mixture of materials whose nitrogen becomes soluble with varying degrees of rapidity, thus automatically distributing the action of the nitrogen over a period of time.

Phosphorus Problem

Different soil types display great variation in phosphorus content and, on the other hand, soils of like total-phosphorus content exhibit great variation in response to phosphate fertilization. The removal of phosphorus by continuous cropping slowly reduces the amount of this element available for crop use unless its addition is provided for by natural means such as overflow, or by agricultural practices such as the addition of farm manure and phosphatic fertilizers and perhaps the use of rotations in which deep-rooting leguminous crops are frequently grown. Results obtained from the soil experiment fields of Illinois show that some soils respond highly to phosphate fertilization, while others give a very low response or none. Reports from county farm advisers and farmers in general are in agreement with these experimental results.

It should be noted that the total quantity of phosphorus in a soil is not a reliable indicator of the probable response to phosphate fertilization. Apparently it is a matter of solubility or the chemical form in which the phosphorus exists rather than total quantity.

A simple field test has recently been devised at the Illinois Experiment Station which will distinguish soils having a high amount of available phosphorus from those having a low amount. Information concerning this test is furnished in Bulletin 337, "A Field Test for Available Phosphorus in Soils."

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

Rock phosphate is a mineral substance found in vast deposits in certain regions. A good grade of the rock should contain 12 to 15 percent of the phosphorus element. The rock should be ground to a powder fine enough to pass thru a 100-mesh sieve, or even finer. Considerable experimentation in the finer grinding is under way in the hope of increasing the plant-food value of the product and thus make possible a reduction in the amount that it is necessary to apply.

Superphosphate is produced by treating rock phosphate with sulfuric acid. The two are mixed in about equal amounts; the product therefore contains about one-half as much phosphorus as the rock phosphate itself. By further processing, different concentrations are produced. The most common grades of superphosphate now on the market contain 7, 8¾, and 10½ percent of the element phosphorus, and even more highly concentrated products containing as high as 21 percent are to be had. In fertilizer literature the term phosphorus is usually expressed as "phosphoric acid" (P_2O_5) rather than the element phosphorus (P), and the chemical relation between the two is such as to make the above figures correspond to 16, 20, 24, and 48 percent of phosphoric acid respectively. Likewise the 12 to 15 percent of phosphorus in rock phosphate corresponds to 29.5 to 34.3 percent of phosphoric acid. Besides phosphorus, superphosphate also contains sulfur, which is likewise an element of plant food, altho this fact has little agricultural significance for Illinois, where the soils generally are sufficiently stocked with sulfur. In general, phosphorus in superphosphate is considered to be more readily available for absorption by plants than is the phosphorus in raw rock phosphate, altho there is often good response in the crops immediately following the application of rock phosphate.

Obviously the carrier of phosphorus that will give the most profitable returns, considered from all standpoints, is the one to use. The question of which is the most profitable, however, remains unsettled, altho it has been the subject of much discussion and investigation. The fact probably is that there is no single carrier that will prove the most economical under all circumstances because so much depends upon soil conditions, crops grown, length of haul, and market conditions.

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

On several of the Illinois soil experiment fields rock phosphate and superphosphate are being compared in systems of management looking toward permanent soil improvement, and are applied in amounts corresponding approximately to equivalent money expenditures. So far as these comparisons show, there

appears to be little consistency in the results. In some years and on some crops superphosphate has furnished the greater profit; in other years and on other crops the reverse is true. In some cases neither material has paid for its cost, indicating that phosphorous is not a limiting factor in production on all soils. On the whole, therefore, if possible residual effects are disregarded, there appears to be no indisputable evidence for general discrimination between the two forms of phosphate.

Potassium Problem

Our most common soils, the silt loams and clay loams, are well stocked with potassium altho it exists mainly in a very slowly soluble form and probably only a very small percentage of the total potassium exists in a form available to plants at any one time.

Many field experiments in various sections of Illinois during the past twenty-five years have shown little or no response to the application of potassium in the production of our common grain and hay crops. On the light-colored soils of southern Illinois, however, where stable manure has not been employed, potassium has been applied with profit, the benefit appearing mainly in the corn crop.

Peat soils usually respond to potash fertilization. The Illinois Experiment Station has demonstrated in field experiments located on peat land that the difference between success and failure in raising crops on such land depends upon the application of a potash fertilizer.

Potassium has proved beneficial also on the so-called "alkali" spots occurring on certain soil types that are rather high in organic matter, including peat and dark-colored sandy, silt, and clay loams. The unproductiveness of these soils is probably due largely to the unavailable condition of the soil potassium as well as to an unbalanced condition of the plant nutrients resulting from an excess of nitrate nitrogen. The addition of potash has a beneficial influence upon both of these unfavorable conditions.

Potash fertilizer may be procured in the form of one of the potassium salts, such as the chlorid, sulfate, or carbonate, and any of these materials may be applied, where needed, at the rate of 50 to 150 pounds an acre according to the method of distribution. For our most common crops about the only basis for choosing among these forms is the matter of price, taking into consideration the potassium content.

Kainit is another substance containing potassium, but it is combined with magnesium in the form of a double salt. It is therefore less concentrated than the salts mentioned above, and so should be applied in larger quantities. An application of about 200 pounds or more of kainit to the acre is suggested.

Use of Mixed Commercial Fertilizers

A mixed commercial fertilizer is a combination of substances containing either two or three of the plant-food elements nitrogen, phosphorus, and potassium. If the material contains all three of these elements, it is said to be a "complete" mixed fertilizer; if only two of the three are present, it is said to be an "incomplete" mixed fertilizer.

A complete mixed fertilizer has the general formula $N-P_2O_5-K_2O$ (nitrogen, phosphorus pentoxid, potassium oxid), the proportions of the elements varying according to the way in which the material is compounded. By substituting figures for the letters in this formula the percentage composition of the fertilizer is indicated. Thus a fertilizer of the formula 5-15-5 contains 5 percent nitrogen, 15 percent phosphorus pentoxid (usually designated as phosphoric acid), and 5 percent potassium oxid (usually called potash). Translated into pounds, this means that a ton of the fertilizer contains 100 pounds of nitrogen, 300 pounds of phosphoric acid, and 100 pounds of potash. For the benefit of those who are accustomed to think in terms of the simple plant-food elements rather than these combinations, it may be explained that the above amounts correspond to 100 pounds of the element nitrogen (N), 131 pounds of the element phosphorus (P), and 83 pounds of the element potassium (K). Changing the formula to read 0-15-5 indicates that no nitrogen is contained in it; 5-15-0 means that no potassium is present; and 5-0-5 indicates that phosphorus is absent.

In compounding these fertilizers, several ingredients carrying a single kind of plant-food element may be used. For example, a portion of the total nitrogen may be furnished by sodium nitrate, while another portion may be carried in dried blood or in ammonium sulfate. In addition to these plant-food materials, fillers and conditioners are often used in such amounts as to make the finished product contain the desired percentage of plant food.

A distinction between what are considered "high-grade" and "low-grade" fertilizers is now being made upon the arbitrary basis of a total of 16 so-called "units of plant food." Thus a 2-8-2 fertilizer carrying 12 units of plant-food would classify as a low-analysis grade. The advantage of using the higher grade products is becoming more and more generally recognized by both consumers and producers of fertilizers. In the latest developments very highly concentrated forms of fertilizers are being produced containing as much as 60 units of plant food. If the economy of production and the agricultural value justify the general use of materials of such high concentration, there should be a great saving in the cost of transportation and handling thru the use of fertilizers of this type.

The question arises repeatedly regarding the employment of mixed commercial fertilizers, and particularly their employment in connection with a basic program of soil improvement built around the use of legumes and limestone where necessary. An important principle to be borne in mind in the use of any fertilizer is represented in the so-called "law of the minimum," that is, that no benefit can result from the application of a given plant-food element unless the need for that element is a limiting factor in plant growth. If, for example, there is already in the soil enough available phosphorus to produce a 40-bushel crop, and the nitrogen supply or the moisture supply is sufficient for only 40 bushels or less, all the phosphorus one might apply would be absolutely ineffective in increasing the yield beyond this 40-bushel limit.

The most serious objection to the indiscriminate use of mixed commercial fertilizers lies in the fact that frequently only one, or perhaps two, of the plant-food elements carried by the fertilizer are actually needed, in which case a useless expense is incurred for the unnecessary element or elements.

This question of the use of commercial fertilizers is exceedingly complicated because so much depends upon numberless conditions of soil and season. We may be able to analyze in part the conditions of the soil, but we are powerless in predicting the conditions of the oncoming season. A given fertilizer may pay a handsome profit this season but on the same field next year may be absolutely without effect, or even detrimental to the crop. That is why it is impossible to make any general statement or to give a blanket recommendation concerning the use of such fertilizers.

The matter finally resolves itself into two questions: cost of material and benefit derived. Fortunately the cost of material can be definitely determined. In order to get an idea of the expense of applying mixed commercial fertilizers, perhaps we cannot do better than to figure the cost per acre based upon the published recommendations and price quotations of a fertilizer company. The following estimates are based upon the recommendations of such a company as given for the dark-colored silt or clay loam soils of Illinois on land having had manure and clover, and the prices are those quoted for the spring of 1929.

Thus, for the corn crop, 150 pounds per acre of a 5-15-5 fertilizer is recommended to be applied in drills or hill-dropped. The price of this fertilizer is quoted at $53.15 a ton, which would make the cost $3.99 per acre. According to an official report, the farm value of corn for December, 1928, in Illinois was 70 cents a bushel. At this rate an increase of 5.7 bushels of corn per acre would be required to cover the cost of the fertilizer, taking no account of the extra expense in applying it.

For spring grains the recommendation is to use a 0-21-9 fertilizer at the rate of 250 pounds an acre if drilled or 400 pounds if broadcast. The price is $45.10 a ton, thus making the cost per acre $5.64 drilled or $9.02 broadcast. If the spring grain were oats, valued at 38 cents a bushel, the increase in yield to cover the cost of fertilizer would have to be nearly 15 bushels an acre in case the fertilizer were drilled; if it were broadcast nearly 24 bushels would be required to pay the cost before any profit would be realized. If instead of oats the spring grain were wheat valued at $1.02 a bushel, the increase in yield necessary to pay for the fertilizer would be 5½ bushels if the fertilizer were drilled and nearly 9 bushels if broadcast. In like manner the recommended application for potatoes is found to cost $13.13 an acre if the fertilizer is drilled and $26.25 if broadcast. The application recommended for pastures and meadows would cost $13.13 an acre.

The above examples afford some idea of the cost of using mixed commercial fertilizers for the production of our common field crops in so far as the prices quoted remain representative. Unfortunately it is impossible to furnish information with the same certainty concerning the profit that is likely to be derived from these fertilizers, for that will depend upon several varying factors, mainly the amount of increase in yield and the price received for it.

What kind of fertilizers will be profitable and under what particular conditions they will pay must be determined mainly on the basis of actual experience. In this connection it should be borne in mind that in all experimental trials great care must be exercised in drawing conclusions. The soil of a farm or even of a

field is seldom perfectly uniform thruout, and differences in yield really due to differences in soil may easily be mistaken for effects of the fertilizer treatment. Therefore small differences in yield should be critically considered before being accepted as significant. It is particularly risky to base conclusions upon the results of a single year, because of peculiar seasonal effects. Never are two seasons exactly alike, and the results of this year may not apply next year. If outstanding effects from fertilizers occur the first year they are tried, such results may be taken as indicative and accepted as a tentative guide for further work, but final conclusions should be withheld until these results are well confirmed in subsequent trials.

To what extent mixed commercial fertilizers can be profitably employed in connection with a basic program of soil improvement is a problem of great consequence. No doubt there are many instances in which such fertilizers may be used with profit, but it is just as certain that in many other instances their use would result in financial loss. Before investing in mixed fertilizers, farmers should carefully consider the cost, which, as explained above, is an item that can be definitely determined. With the investigations now under way, the Experiment Station hopes soon to be in possession of much more definite information than now exists regarding the use, under present-day conditions, of these mixed commercial fertilizers.

List of Soil Reports Published

1 Clay, 1911
2 Moultrie, 1911
3 Hardin, 1912
4 Sangamon, 1912
5 LaSalle, 1913
6 Knox, 1913
7 McDonough, 1913
8 Bond, 1913
9 Lake, 1915
10 McLean, 1915
11 Pike, 1915
12 Winnebago, 1916
13 Kankakee, 1916
14 Tazewell, 1916
15 Edgar, 1917
16 DuPage, 1917
17 Kane, 1917
18 Champaign, 1918
19 Peoria, 1921
20 Bureau, 1921
21 McHenry, 1921
22 Iroquois, 1922
23 DeKalb, 1922
24 Adams, 1922
25 Livingston, 1923
26 Grundy, 1924
27 Hancock, 1924
28 Mason, 1924
29 Mercer, 1925
30 Johnson, 1925
31 Rock Island, 1925
32 Randolph, 1925
33 Saline, 1926
34 Marion, 1926
35 Will, 1926
36 Woodford, 1927
37 Lee, 1927
38 Ogle, 1927
39 Logan, 1927
40 Whiteside, 1928
41 Henry, 1928
42 Morgan, 1928
43 Douglas, 1929
44 Coles, 1929
45 Macon, 1929
46 Edwards, 1930
47 Piatt, 1930
48 Effingham, 1931
49 Wayne, 1931
50 Macoupin, 1932

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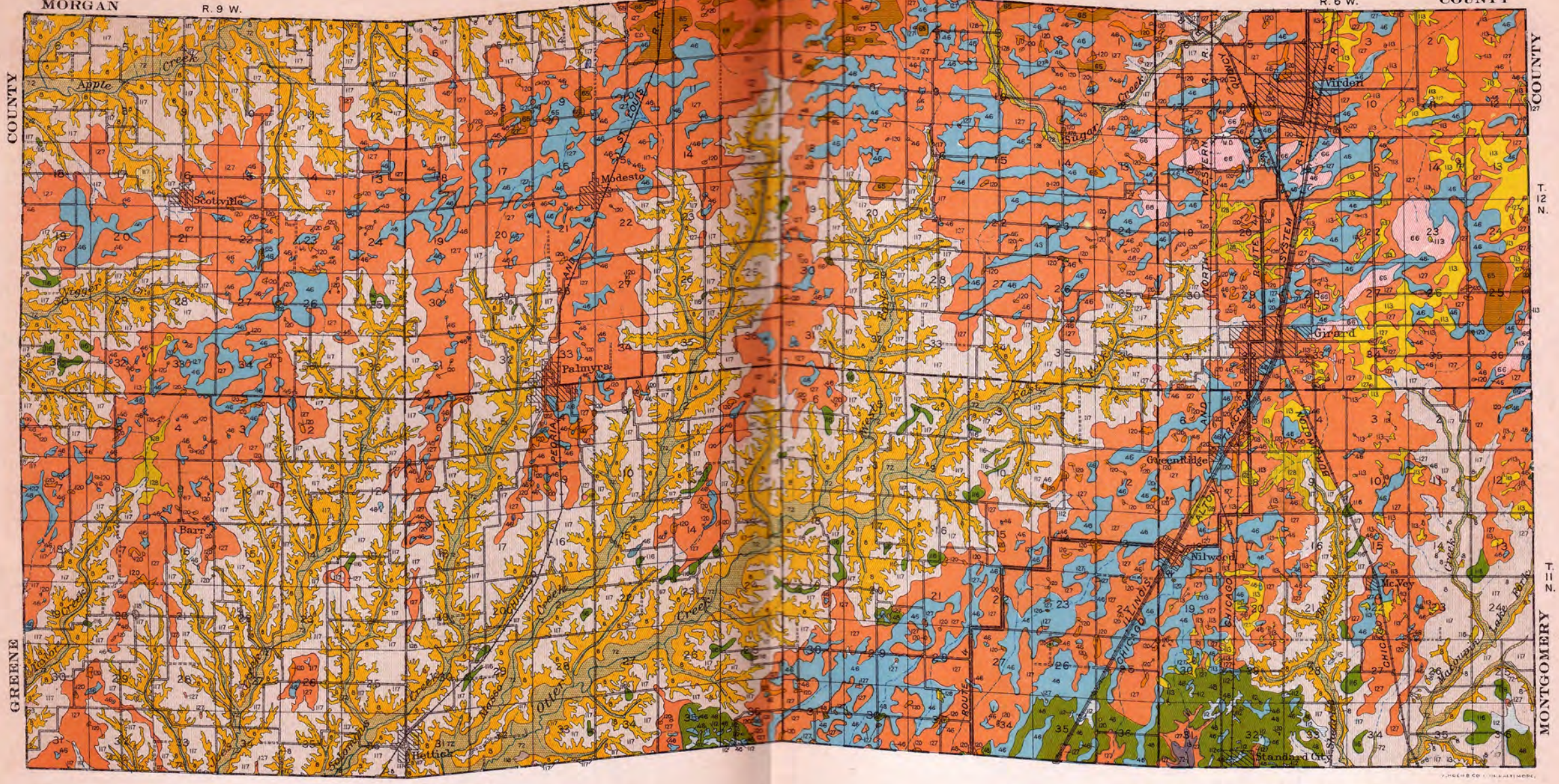

LEGEND

- 1 Deep Gray Silt Loam On Tight Clay
- 2 Gray Silt Loam On Tight Clay
- 3 Gray Silt Loam On Orange-Mottled Tight Clay
- 4 Yellowish Gray Silt Loam On Orange-Mottled Tight Clay
- 5 Eroded Silt Loam
- 8 Eroded Gravelly Loam
- 11 Light Gray Silt Loam On Tight Clay
- 12 Yellow-Gray Silt Loam On Tight Clay
- 13 Yellow-Gray Silt Loam On Compact Medium-Plastic Clay
- 14 Reddish Yellow-Gray Silt Loam
- 15 Reddish Yellow Silt Loam
- 46 Grayish Brown Silt Loam On Clay
- 47 Grayish Black Silt Loam On Clay
- 48 Grayish Drab Silt Loam On Clay
- 50 Grayish Brown Clay Loam On Clay
- 65 Black Clay Loam
- 66 Black Clay Loam On Drab Clay
- 72 Mixed Loam
- 111 Deep Brown-Gray Silt Loam On Tight Clay
- 112 Brown-Gray Silt Loam On Tight Clay
- 113 Brown-Gray Silt Loam On Reddish Brown Tight Clay
- 114 Brown-Gray Silt Loam On Compact Medium-Plastic Clay
- 115 Drabbish Gray Silt Loam On Tight Clay
- 116 Drabbish Yellow-Gray Silt Loam On Tight Clay
- 117 Drabbish Yellow-Gray Silt Loam On Compact Medium-Plastic Clay
- 118 Drabbish Yellow-Gray Silt Loam
- 120 Slick Spots
- 127 Grayish Brown Silt Loam
- 128 Grayish Light Brown Silt Loam

CONVENTIONAL SIGNS

- Public Roads
- Metalled Roads (gravel—all year)
- Paved Roads
- Private Roads
- Railroads (steam)
- Railroads (electric)
- Township Boundary Lines
- County Boundary Lines
- Levees
- Streams (flowing)
- Streams (intermittent)
- Lakes or Ponds
- Small Areas Limestone Rock Outcrop
- Small Areas Sandstone Rock Outcrop
- Small Areas Shale Rock Outcrop
- M.D. Mine Dumps

Scale
0 ¼ ½ 1 2 Miles

SOIL SURVEY MAP OF MACOUPIN COUNTY

UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

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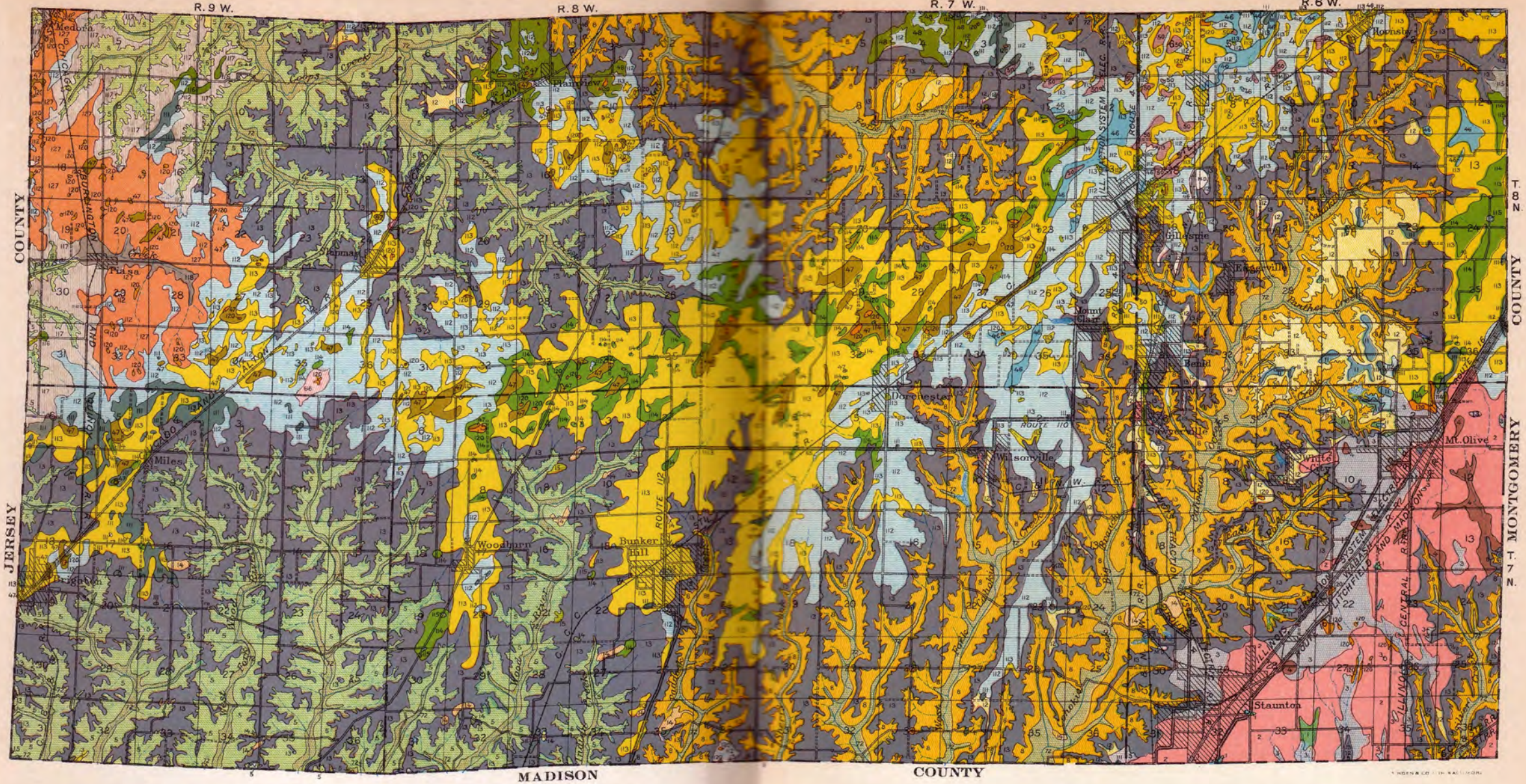

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