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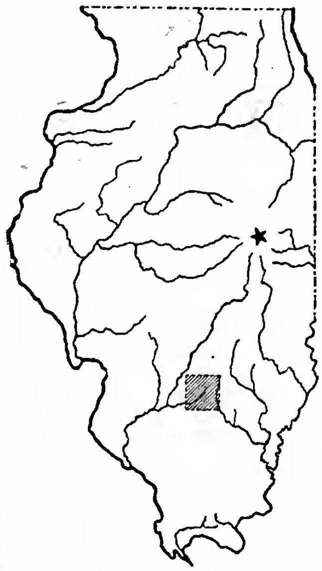
SOIL REPORT No. 34

MARION COUNTY SOILS

By R. S. SMITH, E. A. NORTON, E. E. DeTURK, F. C. BAUER, AND L. H. SMITH



URBANA, ILLINOIS, NOVEMBER, 1926

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 on an Appendix a general discussion of the important principles of soil fertility, in order to help the farmer and landowner to understand the significance of the data furnished by the soil survey and to make intelligent application of the same in the maintenance and improvement of the land. In many cases it will be of advantage to study the Appendix in advance of the soil report proper.

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

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

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MARION COUNTY SOILS

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MARION COUNTY SOILS

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

LOCATION AND CLIMATE OF MARION COUNTY

Marion county is located in the central southern part of Illinois, near the center of that area commonly referred to as "Egypt." The county is square in shape, is of medium size, and contains 565 square miles. It lies entirely within the geological area now thought by geologists to be of pre-Illinoisan age.

The climate of Marion county is characterized by a wide range between the extremes of winter and summer and by an abundant, fairly well-distributed rainfall with the exception that the months of July and August are likely to be drouthy. In some years the rainfall during these months is excessive and comes in the form of thunder showers which beat the ground and are otherwise harmful. The average annual rainfall during the past thirty years, as computed from Weather Bureau stations in the vicinity of Marion county, has been 40.34 inches. The average rainfall by months for this period has been as follows: January, 3.03 inches; February, 2.63; March, 3.24; April, 3.85; May, 3.98; June, 4.19; July, 3.39; August, 3.57; September, 3.66; October, 3.02; November, 2.95; December, 2.83.

The greatest range in temperature for any one year during the past thirty years, also computed from Weather Bureau stations in the vicinity of this county, was 126 degrees in 1899. The lowest temperature recorded was 22° below zero in February, 1899; the highest, 113° in July, 1901. The average date of the last killing frost in the spring is April 14; the earliest in the fall, October 16. The average length of the growing season is 185 days.

AGRICULTURAL PRODUCTION

Marion county is distinctly agricultural; there is no large industry of importance in the county other than that of farming. Farming, however, is tending toward specialized crops, because of certain soil characteristics and the influence of climate. According to the Fourteenth Census of the United States, there were 3,097 farms in Marion county in 1919, the average size of farm being 106.8 acres, 90.7 of which were improved. Of these 3,097 farms, 22.8 percent were operated by tenants in 1919. The number of farms has decreased slightly in the past twenty years, and there has been also a slight decrease in tenantry corresponding to the decrease in farms over the same period.

The principal crops grown in this county are fruits, hay, corn, wheat, and oats. The following tables show the acreage and yield of the more important field crops for the year of 1919, as given by the above-mentioned Census.

---

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

Crops	Acreage	Production	Yield per acre
Corn	32,052	285,994 bu.	8.9 bu.
Wheat	30,638	371,056 bu.	12.1 bu.
Oats	33,059	578,532 bu.	17.5 bu.
Rye	2,987	25,713 bu.	8.6 bu.
Timothy	13,403	11,522 tons	.86 ton
Timothy and clover mixed	2,546	2,779 tons	1.09 tons
Clover	346	415 tons	1.20 tons
Redtop	32,184	22,803 tons	.71 ton
Silage crops	819	3,250 tons	3.96 tons
Corn for forage	10,473	11,461 tons	1.09 tons

In considering these figures it should be borne in mind that they represent the yields of a single year only, those of 1919, which appears to have been an exceedingly poor year for corn. Figures furnished by the U. S. Department of Agriculture give the following average acre yields for the ten-year period 1911-1920: corn, 18.3 bushels; wheat, 12.8 bushels; oats, 18.6 bushels; tame hay, .93 ton. Leguminous crops such as cowpeas and sweet clover have been given considerable attention during the past five years.

Fruits, particularly apples, peaches, and strawberries, have been fairly remunerative in the past and give promise to be more so in the future. The following figures show the production in Marion county for the last Census year:

Tree Fruits	Production	Small Fruits	Production
Apples	170,138 bu.	Strawberries	351,938 qts.
Peaches	27,800 bu.	Raspberries	4,793 qts.
Pears	26,519 bu.	Blackberries and dewberries	30,410 qts.
Cherries	390 bu.	Grapes	48,248 lbs.

Marion county is not an important livestock county. The total value of all livestock and livestock products in 1919 was $3,730,776. The following figures from the 1920 Census show the character of the livestock interests:

Animals and Animal Products	Number	Value
Horses	11,401	$750,981
Mules	1,847	157,920
Beef cattle	5,340	250,497
Dairy cattle	16,078	875,979
Sheep	7,837	89,778
Swine	13,488	156,939
Eggs and chickens	......	562,010
Dairy products	......	477,289

SOIL FORMATION

GEOLOGICAL HISTORY

Previous to the Glacial period the country thruout the state of Illinois was generally rough, having been cut by numerous streams into hilly topography. During the Glacial period snow and ice accumulated in the region of Labrador and to the west of Hudson Bay in such large amounts that the mass pushed outward from these centers, chiefly southward. In moving across the country from the north, the ice gathered up all sorts and sizes of materials including clay, silt, sand, gravel, boulders, and even immense masses of rock. Some of these materials were carried several hundred miles as the ice pushed forward, and an immense amount of rock powder was produced by the grinding or file-like action of the rock material imbedded in the ice.

During this period at least six distinct ice advances occurred that were separated by long periods of time. They are listed as follows, in the order of their occurrence: the Nebraskan, the Kansan, the Illinoisan, the Iowan, the early Wisconsin, and the late Wisconsin. While geologists have accurately traced the limits of advance of the later glaciations, the exact area covered by the earlier ones is difficult to determine because of the effect of subsequent glaciations.

The material transported by the glaciers varied with the character of the rocks over which they passed. Granites, sandstones, limestones, shales, etc., were torn from their lodging places by the enormous denuding power of the ice sheet and ground up together, thus forming an immense amount of fine sediment. A pressure of 40 pounds a square inch is exerted by a mass of ice 100 feet thick, and these ice sheets were hundreds, or possibly thousands, of feet in thickness. The materials carried along in the ice, especially the boulders and pebbles, became powerful agents for grinding and wearing away the surface over which they passed. Preglacial ridges and hills were rubbed down, valleys were filled with debris, and the surface features entirely changed. The mixture of materials deposited by the glacier is known as boulder clay, till, glacial drift, or simply drift.

A glacial advance prior to the Illinoisan extended over most of the state and covered Marion county. Many of the preglacial ridges or valleys were rubbed down or covered up with drift by this ice sheet, so that all surface indications of preglacial topography have been completely obliterated. The upland in the northern part of the county was covered to an average depth of 18 to 25 feet, the deposit being more shallow to the south. Along the southern border of the county the drift is about 12 feet deep, and on the ridges it is rarely over 10 feet and often no more than 5 feet. The old valleys were filled to depths of 40 to 100 feet. The comparatively level surface thruout Marion county is the result of glacial denudation and deposition.

It should be understood that the glacial drift itself makes up only part of the actual soil material in this county, for after the Glacial period this region was partially covered by a stratum of wind-blown, silty material known as loess. This wind-blown material was the rock flour produced by the grinding action of the glacier which was carried out and deposited in the flood plains and river bottoms during the time the glacier was melting and receding. There it dried, was picked up by the wind, and carried over the upland as dust. It was sorted and re-sorted by the wind, the coarser materials being deposited near the source and the finer or lighter material being carried many miles. Marion county received only a shallow deposit of this silty loess because it was some distance from any main drainage outlet. The loessial deposit probably varies from a few inches on the east side of the county to a few feet on the west.

The glacial drift which has been exposed on or near the surface during the long interval of time which has elapsed since its deposition has weathered into finely divided particles with only an occasional pebble, chiefly chert, remaining. It is very difficult, and perhaps impossible, to distinguish between this thoroly weathered drift and loess. In all probability this decomposed glacial material has become mixed with the wind-blown, silty loess, giving the county a loess-like covering varying from 20 inches in the eastern part to about 4 feet in the western part. On the steep slopes, where erosion has removed some or all of this loess-like material, the sandy, pebbly drift is exposed and forms the soil material.

SOIL DEVELOPMENT

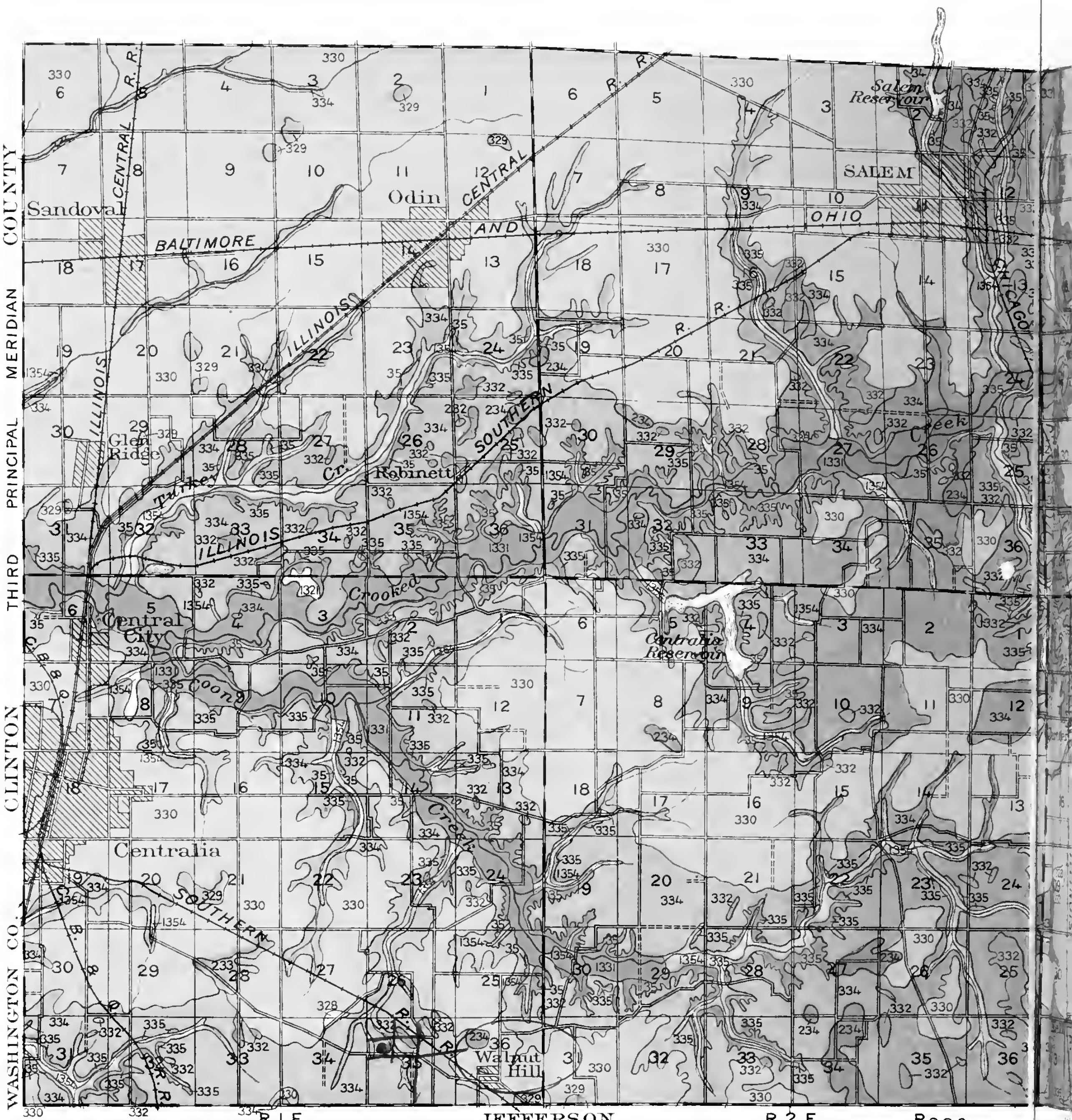
Glacial till and silty loess, principally a mixture of the two, are the soil materials from which the soils of Marion county have been derived. The agencies of weathering acted upon these deposits causing the leaching of certain minerals, the accumulation of others, and the movement of particles into layers, zones, or horizons. This, with the addition of organic matter from the decay of roots and other plant growth, formed the soil.

The soil was probably much darker in color and much more productive in the earlier periods of its existence than at present. As time went on two important changes occurred in the soil which served to reduce its productivity. Shrubs and trees appeared near the stream channels and in well-drained areas, and forests gradually spread over the prairies. In upland forests the residues consist mainly of fallen leaves, branches, and dead trees, which become almost completely destroyed either by burning or by exposure to the oxygen of the air and to fungi. The second important change which took place in the soil was the concentration of the smaller soil particles, thru the downward movement of soil water, into a restricted zone, known as the B horizon, until their accumulation impaired underdrainage. The impervious layer or "tight clay" thus formed has been commonly, tho erroneously, called "hardpan." This condition caused the soil to become water-logged in the rainy seasons, and extremely dry during summer and fall, thus retarding the accumulation of organic matter. The soils of Marion county are characterized by a strongly developed B horizon, or accumulative zone.

PHYSIOGRAPHY AND DRAINAGE

Marion county is one of the most level counties in the state. It does not have extremes in topography; in fact, there is less than 150 feet of difference in the altitude of the highest and lowest points in the county. The altitudes of some of the places are as follows: Centralia 500 feet above sea level; Fairman, 530; Kell, 607; Kinmundy, 609; Patoka, 512; Odin, 529; Salem, 546; Sandoval, 490; Vernon, 525. There are three areas in the county, each covering 10 to 20 square miles, which have rolling topography; one, in the southwest part of Kinmundy township (Township 4 North, Range 3 East); the second, the east half of Haines township (Township 1 North, Range 3 East); and the third, the southern part of Centralia township (Township 1 North, Range 1 East). The remainder of the county is flat to undulating, except for a few preglacial knolls which rise from 15 to 60 feet above the surrounding country, and for slopes caused by recent stream erosion along the main drainage outlets.

Marion county lies within two well-defined drainage basins, the Kaskaskia and Little Wabash rivers (see drainage map, Fig. 1). About 60 percent of the county is drained by the Kaskaskia system. The dividing line between it and the Little Wabash system lies in a north-south direction about three miles east of the center of the county, the line bending toward the northeast as it approaches



(a) UPLAND PRAIRIE SOILS

- 330 Gray silt loam on tight clay
- 328 Brown-gray silt loam on tight clay
- 329 Drab silt loam

(b) UPLAND TIMBER SOILS

- 34, 334 Yellow-gray silt loam
- 35, 335 Yellow silt loam
- 332 Light gray silt loam on tight clay

000 Residual

200 Ridge Soils

300 Lower Illinoisan Glaciation

Scale 0 ¼ ½ 1 2 Miles

SOIL SURVEY MAP

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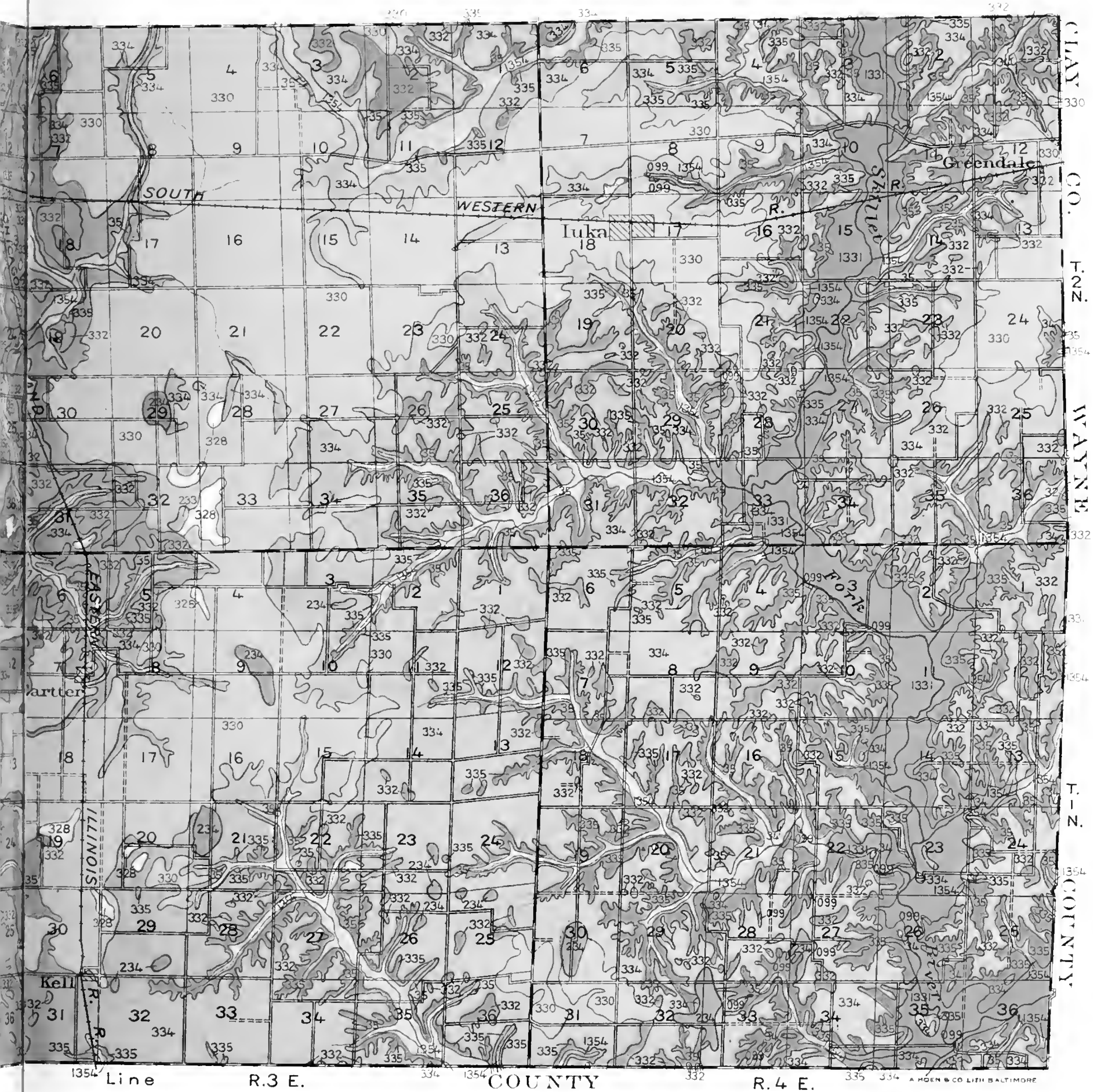


LEGEND

(c) RIDGE SOILS

Gray-red silt loam on tight clay

Yellow-gray silt loam

(d) RESIDUAL SOILS

Rock outcrop (sandstone)

Small areas rock outcrop

(e) 1300 OLD SWAMP AND BOTTOM-LAND SOILS

1331 Deep gray silt loam

1354 Mixed loam

1321 Drab clay loam

AP OF MARION COUNTY

GRI ULTURAL EXPERIMENT STATION

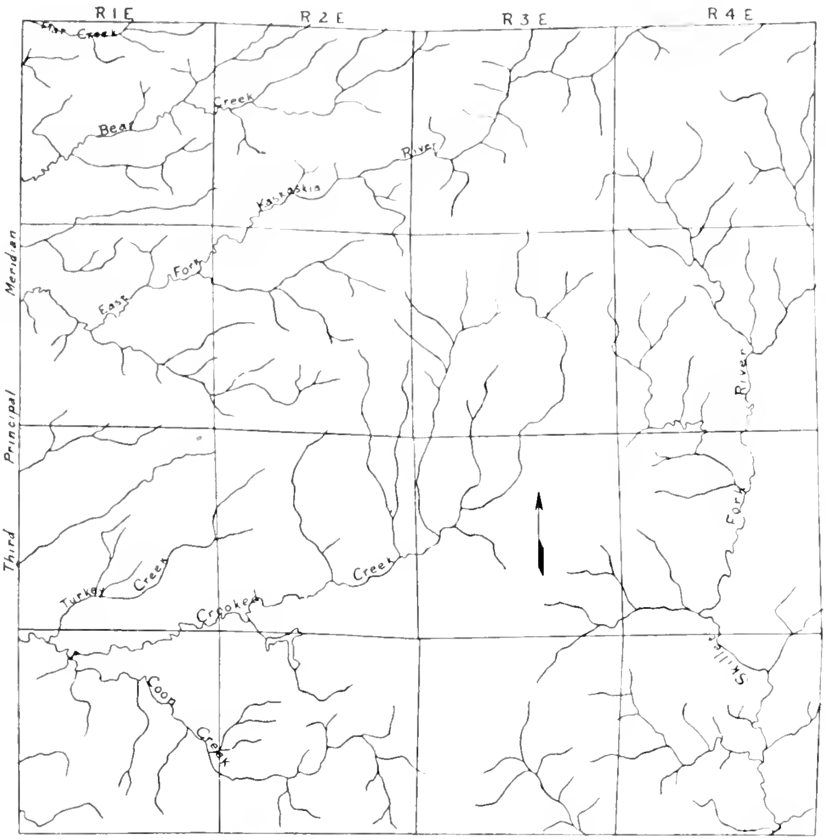


FIG. 1.—DRAINAGE MAP OF MARION COUNTY SHOWING STREAM COURSES

the northern border. Drainage of the western part of the county is west, then south to the Mississippi river, while that of the eastern part is south to the Ohio river. Surface drainage is in the early maturity stage.

Even tho drainage channels are fairly well established thruout the county, underdrainage remains a difficult problem. The tight clay subsoil has proved to be an obstacle which yet remains economically impossible to overcome. Tiling is not successful and open surface ditiching is the only practical means of removing the excess water from the land.

SOIL GROUPS

The soils of Marion county are classified under the following groups:

(a) *Upland Prairie Soils,* including the upland soils that have not been covered with heavy forests.

(b) *Upland Timber Soils,* including nearly all the upland areas which are now, or were formerly, covered with forests.

(c) *Ridge Soils,* including those formed on preglacial ridges under good drainage and well-aerated conditions. (They are designated on the map as of the 200 group, morainal soils.)

(d) *Residual Soils,* including the rock outcrops from which the loess and till have been removed by erosion.

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

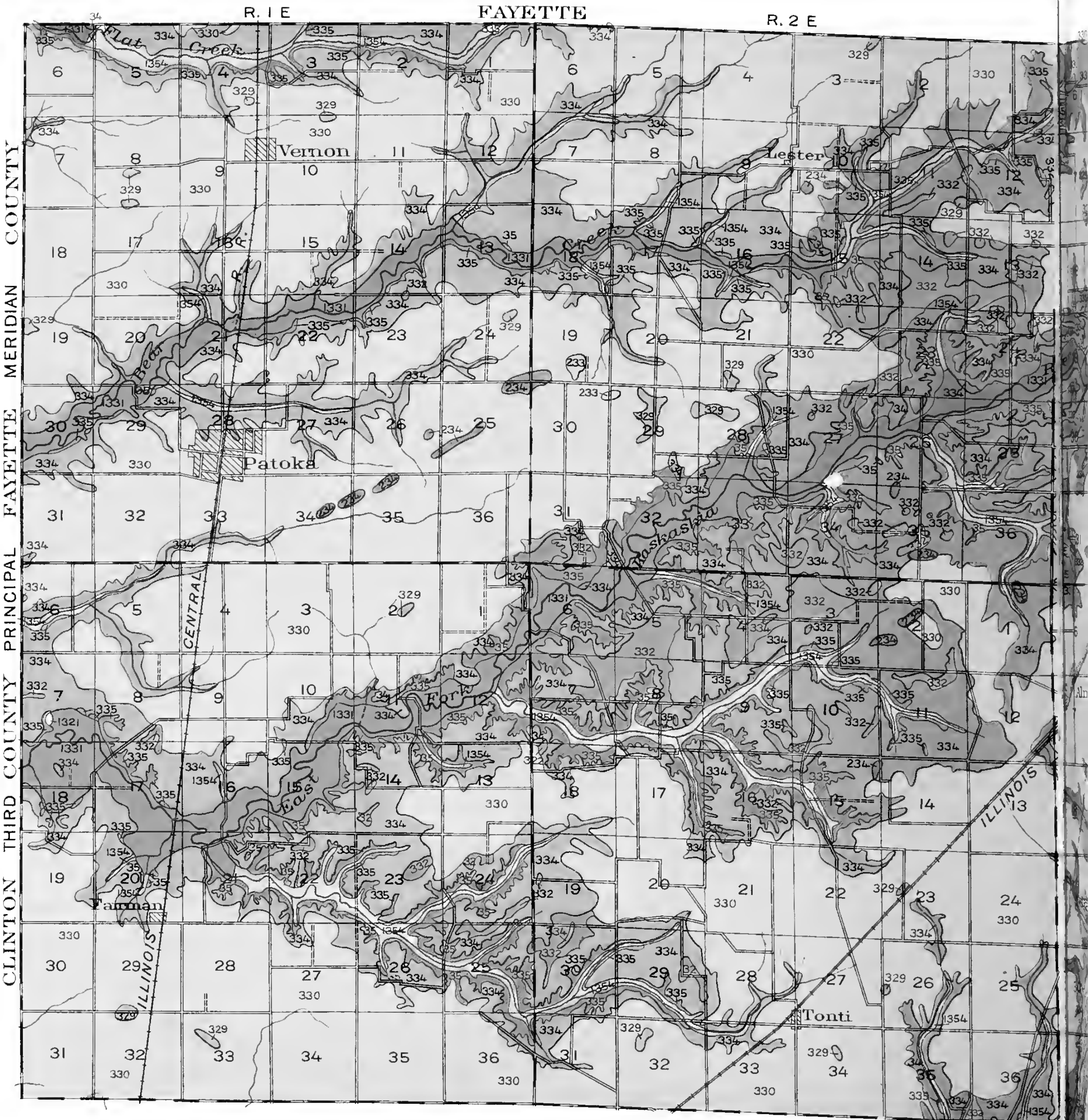
Table 1 gives the area of each type of soil in Marion county and its percentage of the total area. It will be observed that about 90 percent of the county consists of upland prairie and upland timber soils in about equal proportions. The accompanying map, appearing in two sections, shows the location and boundary lines of the various types.

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

TABLE 1.—SOIL TYPES OF MARION COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (300)			
330	Gray Silt Loam On Tight Clay[1]	251.87	161 197	44.55
328	Brown-Gray Silt Loam On Tight Clay	.60	384	.11
329	Drab Silt Loam	2.82	1 805	.5[illegible]
		255.29	163 386	45.16
	(b) Upland Timber Soils (300)			
334	Yellow-Gray Silt Loam[1]	199.73	127 827	35.32
335	Yellow Silt Loam	41.32	26 445	7.30
332	Light Gray Silt Loam On Tight Clay	15.67	10 029	2.77
		256.72	164 301	45.39
	(c) Ridge Soils (200)			
233	Gray-Red Silt Loam On Tight Clay[1]	1.57	1 005	.28
234	Yellow-Gray Silt Loam[1]	2.62	1 677	.46
		4.19	2 682	.74
	(d) Residual Soils (000)			
099	Rock Outcrop	.01	6	.001
	(e) Old Swamp and Bottom-Land Soils (1300)			
1331	Deep Gray Silt Loam	24.85	15 904	4.40
1354	Mixed Loam	23.86	15 270	4.22
1321	Drab Clay Loam	.08	51	.01
		48.79	31 225	8.63
	Water	.46	294	.08
	Total	565.46	361 894	100.00

[1]This is the name under which the type was originally mapped. Later investigation has shown the desirability of making certain differentiations within the type; these are described in the text.



LEGEND

000 Residual

200 Ridge Soils

300 Lower Illinoisan Glaciation

Scale
0 ¼ ½ 1 2 Miles

(a) UPLAND PRAIRIE SOILS

330	Gray silt loam on tight clay
328	Brown-gray silt loam on tight clay
329	Drab silt loam

(b) UPLAND TIMBER SOILS

34 334	Yellow-gray silt loam
35 335	Yellow silt loam
332	Light gray silt loam on tight clay

SOIL SURVEY MAP OF
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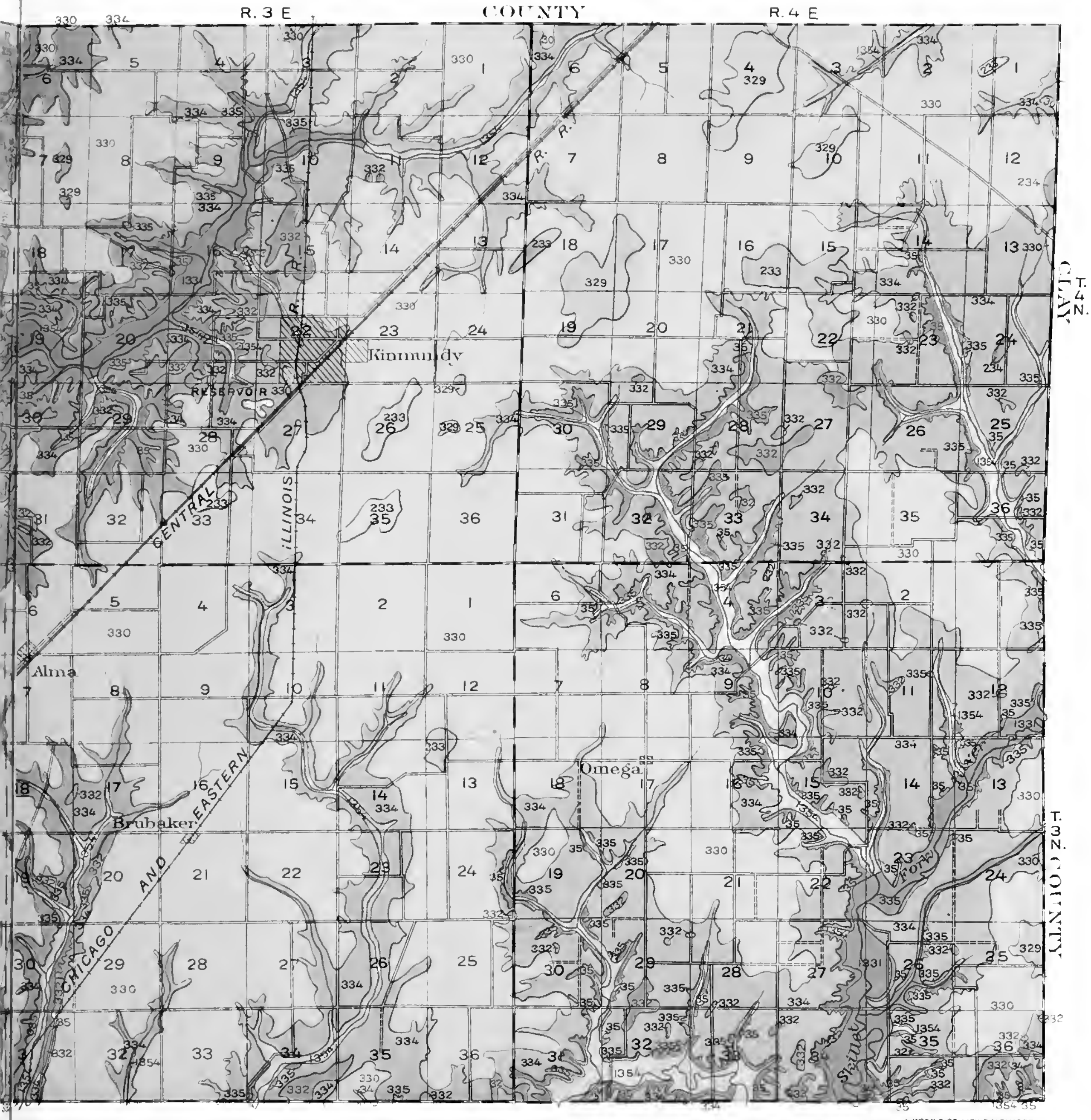

END

IDGE SOILS

Gray-red silt loam on tight clay

Yellow-gray silt loam

(d) RESIDUAL SOILS

Rock outcrop (sandstone)

Small areas rock outcrop

(e) OLD SWAMP AND BOTTOM-LAND SOILS

1331 Deep gray silt loam

1354 Mixed loam

1321 Drab clay loam

OF MARION COUNTY
LTURAL EXPERIMENT STATION

INVOICE OF THE ELEMENTS OF PLANT FOOD IN MARION COUNTY SOILS

In order to obtain a knowledge of its chemical composition, each soil type is sampled in the manner described below and subjected to chemical analysis for its important plant-food elements. For this purpose samples are taken usually in sets of three to represent different strata in the top 40 inches of soil; namely, an upper stratum (0 to 6⅔ inches), a middle stratum (6⅔ to 20 inches), and a lower stratum (20 to 40 inches).

These sampling strata correspond approximately in the common kinds of soil to 2 million pounds per acre of dry soil in the upper stratum, and to two times and three times this quantity in the middle and lower strata respectively. This, of course, is a purely arbitrary division of the soil section, very useful in arriving at a knowledge of the quantity and distribution of the elements of plant food in the soil; but it should be borne in mind that these strata seldom coincide with the natural strata as they actually exist in the soil and which are referred to in describing the soil types as "horizons" A, B, and C. By this system of sampling we have represented separately three zones for plant feeding. The upper, or surface layer, includes at least as much soil as is ordinarily turned with the plow, and this is the part with which the farm manure, limestone, and other fertilizing materials are incorporated.

The chemical analysis of a soil, obtained by the methods here employed, gives the invoice of the total stock of the several plant-food materials actually present in the soil strata sampled and analyzed. It should be understood, however, that the rate of liberation from their insoluble forms, a matter of at least equal importance, is governed by many factors, and therefore is not necessarily proportional to the total amounts present.

For convenience in making application of the chemical analyses, the results as presented here have been translated from the percentage basis and are given in the accompanying tables in terms of pounds per acre. In this the assumption is made that for ordinary types a stratum of dry soil of the area of an acre and 6⅔ inches thick weighs 2 million pounds. It is understood, of course, that this value is only an approximation, but it is believed that with this understanding, it will suffice for the purpose intended. It is a simple matter to convert these figures back to the percentage basis in case one desires to consider the information in that form.

With respect to the presence of limestone and acidity in different strata, no attempt is made to include in the tabulated results figures purporting to represent their averages in the respective types, because of the extreme variations frequently found within a given soil type. In examining each soil type in the field, however, numerous qualitative tests are made which furnish general information regarding the soil reaction, and in the discussion of the individual soil types which follows, recommendations based upon these tests are given concerning the lime requirement of the respective types. Such recommendations cannot be made specific in all cases because local variations exist, and because the lime requirement may change from time to time, especially under cropping and soil treatment. It is often desirable, therefore, to determine the lime requirement for a given field, and in this connection the reader is referred to the section in the Appendix dealing with the application of limestone (page 31).

THE UPPER SAMPLING STRATUM

In Table 2 are reported the total quantities of organic carbon, nitrogen, phosphorus, sulfur, potassium, magnesium, and calcium in 2 million pounds of the surface soil of each type in Marion county.

In connection with this table attention is called to the variation among the soil types with respect to their content of the different plant-food elements. It will be seen from the analyses that the variation in the organic-carbon content of the different soils is accompanied by a similar variation in the nitrogen content. The organic-carbon content, which serves as a measure of the total organic matter present, is usually from 10 to 12 times that of the total nitrogen. This close relationship is explained by the well-established facts that all soil organic matter contains nitrogen, and that most of the soil nitrogen (usually 98 percent or more) is present in a state of organic combination. This close relationship is also maintained in the middle and lower sampling strata, altho it is generally a more narrow ratio at the deeper levels, owing to the more rapid dissipation of soil carbon as compared with nitrogen.

The organic matter, with the accompanying nitrogen, shows some variation among the different soil types but is comparatively low thruout the county. Of the ten soil types for which analyses are reported in this county, only two types contain more than 30,000 pounds of organic carbon in the surface stratum of an acre. These are Drab Clay Loam, Bottom, and Yellow-Gray Silt Loam, Ridge, each containing approximately 43,000 pounds an acre. The remainder of the soils in the county range in organic-carbon content from a minimum of 12,860 pounds an acre in Yellow Silt Loam, up to 29,590 pounds in Deep Gray Silt Loam, Bottom. The total nitrogen figures are correspondingly low, being in the latter two types 990 and 2,900 pounds respectively. Because of the small amounts of both nitrogen and organic matter in these soils, it is particularly important to grow legume crops frequently as green manures and plow them down, in addition to conserving and using all the animal manure which can be produced.

Other elements are not so closely associated with each other as are organic matter and nitrogen. However, there is some degree of correlation between sulfur, another element used by growing plants, and organic carbon. This is because a considerable, tho varying, proportion of the sulfur in the soil exists in the organic form, that is, as a constituent of the organic matter. The sulfur content of Marion county soils is on the whole rather low. It ranges, in the surface soil, from 310 pounds to 1,100 pounds an acre. However, only two types, Yellow-Gray Silt Loam and Drab Clay Loam, contain more than 520 pounds.

The sulfur available to crops is affected not only by the amount and solubility of that contained in the soil, but also by the amount which is brought down from the atmosphere in the rainfall. Sulfur dioxid escapes into the air in the gaseous products from the burning of all kinds of fuel, particularly coal, and possibly to some extent from the decay of vegetable and animal residues. The gaseous sulfur dioxid is soluble in water and consequently it is dissolved out of the air by rain and brought to the earth. In regions of heavy coal consumption the amount of sulfur thus added to the soil is large. At Urbana, during the eight-year period from 1917 to 1924 there was added to the soil by the rainfall 3.5 pounds of sulfur per acre per month, as an average. Similar observations have been made in localities in southern Illinois for shorter periods. At Sparta, in Randolph county, in 1921, there was added in the rainfall 3.51 pounds of sulfur an acre in May, 7.78 pounds in August, and 9.96 pounds in September. At Ewing, in Franklin county, during the entire season of 1921 the average monthly precipitation contained 2.27 pounds of sulfur an acre. These figures will afford some idea of the amount of sulfur added by rain and also of the wide variation in these amounts under different conditions. On the whole, these facts would indicate that the sulfur added from the atmosphere sufficiently supplements that contained in the soil, so that a need for sulfur fertilizers is not likely in Marion county.

The potassium content of the surface soil ranges from 24,680 pounds an acre in Light Gray Silt Loam On Tight Clay to 35,300 pounds in Drab Clay Loam. From a quantitative point of view, the least of these amounts is far above maximum crop requirements. However, the rate at which potassium is liberated in available condition from these large reserves varies widely, and the statements concerning the use of potassium fertilizers in another part of this report are an indication that crop yields may be limited on some of the soils of Marion county by a deficiency of available potassium.

The phosphorus content of the soils of the county is generally low, ranging from 490 pounds an acre in Yellow Silt Loam up to 1,040 pounds in Drab Clay Loam.

The amounts of soil calcium are uniformly low, but not lower than is to be expected in mature soils which are acid. Soil acidity and calcium deficiencies are very frequently, but not always, associated. The smallest amount of calcium in the Marion county soils analyzed, 3,650 pounds an acre, is found in Yellow-Gray Silt Loam. The largest amount found is 8,160 pounds in Drab Clay Loam. These are all non-carbonate soils. Calcium is utilized by crops in fairly large amounts, so that in acid soils low in calcium content, this element possibly may not become available rapidly enough to supply crop needs. The liming of such soils, however, will supply any calcium deficiencies in addition to the correcting of acidity.

The content of magnesium in Marion county soils averages about 25 percent higher than that of calcium. This preponderance of magnesium is a frequent occurrence in heavy, mature soils which have been subjected to much leaching, and, as in the case here, is most pronounced in the lower levels. The smallest amount of magnesium found is 4,230 pounds an acre. Considering the crop requirements for this element, it is doubtful whether magnesium ever becomes a limiting factor in crop production. This statement, however, does not imply the superiority of high-calcium limestone as a soil amendment. The usual commercial grades of high-calcium and magnesian limestones are approximately equal in neutralizing value, and both types of stone also contain an abundance of calcium to make good any soil deficiencies in this element.

THE MIDDLE AND LOWER SAMPLING STRATA

In Tables 3 and 4 are recorded the amounts of the plant-food elements in the middle and lower sampling strata. In comparing these strata with the upper stratum, or with each other, it is necessary to bear in mind that the data as given for the middle and lower sampling strata are on the basis of 4 million and 6 million pounds of soil, and should therefore be divided by 2 and 3, respectively, before they are compared with each other or with the data for the upper stratum, which is on a basis of 2 million pounds.

With this in mind, it will be noted in comparing the three strata with each other, that all of the soil types diminish rather rapidly in organic matter and nitrogen with increasing depth, and that this diminution is very marked even in the middle stratum. The percentages of the other elements remain about the same, or increase slightly in the lower strata with the exception of sulfur and phosphorus, which in some cases decrease with increasing depth. Phosphorus has frequently been found to be low in the middle stratum, altho this condition is not so prevalent in Marion county as is usually the case. It may be attributed

TABLE 2.—PLANT-FOOD ELEMENTS IN THE SOILS OF MARION COUNTY, ILLINOIS
UPPER SAMPLING STRATUM: ABOUT 0 TO 6⅔ INCHES
Average pounds per acre in 2 million pounds of dry soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (300)							
330	Gray Silt Loam On Tight Clay	28 550	2 840	890	520	25 730	4 230	4 480
328	Brown-Gray Silt Loam On Tight Clay	24 520	2 520	540	360	27 060	4 680	4 420
329	Drab Silt Loam	26 820	2 840	620	440	25 810	5 450	5 490
	Upland Timber Soils (300)							
334	Yellow-Gray Silt Loam	23 010	2 140	610	430	29 410	5 540	3 650
335	Yellow Silt Loam	12 860	990	490	310	35 210	7 590	3 760
332	Light Gray Silt Loam On Tight Clay	22 930	2 050	720	400	24 680	5 530	4 010
	Ridge Soils (200)							
233	Gray-Red Silt Loam On Tight Clay	27 380	2 720	760	460	27 300	5 200	4 320
234	Yellow-Gray Silt Loam	43 180	4 000	780	1 100	28 640	7 640	5 620
	Old Swamp and Bottom-Land Soils (1300)							
1331	Deep Gray Silt Loam	29 590	2 900	700	510	33 070	7 300	6 620
1354	Mixed Loam[1]	......	......	......	......	......	......	......
1321	Drab Clay Loam	43 960	4 180	1 040	1 100	35 300	10 920	8 160

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

[1]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type.

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

Average pounds per acre in 4 million pounds of dry soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (300)							
330	Gray Silt Loam On Tight Clay..	27 280	3 070	1 050	720	55 540	9 770	8 050
328	Brown-Gray Silt Loam On Tight Clay........................	44 400	3 560	1 400	840	57 640	9 760	7 280
329	Drab Silt Loam...............	40 620	3 270	1 200	340	42 560	9 800	10 830
	Upland Timber Soils (300)							
334	Yellow-Gray Silt Loam.........	15 120	1 880	1 230	500	62 220	11 260	4 670
335	Yellow Silt Loam..............	11 730	1 550	970	450	70 750	12 710	4 690
332	Light Gray Silt Loam On Tight Clay.......................	15 540	1 960	1 340	580	54 140	11 360	6 680
	Ridge Soils (200)							
233	Gray-Red Silt Loam On Tight Clay..........................	29 000	3 480	1 240	...[2]...	60 680	14 880	7 760
234	Yellow-Gray Silt Loam.........	54 400	5 520	1 360	...[2]...	57 200	20 520	8 160
	Old Swamp and Bottom-Land Soils (1300)							
1331	Deep Gray Silt Loam..........	20 770	3 430	1 190	570	67 090	12 910	9 110
1354	Mixed Loam[1].................	....	......	......	......	....	....	....
1321	Drab Clay Loam..............	38 480	3 800	1 360	...[2]...	71 320	22 440	16 040
	LIMESTONE AND SOIL ACIDITY.—See note in Table 2.							

[1]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type.
[2]No analysis available; sample exhausted.

to the removal of phosphorus from this stratum by the roots of growing plants and subsequent incorporation with the surface soil in the accumulated plant residues.

It is frequently of interest to know the total supply of a plant-food element accessible to the growing crops. While it is impossible to obtain this information exactly, especially for the deeper-rooted crops, it seems probable that practically all of the feeding range of the roots of most of our common field crops is included in the upper 40 inches of soil. By adding together for a given soil type the corresponding figures in Tables 2, 3, and 4, the total amounts of the respective plant-food elements to a depth of 40 inches may be ascertained.

Considered in this manner the tables reveal a considerable variation with respect to the relative abundance of the various elements among the different soil types, as measured by crop requirements. We may compare in this way two extreme soil types in the county, namely, Drab Clay Loam, Bottom, and Yellow Silt Loam, Upland. The respective amounts of nitrogen in the two soils to a depth of 40 inches are 11,640 and 4,100 pounds an acre, which is equivalent to the nitrogen contained in the same number of bushels of corn, since a bushel of corn contains approximately a pound of nitrogen. The Drab Clay Loam thus contains nearly three times as much of this element as the Yellow Silt Loam.

TABLE 4.—PLANT-FOOD ELEMENTS IN THE SOILS OF MARION COUNTY, ILLINOIS
LOWER SAMPLING STRATUM: ABOUT 20 TO 40 INCHES

Average pounds per acre in 6 million pounds of dry soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland Prairie Soils (300)							
330	Gray Silt Loam On Tight Clay..	26 710	3 300	2 080	970	83 020	28 060	18 160
328	Brown-Gray Silt Loam On Tight Clay......................	26 820	3 660	2 460	660	86 520	27 060	11 520
329	Drab Silt Loam..............	39 620	3 920	1 500	540	76 720	20 200	16 060
	Upland Timber Soils (300)							
334	Yellow-Gray Silt Loam........	18 920	2 100	2 040	500	91 770	25 220	12 110
335	Yellow Silt Loam.............	8 560	1 560	1 340	640	101 940	27 140	9 900
332	Light Gray Silt Loam On Tight Clay......................	16 290	2 070	1 800	960	85 470	28 590	17 910
	Ridge Soils (200)							
233	Gray-Red Silt Loam On Tight Clay......................	25 020	3 360	1 800	...[2]...	87 720	19 520	16 620
234	Yellow-Gray Silt Loam........	30 420	3 780	1 440	...[2]...	98 100	35 760	20 700
	Old Swamp and Bottom-Land Soils (1300)							
1331	Deep Gray Silt Loam..........	15 520	2 280	2 220	640	104 660	26 060	10 380
1354	Mixed Loam[1]................	......	......	......	......	......	......	......
1321	Drab Clay Loam..............	33 600	3 660	2 040	...[2]...	107 040	35 880	25 680

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

[1]On account of the heterogeneous character of Mixed Loam, chemical analyses are not included for this type.
[2]No analysis available; sample exhausted.

Drab Clay Loam also contains considerably more phosphorus than Yellow Silt Loam. The former contains 4,440 pounds of phosphorus, which is equivalent to 25,990 bushels of corn, as compared with 2,800 pounds in the latter, equivalent to 16,510 bushels of corn.

A comparison of the total amounts of potassium in the different soil types is of little direct importance when it is considered that the soil containing the smallest total amount of this element (Drab Silt Loam, 329) has in it potassium equivalent to that contained in three-quarters of a million bushels of corn. This large total supply of potassium should not be interpreted to mean that there can be no need for additions of potassium salts in crop production, for potassium minerals in the soil become soluble very slowly, and upon the rate of liberation during the growing season rests the answer to the question whether potassium should be supplied in a form readily available to crops.

The two soil types considered above vary widely in calcium content, the amounts contained to a depth of 40 inches being 49,880 pounds in Drab Clay Loam and only 18,350 pounds in Yellow Silt Loam. The relative amount of calcium is not of so great importance directly in connection with the corn crop as it is with respect to legumes. A ton of red clover hay, for example, contains approximately 29 pounds of calcium. These two soils therefore contain as much calcium as would be removed in 1,720 and 630 tons of red clover hay respectively.

The above statements are not intended to imply that it is possible to predict how long it might be before a certain soil would become exhausted under a given system of cropping. Neither do the figures necessarily indicate the immediate procedure to be followed in the improvement of a soil, for other factors enter into consideration aside from merely the amount of plant-food elements present in the soil. Much depends upon the nature of the crops to be grown, as to their ability to utilize plant-food materials, and much depends upon the condition of the plant-food substances themselves as to their availability. Finally, in planning the detailed procedure for the improvement of a soil, there enter for consideration all the economic factors involved in any fertilizer treatment. Such figures do, however, furnish an inventory of the total stocks of the plant-food elements that can possibly be drawn upon; and in this way these chemical data contribute fundamental information for the intelligent planning, in a broad way, of systems of soil management that will conserve and improve the fertility of the land.

DESCRIPTION OF SOIL TYPES

(a) UPLAND PRAIRIE SOILS

In the following descriptions of soil types an effort is made to describe the types which occur in Marion county as they are recognized at the present time. It will be observed that several of the types as they appear on the soil map, which was completed in 1915, are now recognized to include two or more types. The topographic position and the situations in which each of these new types occur is stated so that, in most cases, they can easily be recognized in the field.

The upland prairie soils of Marion county occupy 255.29 square miles, nearly one-half of the total area of the county. They range in color of surface soil from gray to grayish brown, owing to the variation in the amount and condition of the organic matter. The surface color of the prairie soils is darker than that of the timbered soils, owing to their higher content of organic matter, derived very largely from the roots of prairie grasses. If the present climatic conditions have prevailed ever since the Glacial period, it is unlikely that the soil ever contained any more organic matter or was any darker than at present. It is probable, however, that more favorable climatic conditions prevailed at some time after the retreat of the glacier, and that the soils were richer and darker, containing more organic matter which has since been reduced by the present rather high amount of rainfall, relatively open winters, and hot, dry summers. Because of their great age and loss of mineral plant food, the common prairie soils of southern Illinois have become incapable of supporting a luxuriant plant growth.

The reason for the existence of so large an extent of prairie soil in the state remains debatable. Normally forests invade and spread over the land, particularly in a country where the climate and rainfall are so nearly optimum for the development of forest vegetation as here. This prairie condition may be due to unnatural or accidental causes, such as forest fires continually nipping the new growth; but it more likely is due to the drainage conditions in the soil. Most of the prairie land is relatively flat, and prior to artificial drainage was probably saturated with water or even covered with shallow lakes or ponds during a portion of each year. These shallow lakes or ponds were probably dry only in late summer and fall, at least not more than a few months each year. Forest vegetation would have difficulty in making a start in a soil which remained water-logged most of the year, while the prairie vegetation which matures in a relatively short time could make some growth during each dry season.

Gray Silt Loam On Tight Clay (330)

Gray Silt Loam On Tight Clay, as it was mapped in Marion county, covers an area of 251.87 square miles, or nearly 45 percent of the total area of the county. This type as originally mapped is now recognized to include several types, each with a distinct profile, and each of which is associated with a characteristic topographic expression. The original name, Gray Silt Loam On Tight Clay, has been retained for the designation of one of these types and new names applied to the others. The new names adopted are as follows: *Deep Gray Silt Loam On Tight Clay, Gray Silt Loan On Orange-Mottled Tight Clay, Yellowish Gray Silt Loam On Orange-Mottled Tight Clay, and Gray Silt Loam On Reddish Brown Clay.* The description of each of these types follows, together with a statement as to its occurrence and suggestions for its management.

Deep Gray Silt Loam On Tight Clay occurs in depressions at the heads of small streams or drainage channels, at the base of long slopes, and in level basins. The areas usually are not large, but the type is rather extensive thruout the county. This type has received, and in many places is still receiving, a silty wash, brought down in the run-off as sheet erosion during hard rains, from adjoining higher land. These low-lying, level areas originally were poorly drained and marshy, but now surface drainage is fairly well established. Inasmuch as the impervious layer lies moderately deep, underdrainage can be successfully provided in many places.

The A_1 horizon, 0 to 10 inches, is a silt loam, brownish gray in color, mealy, laminated, and friable in structure. In certain areas black iron concretions are found in this horizon. The A_2 horizon, 10 to 24 inches, is a light brownish gray to gray silt loam, mealy, friable, and iron-stained. A thin, ashy-gray layer occasionally occurs below 20 inches. The B horizon, 24 to 35 inches, is a mottled, pale yellow clay, plastic, compact, and somewhat impervious. Iron concretions are usually present in abundance. Occasionally this horizon has a drabbish cast, which probably is due to an excessively marshy condition. The C horizon, below 35 inches, is a mottled, pale yellow, friable, clayey silt loam.

Management.—Deep Gray Silt Loam On Tight Clay is medium to strongly acid to a depth of 35 or 40 inches. The portion of the type which occupies gentle slopes has good surface drainage and, with an accessible outlet, tile drainage will work satisfactorily on either the gentle slopes or on the low-lying level areas because of the depth at which the impervious layer or "tight clay" lies.

This type is low in organic matter and the first step in increasing its productivity is to add sufficient limestone for the growing of clover and then to make one of the clovers, preferably sweet clover, one of the regular crops in the rotation. After the organic matter and nitrogen deficiency has thus been taken care of, trial should be made of one or more of the commonly used phosphates. This type, properly managed, is one of the best upland soils in the county, and can be better utilized for the production of grain crops than any other upland soil.

Gray Silt Loam On Tight Clay is found on the flat and gently undulating plains. This type includes possibly one-third of the area of the entire type as it is shown on the soil map of the county. The surface material is loess-like, but sandy, pebbly, glacial till is encountered at depths varying from 10 to 50 inches. This type presents the normal soil profile developed under conditions of exceedingly poor drainage. Its topography is flat to gently undulating, and both the surface and underdrainage are very poor.

Numerous small areas known as "slick spots" or "scalds" occur, which are easily recognized by their light gray or greenish gray color in the lower horizons when exposed in road cuts and along drainage channels. Their formation is probably associated with the movement of seepage water which has resulted in the accumulation of mineral salts and changes in the soil profile. Iron and lime are always present to some degree, and often in concretionary form. The concentration of salts in these areas inhibits plant development and often is so strong that plant growth is prevented entirely.

The A_1 horizon, 0 to 8 inches, is a brownish gray, mealy, laminated, friable silt loam. The A_2 horizon, 8 to 17 inches, is an ashy, light gray, friable silt loam. The B horizon, 17 to 28 inches, is a mottled, yellow, plastic, impervious tight clay, often containing some sand and small pebbles mixed with black iron concretions. In the "slick spots" the B, or tight clay, horizon usually occurs immediately under the A_1, or surface, and presents a very pale, greenish yellow appearance, with numerous small pebbles present. The C_1 horizon, below 28 inches, is a mottled, yellow, friable, silty clay loam containing many iron concretions, and having a distinct columnar structure for the first 8 or 10 inches.

Management.—Gray Silt Loam On Tight Clay is low in nitrogen and organic matter and is strongly acid. It has the same management requirements as Deep Gray Silt Loam On Tight Clay, described above, but will respond less favorably to good farming, because drainage is very poor, owing to the nearness of the plastic subsoil to the surface and the presence of numerous scald spots. Tile cannot be used to improve drainage on this type. If this land is to be farmed efficiently, it is necessary to use limestone and grow sweet clover. Any additional treatment should be on a trial basis. There are indications that potash salts may be used at a profit for corn and trial applications of rock or acid phosphate should be made for wheat.

This type produces good timothy hay following the application of limestone and growth of sweet clover. Redtop is a common crop on this soil, both hay and seed being produced. In growing the above crops, some sort of rotation, including a legume, should be used so that the yields may be maintained. The yield of hay or seed usually shows a marked decrease after four or five years of continuous cropping. This soil is also adapted to growing apples. It is not a good soil for corn, but will produce satisfactory yields in seasons which are climatically favorable, if sweet clover has been grown and turned under. Wheat also may be grown, but a relatively large proportion of poor yields may be expected.

Gray Silt Loam On Orange-Mottled Tight Clay occurs on undulating to gently rolling areas. It is equally as extensive thruout the county as Gray Silt Loam On Tight Clay. The loess-like surface covering is about 30 inches deep where the sandy pebbly drift is encountered. This type was formed under poor to fair surface drainage, as is indicated by the undulating to gently rolling topography and by the character of its profile. Slick spots occur on this type but are not numerous.

The A_1 horizon, 0 to 7 inches, is a brownish gray, mealy, friable silt loam with a distinctly laminated structure. The A_2 horizon, 7 to 17 inches, is an ashy-gray, friable silt loam. The A_3 horizon, 17 to 21 inches, is an orange-mottled, ashy-gray, slightly compacted silt loam. The B_1 horizon, 21 to 26 inches, is an orange-mottled, gray, plastic, impervious tight clay. The B_2 horizon, 26 to 31 inches, is a pale yellow mottled, very compact, plastic clay with numerous iron concretions. The C horizon, below 31 inches, is a pale yellow or gray, mottled, silty clay loam with iron concretions, and a columnar structure for the first 8 or 10 inches. This horizon is more friable than either the B_1 or B_2 horizon but is not so friable as the C horizon of the two types previously described.

Management.—This type requires the same management as Gray Silt Loam On Tight Clay. It has good surface drainage and is a somewhat better soil than Gray Silt Loam On Tight Clay.

Yellowish Gray Silt Loam On Orange-Mottled Tight Clay occurs on the rolling land. The areas of this type are rather small but are scattered thruout the county. The loess-like surface covering is shallow, seldom more than 18 inches deep, the material below this being rather sandy. On account of the rolling topography, a profile was developed under fair to good surface drainage conditions. This rolling topography is due to the presence of preglacial knolls which were not smoothed off by the glacier, and to an uneven deposit of glacial drift. Most of these areas have had a light forest growth on them at some time.

The A_1 horizon, 0 to 6 inches, is a brownish yellow to brownish gray, friable silt loam with laminated structure. The A_2 horizon, 6 to 12 inches, is a yellowish gray, mealy, friable silt loam. The A_3 horizon, 12 to 16 inches, is an orange-mottled, yellowish gray, slightly compacted, silty clay loam. The B_1 horizon, 16 to 22 inches, is an orange-mottled, yellowish gray, plastic, impervious tight clay. The B_2 horizon, 22 to 27 inches, is a yellow, mottled, plastic, very compact clay with iron concretions, and often is sandy and pebbly. The C horizon, below 27 inches, is a yellow, mottled, medium-friable, silty clay loam, containing heavy iron concretions, sand, and small pebbles.

Management.—This type is medium to strongly acid in the surface soil and strongly acid in the subsoil. It is good orchard land and is also well adapted for small fruit and vegetable growing. Sufficient limestone should be applied to grow sweet clover if orchard is to be set; and if vegetables are to be grown, the same procedure should be followed unless liberal applications of manure can be made, tho an excess of limestone should be avoided.

This soil may be used for the general farm crops, and if so used, should be given the same management as recommended for Deep Gray Silt Loam On Tight Clay, page 14.

Gray Silt Loam On Reddish Brown Clay occurs on low knolls and slopes where drainage has been very good. This type is not extensive. The sandy, pebbly till is rather close to the surface; in fact, the loess-like covering is seldom more than 10 inches thick. Sheet erosion probably has removed some of the surface material from these areas.

The A_1 horizon, 0 to 9 inches, is a brownish gray, friable silt loam. The B_1 horizon, 9 to 17 inches, is a reddish brown, very compact, somewhat impervious, plastic clay. The C horizon, below 17 inches, is a brown or drabbish yellow, mottled, sandy or silty clay loam, containing iron concretions and small pebbles.

Management.—The very limited extent of this type makes its management of concern only to a few individuals. Anyone who recognizes the type as occurring on his farm is asked to write to the Experiment Station for information regarding it.

Brown-Gray Silt Loam On Tight Clay (328)

The total area of Brown-Gray Silt Loam On Tight Clay as mapped in this county is less than one square mile. It is all confined to the south-central part of the county. The topography of this type is undulating, and the drainage is poor. It differs from Deep Gray Silt Loam On Tight Clay, described above, only in that it has a slightly deeper and darker colored A horizon. The description and management of Deep Gray Silt Loam On Tight Clay (page 14) apply also to this type.

Drab Silt Loam (329)

Drab Silt Loam is not extensive, and is confined principally to three areas in the northeastern part of the county. This type occurs in low flat places which originally were very poorly drained and swampy. The areas have received a deposit of silt, varying in thickness from several inches to more than a foot, which was brought down by sheet erosion from the surrounding slopes. The drainage of this type can be improved by artificial methods, such as deep surface ditching and tiling. This type closely resembles Deep Gray Silt Loam On Tight Clay described above.

The A_1 horizon, 0 to 11 inches, is a dark gray, laminated, friable silt loam. The A_2 horizon, 11 to 26 inches, is a drabbish gray, friable silt loam, containing yellow iron concretions. The B horizon, which is variable and often deeper than 26 to 38 inches, is a yellow, mottled, drabbish gray, compact, medium-plastic clay, containing numerous iron concretions. The C horizon, below 38 inches, is a pale yellow, mottled, more friable silty clay loam, containing iron concretions.

Management.—The reader is referred to the discussion of the management of Deep Gray Silt Loam On Tight Clay, page 14, for suggestions regarding the management of Drab Silt Loam.

(b) UPLAND TIMBER SOILS

The upland timber soils of Marion county occupy 256.72 square miles, about the same area as that of the upland prairie soils. Timber appears first near the stream channels where the soil is well drained, and gradually spreads out over the prairies as the drainage lines are extended. The soil map of this county shows clearly how the timber has spread from the main drainage outlets. It also shows that in the well-drained rolling land, the timber has spread farther away from the main drainage channels, than in the flat, poorly drained areas. Much of the original timber of this county has been cut off, and the areas cultivated, but the soil still retains the effects left by the long-continued forest growth.

Timber soils are characterized by a yellowish or yellowish gray color, which is due in part to the low organic-matter content. In forests the vegetable material from trees accumulates upon the surface, and is either burned or suffers almost complete decay by being exposed to the air. Grasses, with their abundant amounts of humus-forming roots, grow but sparsely because of the shade. Moreover, the organic matter that had accumulated before the timber began growing is dissipated thru various decomposition processes, with the result that the nitrogen and organic-matter contents of the soil are low.

Japanese clover, or lespedeza, a legume which will grow in a strongly acid soil, has spread over the timber soil of this region. It affords some pasture but is particularly beneficial in retarding erosion on cleared areas by checking run-off.

Yellow-Gray Silt Loam (334)

Yellow-Gray Silt Loam occurs principally in the outer timber belts along streams and is by far the most extensive timbered soil type in the county. It covers an area of 199.73 square miles, more than one-third of the entire area of the county. The same situation exists with reference to this type, as it is shown on the soil map, as was described above in the case of Gray Silt Loam On Tight Clay. Yellow-Gray Silt Loam, as it was mapped in Marion county, is now recognized as including two types as follows: *Yellow-Gray Silt Loam On Tight Clay,* which occurs on flat, poorly drained areas, and *Yellow-Gray Silt Loam On Compact Medium-Plastic Clay,* which occurs on areas having fairly good surface drainage. This distinction is not shown on the soil map, but the types will be described separately, since they differ materially in character and in agricultural value.

Yellow-Gray Silt Loam On Tight Clay occurs thruout the county and includes more than half of the timbered soil. The surface material is loess-like. Sandy, pebbly, glacial drift is encountered at depths varying from 15 to 60 inches. This type was developed under poor drainage, and on flat to undulating topography, corresponding to the conditions under which the prairie type, Gray Silt Loam On Tight Clay, was developed. Both the surface drainage and underdrainage of this type are poor. Slick spots, as described in the above-mentioned corresponding prairie type, are found also in this type, but probably are not so numerous.

Cultivation of the virgin timber soil has produced several changes in the soil profile. Plowing, by turning up and mixing in some of the very light-colored A_2 horizon, has tended to increase the depth of the surface or A_1 horizon, as well as to lighten its color. Indications are that the depth and plasticity of the upper subsoil or B horizon are increased by continued cultivation. This would be expected, as frequent stirring of the soil should accentuate the physical movement of smaller particles downward with the drainage water.

The A_1 horizon, 0 to 5 inches, is a yellowish gray, laminated, friable silt loam. The A_2 horizon, 5 to 17 inches, is a very light yellowish gray, friable, ashy silt loam, with occasionally some black iron concretions. This horizon has a laminated structure in its upper 3 or 4 inches. The B horizon, 17 to 32 inches, is a pale yellow, mottled, plastic tight clay with iron concretions. The C_1 horizon 32 to 40 inches, is a pale yellow, mottled, compact silt loam, with distinct columnar structure. The C_2 horizon is a friable silt loam containing iron concretions.

Management.—Yellow-Gray Silt Loam On Tight Clay is acid and very low in nitrogen and organic matter. The yellowish color indicates somewhat better drainage than occurs on Gray Silt Loam On Tight Clay. Underdrainage is not successful, however, because of the impervious nature of the subsoil. The reader is referred to the discussion of Gray Silt Loam On Tight Clay, page 15, for suggestions regarding the management of this type.

Yellow-Gray Silt Loam On Compact Medium-Plastic Clay is of limited occurrence in Marion county because of the flat topography which prevails. It is found, however, in narrow belts just back of the steep, eroded land along the banks of stream channels, and following out small drainage lines. It is also found on some of the timbered glacial and preglacial knolls and ridges. The surface material is all loess-like; but sandy, pebbly, glacial drift lies from 15 to 60 inches below the surface. This type was developed under fairly good drainage conditions, on undulating to gently rolling topography.

The A_1 horizon, 0 to 7 inches, is a brownish or yellowish gray, friable, silt loam, with laminated structure. The A_2 horizon, 7 to 17 inches, is a yellowish gray, friable silt loam. The B horizon, 17 to 31 inches, is a slightly reddish or brownish yellow, mottled, compact, medium-plastic clay containing some iron concretions. The C horizon, below 31 inches, is a yellow, mottled, slightly compacted, clayey silt loam, with columnar structure for the first few inches. This horizon is friable below about 36 inches. Iron concretions, some sand, and few pebbles are found.

Management.—Yellow-Gray Silt Loam On Compact Medium-Plastic Clay is the best timber soil in Marion county. It has good surface drainage, and underdrainage probably can be successfully used. The soil is acid and in need of nitrogen and organic matter; however, it responds well to good farming; and following the use of limestone and sweet clover, good crops can be produced except in years which are climatically very unfavorable. The same suggestions regarding fertilizer treatment which were made for Gray Silt Loam On Tight Clay, page 15, apply to this type.

Yellow Silt Loam (335)

Yellow Silt Loam forms the inner timber belt along streams. It comprizes the hilly land, most of which is badly washed and all of which is subject to erosion. Fortunately the extent of this type in the county is not large. It is confined principally to Skillet Fork creek and its tributaries. Very little, if any, of this type should be cultivated. Its chief use should be for permanent pasture. Orcharding might be practiced on the more gentle slopes. A large part of the area could be profitably utilized for the regrowth of forests; in fact, all of the timber never should have been cut off. Small outcroppings of shale and sandstone rock occur on some of the steeper slopes.

Glacial till, a sandy, pebbly clay mass, is the chief material forming this type. It seldom shows any profile development because of the rapid removal of soil material by erosion. The slopes are steep, the topography is rough, and both the surface and underdrainage are good.

Management.—A very small percentage of this type is at present used for cultivated crops. It affords a little pasture, but, in the main, yields small returns. It is badly gullied and, in view of the fact that there is a large acreage of better land in the county which is not fully utilized, present conditions do not appear to warrant the expenditure of much money in its development. Some of the better areas are well adapted to orcharding but most of the type should be returned to forest.

Light Gray Silt Loam On Tight Clay (332)

Light Gray Silt Loam On Tight Clay occupies the very flat, exceptionally poorly drained areas. It is associated with Yellow-Gray Silt Loam On Tight Clay. It covers a total area of 15.67 square miles, and occurs in small areas scattered thruout the county. Its topography is very flat, and both the surface and underdrainage are very poor. During wet weather the surface soil is soft, while in dry weather it bakes and becomes very hard. These areas are spoken of as "post oak flats" or "hickory flats," because of the kind of timber which grows on them. Black iron pellets, known as "buckshot," are found on the surface.

The A_1 horizon, 0 to 4 inches, is a light yellowish gray, friable silt loam, laminated in structure and containing black iron concretions. The A_2 horizon, 4 to 16 inches, is a light gray to white, ashy silt loam. It is laminated in the upper 6 or 8 inches, and contains iron concretions. The B horizon, 16 to 35 inches, is a pale yellow, mottled, very plastic, impervious tight clay containing iron concretions. The C horizon, below 35 inches, is a pale yellow, mottled, compact silty clay loam. It contains yellow iron concretions, and has a distinct columnar structure in the upper 8 or 10 inches. Below about 35 inches, it becomes a yellow, mottled, friable silt loam. Some sand and small pebbles occur in the B and C horizons, and occasionally the compact gravelly drift is found at 36 inches. Slick spots, as described under the type Gray Silt Loam On Tight Clay, occur in this type. Cultivation of this type has produced changes in the profile such as those described under the type Yellow-Gray Silt Loam On Tight Clay.

Management.—This soil is strongly acid, very low in organic matter, and will not produce the grain crops except in the most favorable seasons. The flat topography of the type makes surface drainage difficult, and underdrainage cannot be used because of the impervious character of the subsoil. Apples do well on this soil.

(c) RIDGE SOILS

The remnants of preglacial topography, left in the form of knolls and ridges, and the accumulations of drift left by the glacier at times when its recession was interrupted, have been mapped as Ridge Soils. These higher areas vary in extent from ten to several hundred acres, and in height from 10 to 80 feet. They vary in topography from gently rolling to fairly steep, and in drainage from fair to exceptionally good. Compact pebbly drift is usually found within 40 inches of the surface, and on the preglacial knolls the depth to bed rock is seldom over 6 feet.

Gray-Red Silt Loam On Tight Clay (233)

Gray-Red Silt Loam On Tight Clay is now recognized as including two types, the characters of which have been developed under different conditions of topography and drainage. The undulating to gently rolling, fairly well-drained areas are now called *Gray Silt Loam On Orange-Mottled Tight Clay.* The rolling, well-drained areas are termed *Yellowish Gray Silt Loam On Orange-Mottled Tight Clay.* Both of these types have been described above, and the reader is referred to the descriptions and management suggestions on page 16.

Yellow-Gray Silt Loam (234)

Yellow-Gray Silt Loam, Ridge, comprizes the timbered knolls and ridges which rise from 30 to 80 feet above the surrounding country. This type is now recognized as including three types as follows: *Yellow-Gray Silt Loam On Compact Medium-Plastic Clay, Reddish Yellow-Gray Silt Loam,* and *Reddish Yellow Silt Loam.*

Yellow-Gray Silt Loam On Compact Medium-Plastic Clay occupies the undulating to gently rolling, fairly well-drained areas. This type includes most of the Yellow-Gray Silt Loam (234) as mapped. The reader is referred to the description of the upland timber type, Yellow-Gray Silt Loam On Medium-Plastic Clay, and the discussion of its management on page 19.

Reddish Yellow-Gray Silt Loam occurs only on the higher ridges in the southern part of the county and is limited in extent. It occupies steep and exceptionally well-drained areas. The surface covering is loess-like, containing more fine sand than is usual for a silt loam, and the pebbly drift is found at about 24 inches in depth. The topography is rolling and the drainage is very good.

The A_1 horizon, 0 to 8 inches, is a brownish or reddish yellow, friable silt loam with laminated structure. The A_2 horizon, 8 to 15 inches, is a grayish yellow, friable silt loam. The B horizon, 15 to 23 inches, is a reddish yellow, slightly mottled compact silty clay loam. The C horizon, below 23 inches, is a yellow, mottled, friable, sandy and gravelly silt loam.

Management.—Reddish Yellow-Gray Silt Loam is medium acid, and is low in organic matter. It is an excellent peach soil and will produce good general farm crops after the acidity has been corrected with limestone, and the nitrogen and organic-matter deficiencies have been taken care of, preferably by the growth of sweet clover.

Reddish Yellow Silt Loam occurs only on two or three of the highest ridges in the southern part of the county. The surface covering is probably all decomposed drift, but the sandy, pebbly drift lies from 10 to 15 inches below the surface. The topography of this type is steep, and the drainage exceptionally good. Much of the surface soil is lost by gullying and sheet washing when this type of soil is cultivated.

The A_1 horizon, 0 to 10 inches, is a distinctly reddish yellow, friable silt loam. The B horizon, 10 to 21 inches, is a reddish yellow, very slightly mottled, slightly compacted silt loam, containing some sand and pebbles. The C horizon, below 21 inches, is a fairly friable, yellow, mottled, sandy, pebbly silt loam.

Management.—Reddish Yellow Silt Loam, because of its steep topography, should be used for orchard or pasture. It is an excellent orchard soil and when planted in trees can be handled in such a way as to prevent erosion.

(d) RESIDUAL SOILS

The areas mapped as residual soil include rock outcrops which are of little, if any, agricultural importance. They are found in gullies and in other places where erosion has removed the glacial drift. The outcroppings are chiefly sandstone and shale, but occasionally a thin ledge of limestone is exposed. These limestone ledges may be used as a local source for ground limestone by installing a portable crusher. They are too thin, however, to be of any general importance.

(e) OLD SWAMP AND BOTTOM-LAND SOILS

This group of soils includes the bottom lands along streams, the swamps, and the poorly drained lowlands. The soil is of alluvial formation and the land is subject to overflow. There are three types occurring in Marion county which are classed in this group.

Deep Gray Silt Loam (1331)

Deep Gray Silt Loam is the predominating bottom-land type in southern Illinois. It occupies 24.85 square miles in this county. The material forming this type is mainly a silt brought down from the surrounding hills, and deposited by slowly moving water during flood times. It has been kept under high moisture conditions thruout most of the year. The streams flowing thru these bottom lands are sluggish and meandering. The bottoms are flat and poorly drained. The soil is not of sufficient age to have any well-developed profile, as each overflow leaves some deposit on the surface.

The A_1 horizon, 7 to 10 inches, is a yellowish gray, friable silt loam with iron concretions. The A_2 horizon, below 10 inches, is a gray, slightly compacted, silt or silty clay loam, containing heavy iron concretions. In areas that are least disturbed by deposition from overflow, a compact subsoil has developed at depths varying from 18 to 22 inches. This compaction is rarely over 4 inches in thickness.

Management.—Deep Gray Silt Loam, Bottom, as it occurs in Marion county, is medium acid. About 80 percent of the type is cleared and somewhat over half of the total area is farmed. The drainage is poor, however, and this fact limits the productivity of this soil more than any other one factor. Corn is the chief crop grown. Tiling is effective on this land. On areas where the overflow and drainage can be taken care of, a very satisfactory level of productivity can easily be attained by the use of limestone and the introduction of clover as a regular crop in the rotation.

Mixed Loam (1354)

Mixed Loam is found in the small bottom lands at the heads of streams. It occupies 23.86 square miles. It overflows after each heavy rain and is continually receiving new deposits of material brought down from the adjoining upland. The soil material is mainly fine sand and silt. The areas have flat topography, and are fairly well drained. The soil shows no true profile development because of its youth. The material ranges from a yellowish gray fine sandy loam on the surface to a light yellowish gray or gray silt loam below 20 inches.

Management.—Mixed Loam, Bottom, is only slightly acid. It is subject to frequent overflow and for this reason will not become more acid with cultivation, as upland soils do. Practically the entire area of this type is farmed in corn.

Drab Clay Loam (1321)

Drab Clay Loam occupies only 51 acres, located along Crooked creek in Township 1 North, Range 1 East. Until recent years this area has been swampy. It differs from Deep Gray Silt Loam only in having more of a drabbish color and containing considerably more clay in the surface. Below 20 inches it is essentially the same as Deep Gray Silt Loam.

Management.—Drab Clay Loam, Bottom, is medium to strongly acid. It is used for corn growing and produces fairly good yields, tho not so good as those produced by Mixed Loam.

APPENDIX

EXPLANATIONS FOR INTERPRETING THE SOIL SURVEY

CLASSIFICATION OF SOILS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SOIL SURVEY METHODS

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

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

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

A soil auger is carried by each man with which he can examine the soil to a depth of 40 inches. An extension for making the auger 80 inches long is taken by each party, so that the deeper subsoil may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by a speedometer or other measuring device, while distances in the field away from the roads are measured by pacing.

Sampling for Analysis.—After all the soil types of a county have been located and mapped, samples representative of the different types are collected for chemical analysis. The samples for this purpose are usually taken in three depths; namely, 0 to 6⅔ inches, 6⅔ to 20 inches, and 20 to 40 inches, as explained in connection with the discussion of the analytical data on page 7.

PRINCIPLES OF SOIL FERTILITY

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

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

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

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

Produce		Nitrogen	Phosphorus	Sulfur	Potassium	Magnesium	Calcium	Iron
Kind	Amount							
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain.	1 bu.	1.42	.24	.10	.26	.08	.02	.01
Wheat straw..	1 ton	10.00	1.60	2.80	18.00	1.60	3.80	.60
Corn, grain...	1 bu.	1.00	.17	.08	.19	.07	.01	.01
Corn stover...	1 ton	16.00	2.00	2.42	17.33	3.33	7.00	1.60
Corn cobs....	1 ton	4.00	.....	.....	4.00	.....	.....	.....
Oats, grain...	1 bu.	.66	.11	.06	.16	.04	.02	.01
Oats 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.

CROP REQUIREMENTS WITH RESPECT TO PLANT-FOOD MATERIALS

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

Table 5 shows the requirements of some of our most common field crops with respect to seven important plant-food elements furnished by the soil. The figures show the weight in pounds of the various elements contained in a bushel or in a ton, as the case may be. From these data the amount of an element removed from an acre of land by a crop of a given yield can easily be computed.

PLANT-FOOD SUPPLY

Of the elements of plant food, three (carbon, oxygen, and hydrogen) are secured from air and water, and the others from the soil. Nitrogen, one of the elements obtained from the soil by all plants, may also be secured from the air by the class of plants known as legumes, in case the amount liberated from the

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

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

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

soil is insufficient; but even these plants, which include only the clovers, peas, beans, and vetches among our common agricultural plants, are dependent upon the soil for the other six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and they also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

The vast difference with respect to the supply of these essential plant-food elements in different soils is well brought out in the data of the Illinois soil survey. For example, it has been found that the nitrogen in the surface 6⅔ inches, which represents the plowed stratum, varies in amount from 180 pounds per acre to more than 35,000 pounds. In like manner the phosphorus content varies from about 420 to 4,900 pounds, and the potassium ranges from 1,530 to about 58,000 pounds. Similar variations are found in all of the other essential plant-food elements of the soil.

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

LIBERATION OF PLANT FOOD

The chemical analysis of the soil gives the invoice of plant-food elements actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are the choice of crops to be grown, the use of limestone, and the incorporation of organic matter. Tillage, especially plowing, also has a considerable effect in this connection.

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

Effect of Limestone.—Limestone corrects the acidity of the soil and supplies calcium, thus encouraging the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the unavailable organic nitrogen into available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium compounds.

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

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

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

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

PERMANENT SOIL IMPROVEMENT

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

The Application of Limestone

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

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

The Potassium Thiocyanate Test for Acidity. This test is made with a 4-percent solution of potassium thiocyanate in alcohol—4 grams of potassium thiocyanate in 100 cubic centimeters of 95-percent alcohol.[1] When a small quantity of soil shaken up in a test tube with this solution gives a red color the soil is acid and limestone should be applied. If the solution remains colorless the soil is not acid. An excess of water interferes with the reaction. The sample when tested, therefore, should be at least as dry as when the soil is in good tillable condition. For a prompt reaction the temperature of the soil and solution should be not lower than that of comfortable working conditions (60° to 75° Fahrenheit).

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

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

Fineness of Material.—The fineness to which limestone is ground is an important consideration in its use for soil improvement. Experiments indicate that a considerable range in this regard is permissible. Very fine grinding insures ready solubility, and thus promptness in action; but the finer the grinding the

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

greater is the expense involved. A grinding, therefore, that furnishes not too large a proportion of coarser particles along with the finer, similar to that of the by-product material on the market, is to be recommended. Altho the exact proportions of coarse and fine material cannot be prescribed, it may be said that a limestone crushed so that the coarsest fragments will pass thru a screen of 4 to 10 meshes to the inch is satisfactory if the total product is used.

The Nitrogen Problem

Nitrogen presents the greatest practical soil problem in American agriculture. Four important reasons for this are: its increasing deficiency in most soils; its cost when purchased on the open market; its removal in large amounts by crops; and its loss from soils thru leaching. Nitrogen usually costs from four to five times as much per pound as phosphorus. A 100-bushel crop of corn requires 150 pounds of nitrogen for its growth, but only 23 pounds of phosphorus. The loss of nitrogen from soils may vary from a few pounds to over one hundred pounds per acre, depending upon the treatment of the soil, the distribution of rainfall, and the protection afforded by growing crops.

An inexhaustible supply of nitrogen is present in the air. Above each acre of the earth's surface there are about sixty-nine million pounds of atmospheric nitrogen. The nitrogen above one square mile weighs twenty million tons, an amount sufficient to supply the entire world for four or five decades. This large supply of nitrogen in the air is the one to which the world must eventually turn.

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

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

It may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy contains 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpea hay contains 43 pounds of nitrogen.
1 ton of alfalfa contains 50 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.
1 ton of young sweet clover, at about the stage of growth when it is plowed under as green manure, contains, on water-free basis, 80 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops. Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks.

The Phosphorus Problem

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

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

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

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

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

Acid phosphate is produced by treating rock phosphate with sulfuric acid. The two are mixed in about equal amounts; the product therefore contains about one-half as much phosphorus as the rock phosphate itself. Besides phosphorus, acid phosphate also contains sulfur, which is likewise an element of plant food. The phosphorus in acid phosphate is more readily available for absorption by plants than that of raw rock phosphate. Acid phosphate of good quality should contain 6 percent or more of the element phosphorus.

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

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

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

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

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

The Potassium Problem

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

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

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

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

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

The Calcium and Magnesium Problem

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

The annual loss of limestone from the soil depends, of course, upon a number of factors aside from those which have to do with climatic conditions.

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

Limestone has a direct value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of Illinois) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

The Sulfur Question

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

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

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

Physical Improvement of Soils

In the management of most soil types, one very important matter, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Organic matter in producing good tilth helps to control washing of soil on rolling land, raises the temperature of drained soil, increases the moisture-holding capacity of the soil, slightly retards capillary rise and consequently loss of moisture by surface evaporation, and helps to overcome the tendency of some soils to run together badly.

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

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

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

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

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

Systems of Crop Rotations

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

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

Six-Year Rotations

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

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the unsalable products should be returned to the soil, and the clover may be clipped and left on the land or returned after threshing out the seed (only the clover seed being sold the fourth and sixth years); or, in livestock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years, as indicated below.

Five-Year Rotations

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

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

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

The last rotation mentioned above allows legumes to be grown four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

Four-Year Rotations

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

Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Three-Year Rotations

First year —Corn	*First year* —Wheat or oats (with clover)
Second year —Oats or wheat (with clover)	*Second year* —Corn
Third year —Clover	*Third year* —Cowpeas or soybeans

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

Two-Year Rotations

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

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

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

SUPPLEMENT: EXPERIMENT FIELD DATA

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

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

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

Size and Arrangement of Fields

The soil experiment fields vary in size from less than two acres up to 40 acres or more. They are laid off into series of plots, the plots commonly being either one-fifth or one-tenth acre in area. Each series is occupied by one kind of crop. Usually there are several series so that a crop rotation can be carried on with every crop represented every year.

Farming Systems

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

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

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

Crop Rotations

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

Soil Treatment

The treatment applied to the plots has, for the most part, been standardized according to a rather definite system, altho deviations from this system occur now and then, particularly in the older fields.

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

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

Plant Manures.—Crop residues produced on the land, such as stalks, straw, and chaff, are returned to the soil, and in addition a green-manure crop of sweet clover is seeded in small 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.—The yearly acre-rates of application have been: for limestone, 1,000 pounds after the first rotation, for which 4 tons was applied; for raw rock phosphate, 500 pounds; and for potassium, usually 200 pounds of kainit. When kainit was not available, owing to conditions brought on by the World war, potassium carbonate was used. The initial application of limestone has usually been 4 tons an acre.

Explanation of Symbols Used

0 = Untreated land or check plots
M = Manure (animal)
R = Residues (from crops, and includes legumes used as green manure)
L = Limestone
P = Phosphorus, in the form of rock phosphate unless otherwise designated (aP = acid phosphate, bP = bone meal, rP = rock phosphate, sP = slag phosphate)
K = Potassium (usually in the form of kainit)
N = Nitrogen (usually in the form contained in dried blood)
Le = Legume used as green manure
Cv = Cover crop
( ) = Parentheses enclosing figures, signifying tons of hay as distinguished from bushels of seed
| = Heavy vertical rule, indicating the beginning of complete treatment
|| = Double vertical rule, indicating a radical change in the cropping system

In discussions of this sort of data, financial profits or losses based upon assigned market values are frequently considered. However, in view of the erratic fluctuations in market values—especially in the past few years—it seems futile to attempt to set any prices for this purpose that are at all satisfactory. The yields are therefore presented with the thought that with these figures at hand the financial returns from a given practice can readily be computed upon the basis of any set of market values that the reader may choose to apply.

THE ODIN FIELD

The Odin soil experiment field, located in Marion county about one mile southwest of Odin, is one of the oldest of the outlying University experiment fields. It was established in 1902.

The field consists of 20 acres of light-colored upland soil, mainly of the type Gray Silt Loam On Tight Clay, which is one of the prevailing prairie types of a large region in southern Illinois. A detailed examination reveals the presence of a small area in the north corner of the field of a type having a somewhat different subsoil from that of the main body of the field and designated as Gray Silt Loam On Plastic Reddish Brown Clay. There is also present near the west corner of the field a very small spot of Yellow-Gray Silt Loam, but this lies almost wholly on the border between plots, and therefore should not materially affect the experimental work. The location of these soil types, as well as the arrangement of plots, is charted on the diagram shown on the following page. The topography, or lay of the land, is indicated on this map by contour lines.

The field at present is laid out into four separate systems of plots, each system with its own plan of experimentation. An account, including complete records, of each of these plot-systems follows.

Series 100, 200, 300, 400

These series are divided into two sections differing from each other with respect to underdrainage. Plots numbering from 6 to 10 inclusive are provided with a system of tile, while the corresponding plots numbering 1 to 5 inclusive are not tiled. During the period from 1907 to 1919 the northeast half of each plot was subjected to subsoil plowing in preparing the land for corn.

The rotation chiefly practiced on Series 100, 200, 300, and 400 has been corn, legumes (cowpeas or soybeans), wheat, and clover. Until 1922 the clover was alsike, soybeans being substituted if the clover failed. Since that time sweet clover has been used instead of alsike. A part of the time cowpeas were seeded in the corn, at the last cultivation.

Crop residues and cover crops have been regularly plowed down on the residue plots. The return of the wheat straw was discontinued in 1922.

In 1902 slaked lime, at the acre rate of 475 pounds, was applied to the limed plots, and in 1903 an additional 2 tons was applied to these plots. No more lime was added until 1908, after which it was applied regularly at the annual rate of 500 pounds of limestone an acre to the northwest halves and 1,000 pounds an acre to the southeast halves of these plots. In 1922 these applications were temporarily discontinued until further need for lime appears.

Phosphorus has been used in the form of steamed bone meal, which was applied at the rate of 200 pounds an acre a year until 1923, when the total amount of the bone meal was evened up on all the phosphorus plots to 4,800 pounds an acre and the application temporarily discontinued. Potassium was applied at the annual rate of 100 pounds an acre of potassium sulfate until 1923. At that time the total amount applied was evened up to 2,500 pounds and plans made to continue the application on the southwest halves of the plots at the normal rate.

Table 7 is presented as a record of the crop yields on these series since the beginning of the experiments. Table 8 summarizes the yields, by crops, for the period during which the plots have been under their full fertilizer treatment. The lower section of this table gives a more condensed summary in terms of crop

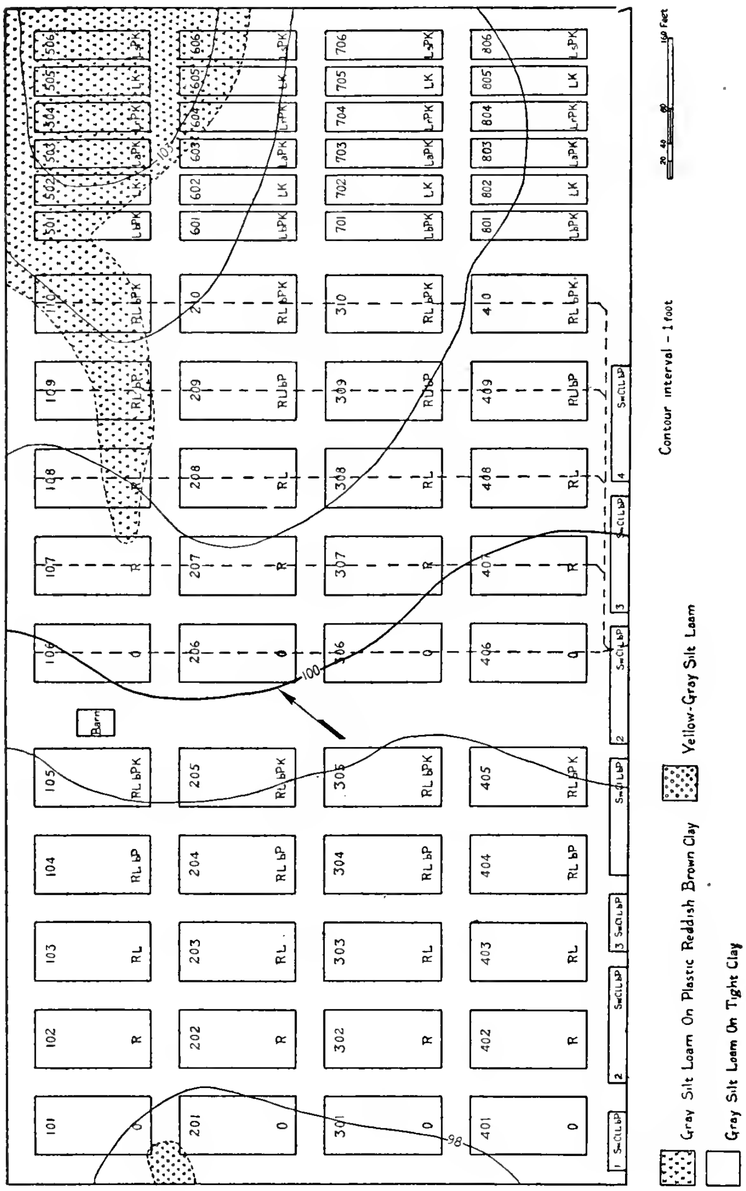

FIG. 2.—DIAGRAM OF THE ODIN EXPERIMENT FIELD

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

TABLE 7.—ODIN FIELD: SERIES 100, 200, 300, 400

Annual Crop Yields—Bushels or (tons) per acre

(1902–1914)

Plot No.	Soil treatment applied	1902 Corn[1]	1903 Oats[1]	1904 Wheat	1905 Cowpeas[2]	1906 Corn	1907 Cowpeas	1908 Wheat	1909 Cowpeas	1910 Corn	1911 Soybeans	1912 Wheat[3]	1913 Clover[2]	1914 Corn
	Land Not Tile-drained													
101	0	12.1	6.9	7.9	....	31.6	(.90)	17.3	(.65)	25.3	7.4	....	....	4.0
102	R	7.2	5.2	5.4	....	28.6	(.95)	14.4	(.67)	28.8	8.3	....	....	2.9
103	RL	8.8	6.2	10.7	....	28.5	(1.00)	18.5	(1.11)	38.0	10.1	....	....	1.8
104	RLbP	4.9	8.6	21.6	....	30.8	(1.08)	26.6	(1.30)	36.6	6.9	....	....	2.3
105	RLbPK	14.4	25.8	24.4	....	35.3	(1.80)	32.6	(1.52)	81.0	13.7	....	....	3.9
	Land Tile-drained													
106	0	11.5	8.1	6.7	....	31.7	(.76)	16.3	(.67)	26.1	8.1	....	....	4.3
107	R	13.5	8.8	8.5	....	40.1	(1.00)	21.2	(.95)	38.9	8.8	....	....	4.8
108	RL	9.7	7.2	9.6	....	34.5	(.98)	22.1	(1.02)	39.9	7.2	....	....	2.8
109	RLbP	9.5	12.3	21.5	....	33.7	(1.01)	28.9	(1.61)	42.0	7.2	....	....	2.0
110	RLbPK	20.7	28.9	25.4	....	43.9	(1.32)	34.8	(1.99)	84.5	12.6	....	....	4.1

(1915–1925)

Plot No.	Soil treatment applied	1915 Soybeans	1916 Wheat	1917 Clover[2]	1918 Corn	1919 Soybeans[4]	1920 Wheat	1920 Stubble clover	1921 Sweet clover	1922 Corn	1923 Soybeans	1924 Wheat	1925 Sweet clover	
	Land Not Tile-drained													
101	0	5.3	1.2	....	4.4	....	4.8	(0.00)	0.00	17.2	18.4	1.3	.44	....
102	R	4.7	3.7	....	6.2	....	8.8	(0.00)	.17	21.2	18.4	1.5	.24	....
103	RL	15.7	9.8	....	9.0	....	21.4	(.90)	2.00	27.5	20.7	6.8	1.44	....
104	RLbP	16.7	15.8	....	10.0	....	26.2	(.86)	1.83	27.8	18.8	12.5	.93	....
105	RLbPK	16.6	24.0	....	17.7	....	22.5	(1.79)	2.67	35.2	23.8	20.4	2.28	....
	Land Tile-drained													
106	0	10.2	.2	....	5.8	....	2.3	(0.00)	0.00	18.8	15.4	.7	0.00	....
107	R	8.2	5.4	....	7.5	....	10.4	(0.00)	.58	24.3	18.9	1.8	.44	....
108	RL	24.4	9.2	....	13.9	....	21.3	(1.19)	1.75	26.5	22.5	5.1	2.53	....
109	RLbP	15.3	17.1	....	15.6	....	26.3	(1.13)	3.33	25.5	24.3	7.5	2.24	....
110	RLbPK	10.1	21.6	....	21.8	....	22.4	(1.57)	4.25	38.4	27.0	10.7	2.38	....

[1]No residues. [2]Removed from Plots 1 and 6 and plowed under on others. [3]Crop failure. [4]Grasshoppers destroyed the crop.

TABLE 7.—ODIN FIELD, *Continued*

Bushels or (tons) per acre

(1902–1914)

Plot No.	Soil treatment applied	1902 Oats[1]	1903 Wheat	1904 Cowpeas[2]	1905 Corn	1906 Cowpeas	1907 Wheat	1908 Cowpeas	1909 Corn	1910 Soybeans	1911 Wheat	1912 Soybeans	1913 Corn	1914 Soybeans
	Land Not Tile-drained													
201	0	15.8	.4	....	36.1	(.93)	14.2	1.7	27.9	8.3	5.3	11.7	3.7	4.4
202	R	16.1	.6	....	46.7	(1.08)	15.1	2.9	31.3	9.8	5.8	17.1	5.4	4.9
203	RL	14.1	.7	....	59.9	(.93)	18.6	2.5	27.3	5.3	15.0	20.4	4.2	5.0
204	RLbP	16.7	5.8	....	57.7	(1.25)	26.8	2.3	35.2	8.8	16.6	21.5	4.3	5.2
205	RLbPK	18.8	14.0	....	79.5	(2.47)	29.8	4.6	69.1	11.7	19.2	27.9	11.7	6.7
	Land Tile-drained													
206	0	12.2	.6	....	42.6	(.83)	14.3	1.4	25.5	6.6	4.9	5.6	2.0	3.6
207	R	10.3	.6	....	37.4	(1.03)	16.9	2.3	26.3	6.8	6.7	6.1	2.1	3.8
208	RL	11.7	2.1	....	57.9	(1.30)	21.1	2.7	30.4	9.6	9.4	12.4	4.0	7.8
209	RLbP	19.2	13.4	....	65.8	(1.68)	29.5	1.8	41.3	8.7	19.5	16.7	9.7	8.7
210	RLbPK	17.7	15.2	....	71.6	(2.27)	31.8	3.9	55.3	14.3	23.2	23.1	8.6	7.6

(1915–1925)

Plot No.	Soil treatment applied	1915 Wheat	1916 Clover	1917 Corn	1918 Soybeans	1919 Wheat	1920 Clover	1921 Corn	1922 Soybeans	1923 Wheat	1924 Sweet clover	1925 Corn		
	Land Not Tile-drained													
201	0	11.9	.42	8.4	3.6	18.7	(0.00)	11.6	4.2	2.5	0.00	23.1	....	....
202	R	15.0	1.25	10.2	5.8	13.5	(0.00)	14.1	4.0	2.7	0.00	31.9	....	....
203	RL	16.0	1.67	7.5	7.4	26.7	(1.66)	10.4	6.6	6.3	1.17	26.6	....	....
204	RLbP	25.0	1.67	9.5	7.2	35.1	(1.86)	9.3	6.4	9.2	.67	24.8	....	....
205	RLbPK	29.7	1.83	33.7	5.8	37.2	(2.47)	25.0	10.3	21.4	1.42	43.7	....	....
	Land Tile-drained													
206	0	14.3	.92	10.4	5.0	14.2	(0.00)	7.3	3.8	1.3	0.00	16.2	....	....
207	R	14.3	1.50	14.1	5.4	20.1	(0.00)	6.9	4.0	1.4	.25	18.1	....	....
208	RL	25.9	3.08	15.5	7.8	33.5	(1.64)	9.7	8.3	7.8	1.92	28.2	....	....
209	RLbP	29.6	2.83	18.1	8.0	35.4	(1.61)	16.1	8.8	18.3	1.25	31.6	....	....
210	RLbPK	31.8	2.00	27.4	3.2	36.1	(1.98)	15.8	8.2	27.9	1.92	39.9	....	....

[1]No residues. [2]Removed from Plots 1 and 6 and plowed under on others.

TABLE 7.—ODIN FIELD, *Continued*

Bushels or (tons) per acre

(1902–1914)

Plot No.	Soil treatment applied	1902 Corn[1]	1903 Cowpeas[2]	1904 Corn	1905 Oats	1906 Wheat	1907 Cowpeas	1908 Corn	1909 Soybeans	1910 Wheat	1911 Soybeans	1912 Corn	1913 Soybeans	1914 Wheat
	Land Not Tile-drained													
301	0..................	19.5	....	53.1	23.0	12.1	(1.24)	39.3	7.4	11.7	11.3	30.3	3.0	5.0
302	R..................	10.7	....	48.8	19.4	13.7	(1.29)	31.4	9.2	7.8	11.7	27.8	2.9	2.7
303	RL.................	8.8	....	44.1	30.3	19.2	(.87)	33.0	5.0	26.3	6.9	44.2	2.4	14.9
304	RLbP..............	10.7	....	44.1	39.2	21.1	(.94)	43.0	5.2	32.4	9.5	46.6	3.1	15.4
305	RLbPK.............	14.5	....	66.6	31.9	29.2	(2.13)	66.4	2.8	34.1	14.0	63.0	3.8	17.9
	Land Tile-drained													
306	0..................	7.5	....	29.4	24.8	11.2	(1.24)	28.6	3.4	6.3	6.1	27.7	3.4	2.4
307	R..................	10.0	....	31.6	24.5	15.5	(1.34)	28.3	3.9	4.4	6.8	35.7	2.9	2.8
308	RL.................	10.0	....	42.8	22.0	20.7	(1.14)	37.5	3.0	19.6	5.8	51.9	5.0	19.0
309	RLbP..............	15.6	....	45.9	26.3	24.8	(.94)	42.6	1.4	31.3	7.0	55.9	4.6	20.0
310	RLbPK.............	16.3	....	64.1	31.1	31.5	(2.31)	70.0	4.5	29.2	12.7	50.9	5.7	20.8

(1915–1925)

Plot No.	Soil treatment applied	1915 Soybeans	1916 Corn	1917 Soybeans	1918 Wheat	1919 Soybeans[3]	1920 Corn	1921 Soybeans	1922 Wheat	1922 Stubble clover	1923 Sweet clover	1924 Corn	1925 Soybeans	
	Land Not Tile-drained													
301	0..................	3.9	15.8	3.1	5.2	....	25.1	8.3	13.1	(0.00)	0.00	6.3	(.96)	....
302	R..................	2.0	18.0	4.2	5.5	....	28.0	8.7	13.1	(0.00)	.17	15.3	(.98)	....
303	RL.................	7.6	22.8	5.7	20.8	....	32.5	11.1	25.9	(.85)	.17	48.0	(1.34)	....
304	RLbP..............	8.6	21.4	4.9	25.8	....	27.4	9.8	23.3	(.79)	.14	47.1	(1.19)	....
305	RLbPK.............	10.4	25.7	7.3	28.4	....	43.6	11.6	24.8	(.85)	.10	65.5	(1.52)	....
	Land Tile-drained													
306	0..................	4.3	10.0	4.4	1.0	....	18.7	7.0	5.3	(0.00)	0.00	5.5	(.74)	....
307	R..................	5.2	14.2	5.8	2.0	....	19.1	7.3	5.3	(0.00)	0.00	15.2	(.68)	....
308	RL.................	11.5	17.7	6.8	15.8	....	22.2	9.1	24.8	(.59)	.21	49.7	(1.09)	....
309	RLbP..............	10.3	18.0	6.9	23.1	....	20.9	9.2	25.8	(.63)	.20	46.2	(1.44)	....
310	RLbPK.............	10.7	33.2	8.5	29.0	....	37.7	12.3	24.5	(.80)	.14	59.4	(1.46)	....

[1]No residues. [2]Removed from Plots 1 and 6 and plowed down on others. [3]Grasshoppers destroyed crop.

TABLE 7.—ODIN FIELD, *Concluded*

Bushels or (tons) per acre
(1902–1914)

Plot No.	Soil treatment applied	1902[1] Cow-peas[2]	1903 Corn	1904 Oats	1905 Wheat	1906 Clover	1907 Corn	1908 Soybeans	1909 Wheat	1910 Cowpeas	1911 Corn	1912 Soybeans	1913 Wheat	1914 Soybeans
	Land Not Tile-drained													
401	0..................	(2.09)	17.9	28.6	15.2	(.22)	48.8	8.6	14.6	(.95)	21.2	13.9	18.5	7.8
402	R..................	....	16.6	36.7	16.6	(.28)	44.4	11.7	15.3	(.93)	23.5	17.8	16.7	8.0
403	RL.................	....	20.2	41.4	24.8	(.32)	45.3	14.0	20.3	(.66)	22.3	18.2	28.2	14.2
404	RLbP...............	....	18.3	39.8	36.5	(.34)	45.7	16.8	27.2	(.52)	21.2	13.7	35.0	12.3
405	RLbPK..............	....	22.3	39.7	35.8	(1.27)	67.1	19.3	31.8	(.96)	43.4	15.4	33.2	12.4
	Land Tile-drained													
406	0..................	(1.88)	8.7	25.1	10.8	(.37)	33.2	7.8	14.0	(.65)	8.9	8.8	16.2	5.9
407	R..................	....	12.8	33.4	18.7	(.36)	48.8	7.8	18.4	(.65)	15.4	11.4	24.2	9.4
408	RL.................	....	17.6	53.3	23.9	(.50)	49.3	11.8	19.4	(.46)	25.1	17.4	31.4	12.2
409	RLbP...............	....	15.9	44.8	35.3	(.63)	45.6	12.8	25.4	(.41)	21.5	18.7	36.9	9.8
410	RLbPK..............	....	15.0	43.1	28.4	(1.31)	62.3	13.0	27.8	(.99)	32.7	25.2	40.7	8.2

(1915–1925)

Plot No.	Soil treatment applied	1915 Corn	1916 Soybeans	1917 Wheat	1918 Clover[2]	1919 Corn	1920 Soybeans	1921 Wheat	1921 Stubble clover	1922 Sweet clover	1923 Corn	1924 Soybeans	1925 Wheat	
	Land Not Tile-drained													
401	0..................	43.7	6.0	20.1	....	.6	13.9	11.3	(0.00)	0.00	26.2	7.9	6.3	....
402	R..................	47.0	8.3	16.9	....	.9	15.1	8.3	(0.00)	0.00	19.5	9.3	10.7	....
403	RL.................	46.3	7.6	26.0	....	4.0	17.8	20.5	(.56)	3.79	20.3	12.1	26.1	....
404	RLbP...............	43.5	4.8	28.2	....	2.1	15.8	25.0	(.61)	2.50	13.6	7.7	27.1	....
405	RLbPK..............	58.2	5.8	27.8	....	1.9	24.4	26.9	(.94)	3.75	46.2	15.0	27.5	....
	Land Tile-drained													
406	0..................	23.4	5.6	11.0	....	.2	8.5	11.8	(0.00)	0.00	19.9	2.8	.8	....
407	R..................	36.7	7.1	21.6	....	.2	15.4	15.0	(0.00)	0.00	24.2	7.5	9.0	....
408	RL.................	45.3	5.8	19.7	....	1.7	14.8	22.2	(.22)	.83	9.7	10.4	21.6	....
409	RLbP...............	41.7	4.1	23.1	....	2.0	16.9	26.5	(.33)	.83	12.2	10.0	27.3	....
410	RLbPK..............	49.2	7.5	24.8	....	4.3	18.4	26.9	(.75)	2.04	40.4	17.9	23.7	....

[1]No residues. [2]Removed on Plots 1 and 6 and plowed under on others.

TABLE 8.—ODIN FIELD: SERIES 100, 200, 300, 400
Average Annual Yields 1903–1925—Bushels or (tons) per acre

Serial Plot No.	Soil treatment applied[1]	Corn	Soy-beans	Wheat	Alsike clover		Sweet clover	Stubble clover	Cowpeas	
					Hay	Seed			Hay	Seed
		22 crops	*19 crops*	*23 crops*	*2 crops*	*1 crop*	*3 crops*	*2 crops*	*8 crops*	*1 crop*
1	0..............	22.8	8.1	9.5	(.11)	.42	0.00	(0.00)	(.58)	1.7
2	R..............	23.5	9.3	9.3	(.14)	1.25	.06	(0.00)	(.62)	2.9
3	RL............	27.1	10.9	17.5	(.99)	1.67	1.71	(.70)	(.57)	2.5
4	RLP..........	27.1	10.3	22.5	(1.10)	1.67	1.10	(.70)	(.64)	2.3
5	RLPK.........	43.7	13.3	25.8	(1.87)	1.83	1.76	(.90)	(1.11)	4.6
6	0..............	17.7	6.4	7.2	(.19)	.92	0.00	(0.00)	(.52)	1.4
7	R..............	22.0	7.7	10.6	(.18)	1.50	.08	(0.00)	(.62)	2.3
8	RL............	27.5	10.8	17.6	(1.07)	3.08	.99	(.41)	(.61)	2.7
9	RLP..........	29.0	10.6	23.8	(1.12)	2.83	.76	(.48)	(.71)	1.8
10	RLPK.........	40.5	13.0	25.6	(1.65)	2.00	1.37	(.78)	(1.11)	3.9
	R over 0........	2.5	1.3	1.6	(.01)	.71	.07	(0.00)	(.07)	.1
	RL over R......	4.6	2.4	7.6	(.87)	1.00	1.28	(.56)	(−.03)	0.0
	RLP over RL...	.8	−.4	5.6	(.08)	−.13	−.42	(.04)	(.09)	−.6
	RLPK over RLP	14.1	2.7	2.7	(.65)	−.34	.59	(.25)	(.44)	2.3

[1]Plots 1 to 5 not tiled; Plots 6 to 10 tiled.

increases, indicating the effects of the different fertilizing materials as they were used in these experiments. The figures given are derived from the results of the corresponding tiled and untiled plots averaged together.

Organic manure is provided in these experiments by plowing under crop residues and legume crops used as green manure. The crop yields show little effect from residues alone. Residues with limestone, however, have produced, with a single exception, notable increases in yields. It is of interest to note that the one crop which does not show a beneficial effect from limestone is cowpeas, and the cowpea is generally known as a plant tolerant to soil acidity.

Regarding the phosphorus treatment on these series it will be observed that wheat shows a marked benefit from bone meal, but the other crops have responded

FIG. 3.—WHEAT ON THE ODIN FIELD IN 1920

At the left is a check plot, receiving no soil treatment, where the average yield of wheat for 23 crops has been 8.4 bushels an acre. At the right, thru the use of limestone and crop residues, this yield was doubled. By adding bonemeal to this treatment, another increase was produced, bringing the yield up to 23.2 bushels.

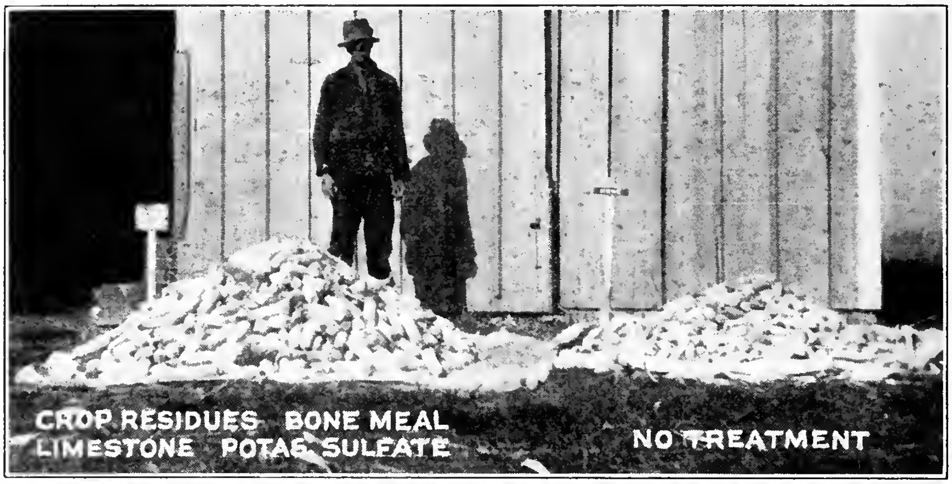

FIG. 4.—CORN YIELD DOUBLED BY SOIL TREATMENT ON THE ODIN FIELD IN 1923

The pile of corn at the right was produced on a plot receiving no soil treatment. The pile at the left was produced on a plot receiving crop residues, limestone, bonemeal, and potassium sulfate.

indifferently. With a single exception, the potassium treatment has been attended by some increase in yield, and in the case of the corn this increase is very pronounced.

So far as the effect of tiling is concerned, the average results show no consistent differences of consequence between the plots of the tiled section and those of the untiled section. It is probably on account of the impervious nature of the subsoil that the presence of the tile has had little effect on the drainage.

These results on the whole point to the necessity of using limestone with organic manures in improving this soil. The organic manure has been supplied in these experiments by crop residues and legumes, but on the farm, of course, all available stable manure should be utilized.

Experiments in Subsoiling

In order to learn whether something could be done to overcome the unfavorable subsoil condition in this kind of land, by subsoil plowing, an experiment was started in 1907 and continued for thirteen years. In this experiment one-half of each plot in both tiled and untiled sections was plowed and subsoiled, with a few exceptions, in the late fall. The effect on crop yields was measured only in the corn, this crop being harvested by half plots. The yields are given in Table 9, the figures representing the averages for corresponding tiled and untiled plots.

The general averages for the entire thirteen-year period show only insignificant differences in yield between subsoiled plots and plots not subsoiled. Indeed these differences are so small that they may be regarded as being within the experimental error, and the only conclusion warranted is that the expensive practice of subsoiling has produced no significant effect upon the yield of corn in this investigation.

For a more detailed account of this experiment in subsoiling, the reader is referred to Bulletin 258 of this Station.

TABLE 9.—ODIN FIELD: EXPERIMENTS IN SUBSOILING
Yields of Corn—Bushels per acre

Soil treatment	None		R		RL		RLP		RLPK	
Tillage treatment	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled	Not sub-soiled	Sub-soiled
1907[1]	44.4	37.6	50.1	43.2	47.3	47.3	47.0	44.4	70.1	59.4
1908[1]	35.5	32.5	33.2	26.4	35.5	34.9	39.9	45.9	76.1	60.3
1909	29.3	24.1	30.4	27.2	29.2	28.5	28.9	37.6	54.0	60.4
1910	28.9	22.5	32.8	35.1	40.3	37.5	38.7	39.9	79.9	85.7
1911	16.8	13.3	19.0	19.9	24.7	22.7	22.8	19.9	35.7	40.4
1912[2]	26.1	31.7	39.6	24.0	48.6	47.5	49.4	53.1	65.4	48.5
1913[1]	2.5	3.2	3.9	3.6	4.1	4.1	6.1	7.9	10.1	10.2
1914[1]	4.3	4.0	3.3	4.3	2.1	2.4	2.0	2.5	3.1	5.0
1915[1]	35.3	31.7	40.5	43.3	47.6	44.0	43.2	41.9	57.4	50.0
1916[1]	13.4	12.4	15.7	16.5	19.5	21.0	19.5	19.9	31.9	27.0
1917	9.3	9.5	14.1	10.3	11.2	11.8	13.8	13.8	30.9	30.2
1918[1]	4.2	6.0	7.4	6.3	11.5	11.3	12.8	12.7	19.8	19.7
1919	.5	.3	.7	.4	2.8	3.0	1.9	2.3	3.5	3.3
Average	19.9	17.7	22.3	20.0	24.7	24.3	25.0	26.3	41.3	38.4

[1]Replowed in spring. [2]Plowed and subsoiled in spring.

Comparative Phosphate Tests

The land included in the present Series 500, 600, 700, and 800 was originally plotted as one series of six long plots designated as Series 500 and used for the purpose of studying the relative value of various carriers of phosphorus applied in amounts equivalent to equal money values on limed and unlimed land.

A rotation of corn, oats, and three years of clover-timothy meadow was first established on this series. Cowpeas were seeded in the corn for use as residues. The phosphates were applied at the annual acre rate of 200 pounds of steamed bone meal, 333 pounds of acid phosphate, 666 pounds of rock phosphate, and 250 pounds of slag phosphate, amounts representing equivalent money value at the time these experiments were planned. The first application of lime was at the acre rate of 1½ tons to the southeast halves. Subsequent applications were at the annual acre rate of 1,000 pounds. Potassium at the annual acre rate of 100 pounds of potassium sulfate was applied to all plots. These applications were discontinued in 1913.

The annual yields from these plots are given in detail in Table 10, and the results are summarized by crops in Table 11. The lower part of Table 11 shows differences in crop yields presumed to have resulted from applying the various forms of phosphatic fertilizers for all the crops harvested from 1904 up to 1921, after which time the plot treatments were modified. Altho it is recognized that these data are too meagre for final conclusions, the following comments based upon these figures for crop increases may be made.

It appears that the various phosphorus carriers—bone meal, acid phosphate, rock phosphate, and slag phosphate—rank differently in efficiency, according to the kind of crop produced. Considering first the results without limestone, we find the following order of efficiency: for corn—bone, acid, slag, rock; for oats—acid, either bone or rock, slag; and for hay—bone, slag, either acid or rock.

TABLE 10.—ODIN FIELD: COMPARATIVE PHOSPHATE TEST

Annual Crop Yields—Bushels or (tons) per acre

(1904–1912)

Plot No.	Soil treatment applied	1904 Corn[1]	1905 Oats	1906 Timothy	1907 Timothy	1908 Timothy and clover	1909 Corn	1910 Oats	1911 Timothy	1912 Timothy
501 NW	RK, *bone* phosphate	52.5	22.6	(.82)	(1.06)	(1.09)	39.1	55.6	(.55)	(1.26)
501 SE	RKL, *bone* phosphate	53.8		(.85)	(1.64)	(1.88)	45.3	55.5	(.93)	(1.50)
502 NW	RK	41.0	24.4	(.64)	(.98)	(.72)	39.5	44.1	(.35)	(.67)
502 SE	RKL	33.8		(.96)	(1.06)	(1.46)	44.2	48.5	(.92)	(1.31)
503 NW	RK, *acid* phosphate	50.0	27.1	(.71)	(1.01)	(.70)	38.3	53.9	(.83)	(.93)
503 SE	RKL, *acid* phosphate	49.0		(1.06)	(1.19)	(1.45)	39.9	42.8	(1.05)	(1.39)
504 NW	RK, *rock* phosphate	46.8	26.4	(.64)	(.91)	(.67)	32.5	50.5	(.59)	(.95)
504 SE	RKL, *rock* phosphate	49.5		(1.08)	(1.20)	(1.63)	44.7	52.4	(1.25)	(1.52)
505 NW	RK	33.0	27.4	(.57)	(.85)	(.47)	31.1	40.1	(.24)	(1.12)
505 SE	RKL	38.5		(1.04)	(1.14)	(1.29)	41.5	50.0	(.99)	(1.52)
506 NW	RK, *slag* phosphate	46.0	25.2	(.64)	(.94)	(.74)	34.0	47.6	(.48)	(1.13)
506 SE	RKL, *slag* phosphate	51.0		(.87)	(1.48)	(1.66)	44.9	61.4	(1.17)	(1.38)

(1913–1921)

Plot No.	Soil treatment applied	1913 Timothy	1914 Corn	1915 Oats	1916 Timothy and clover	1917 Timothy	1918 Timothy	1919 Corn	1920 Oats[2]	1921 Timothy and clover
501 NW	RK, *bone* phosphate	(.84)	2.6	74.5	(1.19)	(1.61)	(2.11)	.2	......	(0.00)
501 SE	RKL, *bone* phosphate	(1.03)	2.7	65.4	(1.10)	(1.75)	(1.63)	2.2	......	(1.91)
502 NW	RK	(.49)	2.4	62.8	(.49)	(.75)	(1.14)	.1	......	(0.00)
502 SE	RKL	(.73)	2.2	58.9	(.98)	(1.64)	(1.44)	4.3	......	(2.31)
503 NW	RK, *acid* phosphate	(.47)	1.4	77.5	(.57)	(.62)	(.93)	.3	......	(0.00)
503 SE	RKL, *acid* phosphate	(1.00)	1.8	60.6	(1.04)	(1.73)	(1.44)	4.0	......	(1.91)
504 NW	RK, *rock* phosphate	(.55)	1.6	79.8	(.51)	(.76)	(1.18)	.1	......	(0.00)
504 SE	RKL, *rock* phosphate	(1.02)	2.6	66.4	(1.09)	(1.67)	(1.44)	5.1	......	(1.67)
505 NW	RK	(.41)	1.0	55.8	(.33)	(.44)	(.72)	.1	......	(0.00)
505 SE	RKL	(.76)	1.8	66.9	(1.03)	(1.47)	(1.37)	5.4	......	(1.75)
506 NW	RK, *slag* phosphate	(.72)	1.8	78.0	(.87)	(.83)	(1.13)	.1	......	(.30)
506 SE	RKL, *slag* phosphate	(1.04)	2.2	80.8	(1.08)	(1.52)	(1.52)	2.6	......	(1.64)

[1]No residues. [2]Crop failure.

TABLE 11.—ODIN FIELD: COMPARATIVE PHOSPHATE TESTS
Summary of Crop Yields 1904–1921—Bushels or (tons) per acre

Plot No.	Soil treatment applied	Corn *4 crops*	Oats *3 crops*	Hay *10 crops*
501 NW	RK, *bone* phosphate	23.6	43.4	(1.05)
501 SE	RKL, *bone* phosphate	26.0	40.3	(1.42)
502 NW	RK	20.8	35.6	(.62)
502 SE	RKL	21.1	35.8	(1.28)
503 NW	RK, *acid* phosphate	22.5	43.8	(.68)
503 SE	RKL, *acid* phosphate	23.7	34.5	(1.33)
504 NW	RK, *rock* phosphate	20.3	43.4	(.68)
504 SE	RKL, *rock* phosphate	25.5	39.6	(1.36)
505 NW	RK	16.3	32.0	(.52)
505 SE	RKL	21.8	39.0	(1.24)
506 NW	RK, *slag* phosphate	20.5	41.9	(.78)
506 SE	RKL, *slag* phosphate	25.2	47.4	(1.34)
	RKbP over RK	5.1	9.6	(.48)
	RKLbP over RKL	4.5	2.9	(.16)
	RKaP over RK	4.0	10.0	(.11)
	RKLaP over RKL	2.2	−2.9	(.07)
	RKrP over RK	1.8	9.6	(.11)
	RKLrP over RKL	4.0	2.2	(.10)
	RKsP over RK	2.0	8.1	(.21)
	RKLsP over RKL	3.7	10.0	(.08)

Used with limestone, the relative efficiencies run as follows: for corn—bone, rock, slag, acid; for oats—slag, bone, rock, acid; and for hay—bone, rock, slag, acid. In general, the differences are small and a careful analysis of the data shows that most of them are to be considered insignificant, that is to say, well within the experimental error.

These results illustrate well the difficulty of laying down definite rules for practice in applying phosphorus fertilizer. To this point in the discussion there has been taken into account only the effect on production. When the economy from a financial standpoint is considered, the matter becomes more complicated, for all depends upon relative cost of materials applied as well as upon the market value of produce sold, both of which are constantly fluctuating. However, with the data of Table 11, one may compute for himself the relative economy of producing these crop increases by applying any set of prices for crops and fertilizers which appears to be most applicable according to prevailing market conditions. In so doing, however, it should constantly be borne in mind that the order of efficiency might easily be shifted thru a relatively small change in commodity prices.

In 1922 this series was replotted into the present 500, 600, 700, and 800 series, and a different system of rotation established for further investigation of the various forms of phosphorus fertilizer. Limestone at the rate of one ton an acre was applied for the first time to the originally unlimed areas, and further

TABLE 12.—ODIN FIELD: COMPARATIVE PHOSPHATE TESTS, REVISED
Annual Crop Yields 1922–1925—Bushels per acre

Plot No.	Soil treatment applied[1]	1922 Corn[2]	1923 Wheat[2]	1924 Corn	1925 Wheat
501	LeLK, *bone* phosphate.......	36.6	17.5	24.0	15.2
502	LeLK.....................	24.6	6.0	27.4	8.7
503	LeLK, *acid* phosphate.......	32.8	14.5	21.6	12.3
504	LeLK, *rock* phosphate.......	32.6	13.3	29.2	14.5
505	LeLK.....................	21.2	6.2	23.6	7.3
506	LeLK, *slag* phosphate.......	30.2	16.0	42.4	14.5
		Oats[2]	Corn	Wheat	Corn
601	LeLK, *bone* phosphate.......	1.9	10.8	22.5	24.0
602	LeLK.....................	1.6	7.2	1.0	25.8
603	LeLK, *acid* phosphate.......	1.9	9.8	18.8	30.4
604	LeLK, *rock* phosphate.......	1.9	8.8	10.8	18.0
605	LeLK.....................	1.9	10.2	.7	15.6
606	LeLK, *slag* phosphate.......	5.0	17.2	13.5	11.6
		Corn[2]	Wheat[2]	Corn	Wheat
701	LeLK, *bone* phosphate.......	20.4	24.7	24.4	24.2
702	LeLK.....................	20.0	24.2	28.0	25.5
703	LeLK, *acid* phosphate.......	19.8	19.8	33.8	20.8
704	LeLK, *rock* phosphate.......	19.6	18.0	40.8	22.0
705	LeLK.....................	23.0	18.7	45.8	17.3
706	LeLK, *slag* phosphate.......	25.2	21.2	26.4	23.0
		Oats[2]	Corn	Wheat	Corn
801	LeLK, *bone* phosphate.......	6.6	35.6	17.2	39.8
802	LeLK.....................	6.9	33.2	18.8	42.8
803	LeLK, *acid* phosphate.......	7.8	35.0	17.2	41.0
804	LeLK, *rock* phosphate.......	7.5	28.8	18.3	42.2
805	LeLK.....................	10.6	29.2	15.8	44.2
806	LeLK, *slag* phosphate.......	7.5	29.0	21.7	44.0

[1] Series 500 and 600 have received 1 ton of limestone per acre; Series 700 and 800 have received 8 tons per acre.
[2] No legume treatment.

application is to be deferred until a need for it appears. No limestone was applied to Series 700 and 800, which had been limed originally. No phosphates have been applied since 1919 and no further applications will be made for an indefinite period. For the time being, a crop rotation of corn and wheat with sweet clover seeding will be practiced on Series 500 and 600 and repeated on Series 700 and 800. The results for the four years during which this work has been running are given as a matter of record in Table 12, but because of the small number of crops that can be included, no attempt is made at this time to summarize these results or to discuss them.

Experiments with Sweet Clover in Rotations

In addition to the above described series, seven plots on the Odin field have been devoted to two special rotations featuring sweet clover. On three plots a rotation of corn, cowpeas or soybeans, and wheat has been practiced. Sweet clover has been seeded in both the corn and the wheat and plowed down as a green manure for the succeeding crop. On the other four plots the rotation has been corn, cowpeas or soybeans, wheat, and sweet clover. In this system the sweet clover has been allowed to make its second year's growth and produce a seed

TABLE 13.—ODIN FIELD: SWEET-CLOVER ROTATIONS
Annual Crop Yields 1906-1925—Bushels or (tons) per acre

Year	Three-year rotation			Four-year rotation			
	Corn	Soy-beans	Wheat	Corn	Soy-beans	Wheat	Sweet clover
1906	38.3	(1.90)[1]	28.3	24.0	(1.60)[1]	32.7	([4])
1907	46.8	(1.27)[1]	24.0	51.5	(1.39)[1]	30.0	([4])
1908	48.0	9.6	30.7	58.3	8.8	27.7	([4])
1909	24.4	.7	23.3	39.2	1.5	25.5	([4])
1910	32.7	3.9	39.4[3]	41.3	5.0	70.3[3]	6.90
1911	25.3	8.0	12.8	59.5	7.1	17.2	3.60
1912	54.4	11.1	([2])	68.4	18.6	([2])	([4])
1913	7.3	([2])	22.7	10.3	3.9	40.8	([4])
1914	7.3	2.2	12.8	2.0	4.4	23.3	([6])
1915	42.0	1.7	27.8	59.7	1.7	24 7	.83
1916	18.4	.6	2.2	19.8	8.0	2.2	2.78
1917	14.0	5.0	10.0	19.7	11.1	39.2	1.25
1918	5.5	3.3	24.4	2.6	.8	23.0	([2])
1919	.7	([5])	32.8	7.7	([5])	26.7	([2])
1920	54.7	19.4	([2])	66.7	21.1	([2])	1.94
1921	20.7	8.3	26.1	24.0	11.1	28.1	6.11
1922	19.7	7.2	17.2	22.3	6.4	35.3	3.42
1923	49.3	12.5	16.1	41.7	23.9	12.2	.36
1924	47.3	(.83)	11.1	61.7	13.9	11.7	.83
1925	34.6	(1.25)	3.3	29.7	(2.67)	22.2	2.67

[1]Cowpeas. [2]Not harvested. [3]Oats; wheat destroyed by grasshoppers. [4]No record of yields; sweet clover plowed under. [5]Crop destroyed by grasshoppers. [6]Crop destroyed by fire.

crop, the straw and chaff being returned to the land. Limestone and bone meal have been used in both these rotations, and the crop residues have been returned to the land.

The annual crop yields of the two systems are recorded in Table 13, and a general summary of each is presented for comparison in Table 14.

The markerly higher production in all crops in the four-year rotation indicates the advantage of this system, in which one field out of four is devoted to the production of sweet clover, over the three-year system in which only catch crops of sweet clover are grown.

TABLE 14.—ODIN FIELD: USE OF SWEET CLOVER IN ROTATIONS
Average Annual Crop Yields 1906-1925—Bushels per acre

Rotation	Corn *20 crops*	Soybeans[1] *16 crops*	Wheat *19 crops*	Clover seed *11 crops*
Three-year	31.7	7.1	17.1	......
Four-year	35.3	10.9	22.2	2.79

[1]Or cowpeas.

THE 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.

TABLE 15.—TOLEDO FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1914–1925—Bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *8 crops*	Corn *12 crops*	Oats *11 crops*	Clover[1] *4 crops*	Sweet clover *3 crops*	Soy-beans *3 crops*
1	0	8.5	22.2	16.5	(.06)	.11	(.70)
2	M	10.2	28.6	19.0	(.18)	.24	(.72)
3	ML	21.8	39.1	31.4	(.89)	2.45	(1.27)
4	MLrP	24.4	39.1	33.6	(.97)	2.42	(1.21)
5	0	8.1	18.3	15.6	(.05)	.26	3.8
6	R	9.5	19.8	17.1	(.24)	.53	4.7
7	RL	21.0	29.6	32.6	(1.19)	1.84	9.4
8	RLrP	24.3	30.8	35.2	(1.16)	1.77	10.5
9	RLrPK	26.8	41.0	38.4	(1.14)	2.48	11.8
10	0	5.3	15.7	16.9	(.17)	.23	(.53)

[1]Some seed evaluated as hay.

Series 100, 200, 300, 400

The system of plots made up of Series 100, 200, 300, and 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. At that time, after the plots had received a total of 6½ to 8 tons of limestone an acre on the different series, application of this material was suspended until further need for it becomes apparent. In 1923 the return of the wheat straw on the residues plots was discontinued.

Table 15 presents a summary of the crop yields including the years in which the complete plot treatments have been in effect. The results confirm those of other fields located on similar soil and, 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. A limited response to rock phosphate applied with organic manures and limestone but not sufficient to cover the cost of material.
5. A rather general response to potassium fertilizer becoming very marked in the case of the corn.

Series 500, 600, 700, 800

The second set of plots on the Toledo field, comprizing Series 500, 600, 700, and 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 16.—TOLEDO FIELD: TILLAGE EXPERIMENTS
Average Annual Yields 1913-1922—Bushels per acre

Tillage treatment	Corn	Soybeans	Wheat	Sweet-clover seed
	9 crops	*7 crops*	*6 crops*	*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 16. 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 beneficial effect on crop yields. Deep tilling apparently decreased yields, probably because of the mixing of subsurface and subsoil with the surface soil.

THE NEWTON FIELD

A 30-acre experiment field has been maintained by the University at Newton in Jasper county since 1912. The soil type has been mapped as Gray Silt Loam On Tight Clay but the field is not altogether uniform, as is shown by variations in the crop yields. The land is almost level. Drainage has been provided by a system of tile. Owing to the impervious nature of the subsoil, however, the tile did not materially improve the drainage until the scheme was devised of using the tiles as sewers to carry away the surplus water conducted to them thru a system of ditches and catch basins.

The field is laid off into 12 series of plots and these series make up four separate combinations or plot systems, only two of which will be considered here.

TABLE 17.—NEWTON FIELD: SERIES 100, 200, 300, SUMMARY OF CROP YIELDS
Average Annual Yields 1913–1925—Bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat	Corn	Soybeans[1]
		10 crops	*13 crops*	*12 crops*
1	0	.5	10.7	5.6
2	M	.8	15.6	7.8
3	ML	8.8	24.7	11.7
4	MLrP	14.5	25.9	12.7
5	0	1.4	11.3	5.4
6	R	1.0	11.9	4.7
7	RL	7.6	18.0	8.1
8	RLrP	13.6	18.6	9.2
9	RLrPK	16.7	23.1	10.0
10	0	.2	7.3	5.2

[1]Some hay evaluated as seed.

Series 100, 200, 300

A rotation of corn, soybeans, and wheat has been practiced on Series 100, 200, and 300. Cowpeas have been seeded in the corn and sweet clover in the wheat as catch crops to help supply the organic matter and nitrogen on the residues plots. In 1920 the use of the cowpea catch crop was discontinued, as was also the return of wheat straw in 1922.

The limestone used on these series has been of the dolomitic form ground sufficiently fine to pass a 10-mesh sieve. The usual large initial amount of limestone was not applied here. Up to 1922 the different series had received 5 to 6 tons an acre, when the regular applications were suspended until further need for lime becomes apparent.

Table 17 gives a summary of the crop yields obtained, including the years that the respective, complete soil treatments have been in effect.

The results of these experiments are characteristic of those of other fields located on this soil type. They demonstrate once more the absolute necessity of liming as the foundation for soil improvement. Without lime, legumes fail completely and the use of manure alone is practically ineffective. Phosphorus in combination with lime and organic manure has, as usual, materially benefited the wheat but, in the manner used, the rock phosphate has not paid for itself. Some increase in yield of both wheat and corn has followed the use of potassium fertilizer, but the money value of this increase is not sufficient to cover the cost.

A profitable system of farming on this field must lie in other plans of cropping than that employed in these experiments, for even under the best treatment the plane of production is too low to represent a successful farming enterprise.

Special Limestone Experiments

After demonstrating the great value of limestone for soil improvement, especially in southern Illinois, a number of very practical questions immediately arose concerning details of its application as, for example: What is the most favorable amount to apply from various standpoints of economy? What degree of fineness of material is most suitable? Is magnesian or dolomitic limestone as effective as high-calcium stone? Is there any advantage in the use of burnt material over that of the raw crushed stone? To answer these questions a series of tests was started on Series 500 to 1000. The comparisons were arranged in the following manner.

The odd-numbered series (500, 700, 900) have received applications of high-calcium material, either crushed stone or burned, and the even-numbered series (600, 800, 1000) have received corresponding amounts of dolomitic material. On all series, Plots 2 to 6 have received limestone at the rate of 500 pounds an acre a year; Plots 8 to 12 have received 1,000 pounds; and Plots 13 to 18 have received 2,000 pounds. All applications were based upon the equivalent of pure calcium carbonate.

In addition to the lime on these plots, all have received rock phosphate and kainit in amounts and manner previously described. A crop rotation of corn, soybeans, and wheat was practiced until 1920, when it was changed to corn, wheat, and sweet clover. Since that time the wheat straw and sweet-clover chaff have

TABLE 18.—NEWTON FIELD: SPECIAL LIMESTONE TEST
Summary of Crop Yields 1913–1925—Bushels per acre

Serial plot No.	Fineness of grinding (meshes per inch)	Wheat 13 crops		Corn 13 crops		Soybeans 5 crops		Sweet clover 6 crops	
		High calcium	Dolo-mitic	High calcium	Dolo-mitic	High calcium	Dolo-mitic	High calcium	Dolo-mitic
1	No lime....	7.5	9.0	11.3	10.8	3.4	3.8	0.00	0.00
Applications of 500 pounds per acre per year to total of 3 tons per acre									
2	4 down....	15.0	12.7	17.9	18.2	5.3	5.5	2.21	1.77
3	4 to 10.....	12.6	13.8	16.3	22.7	5.1	5.6	2.30	2.09
4	10 down....	13.8	13.2	17.7	15.6	5.1	5.3	1.98	2.27
5	50 down...	13.6	12.0	15.9	13.0	4.5	4.6	2.13	1.91
6	Burnt lime[1]	13.9	12.9	12.6	13.7	5.0	5.1	2.36	2.09
7	No lime....	8.2	8.4	8.9	11.2	3.3	3.6	0.00	.10
Applications of 1,000 pounds per acre per year to total of 6 tons per acre									
8	4 down....	13.0	12.2	14.4	16.1	5.2	5.2	2.37	2.29
9	4 to 10.....	11.9	11.1	14.1	15.1	5.0	4.9	2.42	2.23
10	10 down...	13.1	12.2	13.8	13.1	5.1	5.3	2.12	1.88
11	50 down...	13.9	12.5	14.4	12.2	4.8	4.9	2.45	2.07
12	Burnt lime[1]	13.7	13.4	14.1	12.2	5.3	4.4	2.87	2.40
13	No lime....	7.9	7.4	9.8	10.0	3.7	3.4	.37	.11
Applications of 2,000 pounds per acre per year to total of 12 tons per acre									
14	4 down....	14.4	14.2	17.9	15.3	6.1	5.7	3.37	2.55
15	4 to 10	12.8	13.9	17.6	18.2	5.4	5.1	3.29	2.10
16	10 down...	16.2	15.6	17.5	18.0	5.4	5.9	3.31	2.27
17	50 down...	17.6	17.4	17.0	16.8	6.7	6.1	3.00	2.51
18	Burnt lime[1]	17.8	18.2	18.9	19.8	6.4	6.6	3.19	2.99
19	No lime....	8.3	8.8	12.9	14.1	3.0	3.4	.20	.16

[1]Purchased as burnt lime, but applied after hydrating or slaking.

been returned to the land; the cornstalks have been removed. In 1922 limestone was evened up to a uniform total amount of 3 tons an acre on the plots receiving light applications, to 6 tons an acre on plots receiving medium applications, and to 12 tons on plots receiving heavy applications. No more lime will be applied until an apparent need for it develops.

A summary of the crop yields including the years since the complete plot treatments have been under way is shown in Table 18. In order to study the relative economy of the various amounts and kinds of lime applied, the value of the respective crop yields have been calculated and these are shown in Table 19, along with the value of the corresponding increases due to treatment. Using these figures as a basis, the value of a ton of limestone has also been calculated, and finally the returns per dollar invested in the different forms and amounts of lime are included in this table.

In considering the results it is to be noted that the subsoil on this field is not altogether uniform with respect to acidity. Spots have been found in which carbonates exist. Therefore definite conclusions are probably warranted only on the more outstanding differences. Without going into a fine analysis of the data, the following facts appear from scanning the figures of these tables:

Amount of Lime.—Considered from the standpoint of total production, the heavy applications produced the greatest yield, altho the light applications produced somewhat higher yields than the medium. If, however, the profitableness of the practice be considered from the standpoint of value per ton of material applied, the law of diminishing returns becomes operative, making the value per ton two or three times as much in the light application as that in the heavy application. The effect is magnified in the returns per dollar invested. The figures show about $12 to $17 return for the light applications as compared with about $4 return per dollar invested in the heavy applications. Presumably the residual effect will be greater with the heavy application which, in the course of time, will compensate to some extent for the smaller profit thus far obtained.

Fineness of Material.—Aside from a possible slight tendency in the heavy application toward higher production from finer grinding, there seem to be no very well-defined differences with respect to fineness of grinding. The practical conclusion therefore is that there is little or no advantage to be gained in reducing the stone completely to a powder.

High-Calcium Compared with Dolomitic Material.—The figures showing value of annual increase indicate a certain tendency in favor of the high-calcium over the dolomitic material. Some of the differences, however, are rather small and there are among the fifteen possible comparisons three exceptions. Altho

TABLE 19.—NEWTON FIELD: SPECIAL LIMESTONE TEST, FINANCIAL COMPARISONS[1]

Serial plot No.	Fineness of grinding (meshes per inch)	Average annual acre value of crops		Value of annual increase for lime		Value of one ton of limestone[2]		Returns per dollar invested	
		High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic
1	No lime....	$7.86	$8.64	....	....	....	....	....	....
	Applications of limestone: 500 pounds per acre per year to a total of 3 tons								
2	4 down....	$16.91	$15.02	$9.13	$6.51	$39.52	$28.18	$19.76	$14.09
3	4 to 10.....	15.29	17.20	7.51	8.69	32.51	37.62	16.26	18.81
4	10 down...	15.97	15.24	8.19	6.73	35.45	29.13	17.73	14.57
5	50 down...	15.43	13.30	7.65	4.79	33.12	20.74	16.56	10.37
6	Burnt lime.	15.11	14.37	7.33	5.86	31.73	25.37	4.00	3.24
7	No lime....	$7.70	$8.38	....	....	....	....	....	....
	Applications of limestone: 1,000 pounds per acre per year to a total of 6 tons								
8	4 down....	$15.25	$14.92	$6.72	$6.97	$14.55	$15.09	$7.68	$7.55
9	4 to 10.....	14.56	13.92	6.03	5.97	13.05	12.90	6.53	6.45
10	10 down...	14.77	13.56	6.24	5.61	13.51	12.14	6.76	6.07
11	50 down...	15.61	13.64	7.08	5.69	15.32	12.32	7.66	6.61
12	Burnt lime.	16.02	14.44	7.49	6.49	16.21	14.05	2.07	1.79
13	No lime....	$9.36	$7.51	....	....	....	....	....	....
	Applications of limestone: 2,000 pounds per acre per year to a total of 12 tons								
14	4 down....	$18.27	$16.17	$9.27	$7.71	$10.04	$8.35	$5.02	$4.18
15	4 to 10.....	17.15	16.07	8.15	7.61	8.83	8.24	4.42	4.12
16	10 down...	18.81	17.32	9.81	8.86	10.63	9.60	5.32	4.80
17	50 down...	19.23	18.21	10.23	9.75	11.08	10.56	5.54	5.28
18	Burnt lime.	19.54	20.16	10.54	11.70	11.42	12.68	1.42	1.48
19	No lime....	$8.63	$9.40	....	....	....	....	....	....

[1]Based upon the following prices: wheat, $1.50 per bushel; corn, 75 cents; soybeans, $1.50; sweet clover, $7.50; crushed limestone, $2 a ton; burnt lime, $14 a ton.
[2]Or its equivalent in burnt lime.

this trend is of interest, the experiments are not sufficiently extended to warrant without further evidence a discrimination between the two kinds of stone. In the purchase of limestone there is another consideration to bear in mind, and that is the possible need of the soil for magnesium, which element is furnished in dolomitic stone. For further discussion of this phase of the problem, see Appendix, page 32.

Burnt Lime Compared with Ground Limestone.—It may be explained that the term "burnt limestone" is used here to comply with the previous records. As a matter of fact, the material was purchased as burnt lime but it was hydrated or slaked before being applied to the soil.

In the light application the burnt material appears to be slightly less effective than the average of the crushed grades, both in the high-calcium and in the dolomitic products. In the medium and heavy applications, however, the reverse

FIG. 5.—WITHOUT LIMESTONE SWEET CLOVER REFUSES TO GROW
At the right where no clover is seen, no limestone has been applied.

is true, altho in no case is the difference great. In the value of a ton of limestone the figures follow the same order.

The most striking comparison is found in the returns per dollar invested, owing of course to the high cost of the burnt material. In these estimates the local dealers' present market price of $14 a ton in carload lots is allowed with no consideration of the extra trouble in preparing it for application by slaking. In the light application the returns on a dollar invested for high-calcium burnt lime is $4, while for the corresponding crushed stone it is $17.58. In the heavy applications the corresponding figures are $1.42 and $5.08 respectively. The figures for the dolomitic material are in about the same order.

From these results it appears that the answer to the question whether to use burnt lime or ground limestone will depend, not upon the relative effectiveness of the two in the soil, but rather upon the economy of their application. Only under exceptional circumstance would burnt lime compete with ground limestone. Such a situation might be one in which crushed limestone is not readily accessible and burnt lime could be produced very cheaply; or for gardening, where only small quantities are required, burnt lime may be procured wherever building supplies are sold.

THE DUBOIS FIELD

Another experiment field on Gray Silt Loam On Tight Clay is located at DuBois in Washington county. This land lies practically level and appears to be uniform in soil type. The experiments were started in 1902. The field was laid off into a single series of plots having two sections, one tiled and the other untiled.

The rotation practiced the first eight years was corn, oats, and wheat followed by a legume. After two of these rotations the order was changed to corn, oats, clover, wheat, with a seeding of sweet clover and alsike on the residues plots for use as a green manure. Since there appeared to be little difference between the tiled and untiled sections, another change in cropping was made in 1922 by which corn is grown on one section and wheat with a seeding of sweet clover on the other.

Five tons of hydrated lime an acre was applied in 1902, and no further application of lime was made until 1922, when 2 tons of limestone an acre was applied on the east section and 1,000 pounds an acre on the west section.

Until 1905 nitrogen was applied annually in approximately 650 pounds of dried blood an acre on what are now the residues plots; thereafter crop residues were substituted. Phosphorus was supplied in form of steamed bone meal applied at the rate of 200 pounds an acre a year, and potassium in 100 pounds of potassium sulfate an acre a year. In 1922 the applications of both phosphorus and potassium were discontinued temporarily.

A general summary of the annual crop yields is assembled in Table 20, and for convenience in studying the effect of the treatments the various possible comparisons are brought together in Table 21, where the results of the corresponding plots of the two sections are averaged and expressed in terms of crop increases. Some points of interests brought out by these comparisons are the following:

Altho *lime*, as used in these experiments, has produced some increase in all crops, when applied alone it does not raise the plane of production sufficiently to give a profitable system of farming. In the presence of other fertilizing materials, however, its effectiveness is greatly enhanced.

The response to *residues* in the various combinations is rather complex. In some cases the increases to be ascribed to residues are marked. In the treatment with lime, phosphorus, and potassium, the effect of residues on the grain crops is quite indifferent, while on the hay crop it is very pronounced. In considering these residues results it should be noted that they include the data of the earlier years, when dried blood was used instead of residues to furnish nitrogen.

Phosphorus has given increases in all combinations in all crops, but the most significant effect produced has been on the wheat. *Potassium* has produced a remarkable effect on the corn; in some cases the yields have been practically doubled following the potassium treatment.

TABLE 20.—DUBOIS FIELD: SUMMARY OF CROP YIELDS
Average Annual Yields 1902–1923—Bushels or (tons) per acre

Plot No.[1]	Soil treatment applied[2]	Wheat 6 crops	Corn 6 crops	Oats 5 crops	Clover Hay 4 crops	Clover Seed 2 crops	Soybeans 1 crop
1	0	5.4	10.8	14.0	(.58)	......	3.5
2	L	9.7	13.0	23.0	(.61)	......	6.7
3	LR	13.6	17.6	30.8	(.89)[3]	.80	7.2
4	LP	20.7	17.1	35.2	(1.04)	......	8.5
5	LK	16.7	25.9	30.8	(.89)	......	9.3
6	LRP	26.5	17.5	33.8	(1.17)[3]	1.88	8.2
7	LRK	19.7	25.2	32.9	(1.74)[3]	2.38	7.8
8	LPK	28.0	29.1	37.6	(1.67)	......	9.5
9	LRPK	27.0	28.8	34.8	(2.22)[3]	2.09	7.8
10	RPK	18.9	22.1	26.5	(2.00)[3]	2.09	6.3
11	0	6.3	11.7	14.3	(.54)	......	3.3
12	L	13.6	13.8	22.5	(.77)	......	6.2
13	LR	16.2	16.4	28.0	(1.33)[3]	1.33	6.7
14	LP	22.2	13.3	32.4	(1.14)	......	7.2
15	LK	16.1	25.2	33.8	(1.23)	......	7.8
16	LRP	27.0	18.3	38.1	(2.11)[3]	2.42	8.8
17	LRK	23.3	29.7	32.4	(2.19)[3]	2.04	10.2
18	LPK	30.0	32.4	34.8	(1.88)	......	10.3
19	LRPK	28.0	30.8	33.1	(2.67)[3]	2.08	11.3
20	RPK	18.8	21.8	30.2	(2.41)[3]	2.25	6.7

[1]Plots 1 to 10 not tiled. Plots 11 to 20 tiled.
[2]Until 1905 dried blood was applied instead of residues.
[3]Only two crops of hay on Plots 3, 5, 7, 9, 10, 13, 16, 17, 19, and 20.

TABLE 21.—DUBOIS FIELD: EFFECT OF TREATMENTS IN TERMS OF ANNUAL CROP INCREASES
Bushels or (tons) per acre

Comparison of treatments	Wheat 6 crops	Corn 6 crops	Oats 5 crops	Clover hay[1] 2 or 4 crops	Soybeans 1 crop
Lime					
L over 0	5.8	2.2	8.6	(.13)	3.1
LRPK over RPK	8.7	7.9	5.6	(.24)	3.1
Residues					
LR over L	3.3	3.6	6.7	(.42)	.5
LRP over LP	5.3	2.7	2.2	(.55)	.7
LRK over LK	5.1	1.9	.4	(.91)	.5
LRPK over LPK	−1.5	−1.0	−2.3	(.67)	−.4
Phosphorus					
LP over L	9.8	1.8	11.1	(.40)	1.4
LRP over LR	11.9	.9	6.6	(.53)	1.6
LPK over LK	12.6	5.2	3.9	(.72)	1.4
LRPK over LRK	6.0	2.4	1.3	(.48)	.6
Potassium					
LK over L	4.8	12.2	9.6	(.37)	2.1
LRK over LR	6.6	10.5	3.3	(.86)	2.1
LPK over LP	7.6	15.6	2.4	(.69)	2.1
LRPK over LRP	.8	11.9	−2.0	(.81)	1.1

[1]Omitting any consideration of clover seed produced on certain plots.

These results in general confirm those of the other fields located on the same soil type, in that wheat responds in a notable way to phosphorus treatment while corn receives its greatest benefit from potassium treatment. A rational system of general farming designed to bring this land into the highest production of which it is capable calls for the application of both these elements of plant food to be used in conjunction with limestone and organic manures.

The marked benefit to wheat and the indifferent response of all other crops following the use of bone meal suggest that in practice perhaps phosphorus could be supplied more economically by using somewhat smaller quantities of phosphatic fertilizer and applying it directly to the wheat crop. Likewise, it seems probable, judging from the relative crop responses to potassium treatment, that the expense of potassium fertilizer might be reduced by cutting down the quantity used in these tests, applying the material direct to the corn crop. The organic manures are well furnished by crop residues and legumes plowed down but, under some circumstances, at least a part of the legumes and crop residues will be utilized advantageously by pasturing or feeding them to livestock, the manure produced therefrom to be carefully conserved and regularly returned to the land.

THE 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 very 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.

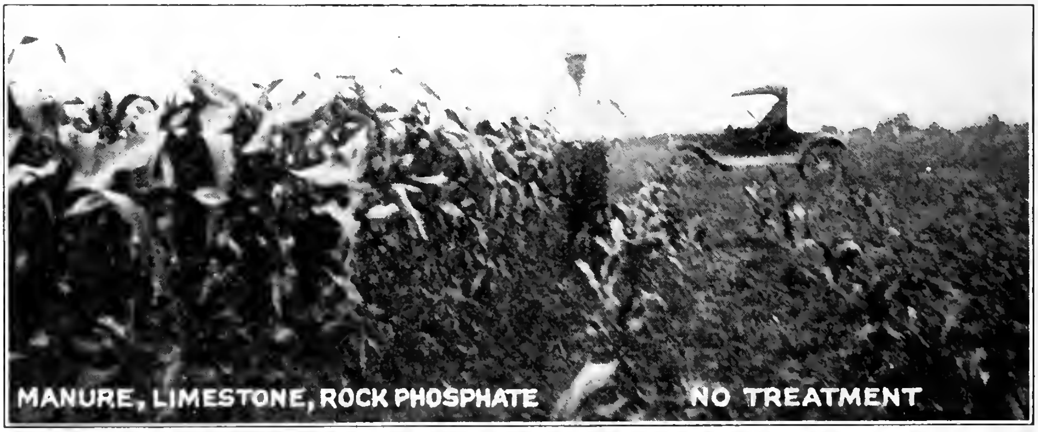

Fig. 6.—Corn Growing on Neighboring Plots on the Ewing Field in 1924

At the right is a check plot which has produced, as an average of eight years, only 15 bushels of corn an acre; while at the left the plot treated with manure, limestone, and rock phosphate has produced 49 bushels an acre as an average for this same period.

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 plot. 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 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 the wheat straw as a residue was also discontinued at that time. In 1923 the rock phosphate was evened up on all phosphorus plots to 8,500 pounds an acre, and no more will be applied for an indefinite period.

TABLE 22.—EWING FIELD: SERIES 100 and 200, SUMMARY OF CROP YIELDS
Average Annual Yields 1911–1925—Bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *6 crops*	Corn *8 crops*	Oats *8 crops*	Clover *2 crops*	Soybeans *3 crops*	Sweet clover *2 crops*
1	0	2.2	15.3	9.8	(.26)	(.36)	0.00
2	M	4.1	30.6	15.4	(.31)	(.42)	0.00
3	ML	14.8	47.8	29.0	(.91)	(.89)	2.23
4	MLrP	20.0	49.0	31.0	(1.12)	(1.02)	2.25
5	0	2.2	14.9	9.4	(.19)	1.8	0.00
6	R	1.7	15.2	9.9	(.23)	1.8	0.00
7	RL	15.9	33.2	26.2	(.87)	6.1	2.46
8	RLrP	19.0	31.7	27.2	(1.15)	7.2	2.07
9	RLrPK	26.1	47.3	34.9	(1.06)	8.5	2.08
10	0	3.3	20.1	10.9	(.37)	(.42)	0.00

A summary of the results is presented in Table 22, 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 testify to the natural poverty 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.

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.

Rock phosphate has produced a substantial increase in the yield of wheat, but it has had little or no significant effect on other crops. Used in the quantity applied in these experiments, the profits on the wheat would scarcely carry the cost of material. As explained above, however, the phosphate applications have been suspended to observe the residual effect. The results of the next few years should furnish new light on the economy in the use of phosphate on this soil.

Potassium fertilizer, as used in these experiments, has had a decidedly beneficial effect on all the grain crops.

The response to treatment on this field resembles in general that on the group of fields discussed above. The suggestions, therefore, for the practical improvement of this soil type correspond to those for Gray Silt Loam On Tight Clay.

Soil Reports Published

1 Clay, 1911
2 Moultrie, 1911
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6 Knox, 1913
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11 Pike, 1915
12 Winnebago, 1916
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