INVESTIGATIONS OF AGRICULTURAL SOILS IN SOUTHERN ILLINOIS.

H. J. SNIDER, UNIVERSITY OF ILLINOIS.

INTRODUCTION.

It is difficult to mark out exactly a satisfactory boundary for southern Illinois, since it is not in itself a distinct political subdivision; yet it has many characteristics, particularly in agriculture, which distinguish it from the remainder of the state. For the purpose set forth in this paper the boundary indicated by Mosier (1918) will be used. This boundary is formed by the northern line of Madison, Bond, Fayette, Effingham, Jasper, and Crawford counties. Southern Illinois includes these and all other counties south of this line, with the Mississippi River on the west, the Wabash on the east, and the Ohio on the south. This territory includes some 34 counties comprising approximately 8,000,000 acres of land in farms, and a very high percentage of this is tillable land. This region has a climate most favorable to agricultural production, and regarding this point Curtiss (1852) says: "all the grains, fruits and roots of the temperate regions of the earth grow luxuriantly in Illinois; the wheat is of excellent quality, and there is no part of the western country where corn is raised with greater ease and abundance." This quotation written some 75 years ago indicates that this region was then highly regarded for its agricultural value based upon its climate, location, and other advantages.

GEOLOGICAL INFLUENCES.

A very large part of southern Illinois is within a glaciated area representing one of the oldest glacial periods in the state. This region is comparatively level having been plained off by the action of the ice sheet and is sometimes referred to as a "low flat country". These comparatively early geological changes left a condition from which came the present prairie farm lands. Regarding the formation of the prairie, Woodward (1923) points out, "All the earlier glaciations left a comparatively plain surface, a large part of which has not been

dissected up to the present time." He goes on to say that prairie grass first invaded these vast level areas because it was able to live through the severe summer droughts to which these regions were subjected to. The prairie grass sod tended to exclude trees although the young tree seedlings could not on these level plains survive the severe drouth brought about mainly by the high winds. The trees could and did survive along streams and on ridges where erosion removed the sod and the elevation or depression of the land cut down the velocity of the wind and prevented the extreme drying out of the soil. The trees when once established would furnish their own protection against the dessicating action of the wind, and would slowly destroy the heavy sod and by this means gradually invade the open prairies. Thus were developed the prairie and timber lands of this glaciated region.

The vast prairie and timber areas of southern Illinois furnish an almost ideal topography for farm lands. This type of land can practically all be utilized for cultivated crops, as there is buit little or no waste land on each farm due to irregular topography. These level farms are adapted to production on a large scale. It is this large scale farming which has helped to create a progressive type of farmer, it has olwered the cost of producing farm products, and according to Waters (1911), for the first time in history, given the world food enough to go around.

The seven counties in the extreme southern part of Illinois and parts of the adjoining counties are made up of farm lands which have a somewhat different geological history, from that of the remaining counties to the north. The elevation here varies from 310 feet above sea level to 1046 feet above at the highest point of the Ozark Ridge in Pope County. According to Weller (1921), this region during geological time had a tendency to be uplifted at intervals to a greater degree than its surroundings. At one time it was an island encircled by the waters of an ancient sea, while at other times it was completely covered with water. In the same article, Weller cites evidences of an ancient volcano in a part

of this region. Such geological agencies have left a vastly different type of agricultural land from that left by glacial action. This unglaciated land is of a very uneven topography, it is dissected by streams and is constantly being changed by erosion. The land was once all heavily forested, and the composition, color and texture of the soil varies considerably from that of the glaciated area to the north.

AGRICULTURAL HISTORY.

It is apparent from historical accounts that the early settlers learned that wheat was one of the important crops for southern Illinois. In this point Carrier (1923) records, "In 1746 the Illinois country sent down the Mississippi to New Orleans 50 tons of flour." This was scarcely more than 60 years after the first missions were started in this territory.

Some agricultural conditions which existed in the early part of the past century are revealed by Peck, who wrote in 1837 regarding some southern Illinois counties. He reports that wheat, if properly seeded, rarely fails to average 25 to 35 bushels an acre. Oats often yield 40 to 50 bushels. He also mentions good results with hemp, cotton, tobacco, flax and that considerable quantities of castor oil beans were produced in Madison, Randolph and other counties. Of clover, Peck says, "A prejudice exists against it, as it is imagined to injure horses by affecting the glands of the mouth and causing them to slaver." Regarding corn he writes, "No farmer can live without it and hundreds raise little else. This is chiefly owing to the ease with which it is cultivated. Its average yield is 50 bushels per acre. I have often seen it produce 75 bushels per acre, in a few cases exceed 100." In the same book he laments that so few of the Illinois farmers have barns for the security of their crops.

The early historical accounts indicate that the early settlers found in southern Illinois, a very desirable agricultural country, in which they could successfully grow a variety of crops. Some of these crops, particularly wheat and corn, they produced on a large scale and obtained rather large acre yields.

CLIMATIC CONDITIONS.

The climatic conditions have a very great influence upon soil conditions, and have a significant bearing upon agricultural production. The amount and distribution of rainfall is an all important factor in crop production, also is the length of growing season, temperature, sunshine, etc.

The annual rainfall for south central Illinois as reported by Mosier (1918) as a fifty year average was 41.48 inches, with 56.6 percent of this falling from March to August. June is the month with the highest rainfall, and October, the month of lowest rainfall. The Ozark Ridge region has an average annual rainfall of 43.28 inches, which is almost 10 inches more than that of the extreme northern part of the state.

Mosier states that the recurrence of months with less than 2 inches of rainfall are less frequent in this region than in the central and northern part of the state. The greater injurious effects from drouth are due almost entirely to soil conditions.

The last killing frost in the spring in the south central area averages April 15 and the first killing frost in the fall averages October 20 giving a growing season of approximately 188 days. In the Ozark Ridge region from killing frost to killing frost averages April 14 to October 24, giving a growing season of approximately 193 days, which is 32 days longer than the growing season in the extreme northern part of Illinois.

The average annual snowfall in southern Illinois is 17.5 inches, while in northern Illinois, it averages 31.7 inches.

The south central area has sunshine 55.1 percent of the time out of the possible time that the sun could shine. This is the highest percent sunshine in the state.

This very careful and detailed climatic survey indicates that southern Illinois has an ample and well distributed annual rainfall. It has a comparatively long growing season, and not very severe winters. From the standpoint of climate, it is a favored agricultural region.

AGRICULTURAL STATISTICS.

The distribution of population has a very marked influence on agricultural production and markets. When the population of a region is very largely concentrated in towns and cities there is apt to be ample nearby markets for produce, but when the population is mostly rural, the farm products must usually be shipped long distances to market. According to census reports (1920) southern Illinois had in 1900 in round numbers 99,000 urban population and 646,000 rural population. In 1920 the urban population was 358,000 and the rural population was 595,000. In this 20 year period the total population has increased, but there was a decrease in rural population and a large increase in urban population. The tendency is decidedly toward a larger urban population which will tend to furnish larger demands and better markets for farm products.

Southern Illinois has approximately 71,000 individual farms which average about 110 acres per farm, according to census reports (1925). Approximately 69.6 percent of the farms were operated by owners and 29.9 percent operated by tenants as compared to 42 percent tenants for the entire state. Approximately only 0.5 percent of the farms were operated by managers.

This region is adapted to growing a wide variety of farm crops, however, corn, wheat, oats, and hay occupy the larger part of the farm lands. In 1924 there were 62.8 percent of the farm lands in crops composed mainly of the following: Corn 24.3 percent, wheat 14.7 percent, oats 6.9 percent, and hay 29.3 percent. These four crops making up over three-fourths of the total area in crops.

Some extracts from the census report (1920) show that in 1919 southern Illinois grew in round numbers 955,000 pounds of broom corn, 25,000 acres of potatoes, 6,000 acres of sweet potatoes, 8,000 acres of other vegetables, 6,000 acres of sorghum, making 268,000 gallons of syrup. There were in this year approximately 2,979,000 orchard trees of bearing age, 4,400 acres of small fruit and 419,000 grape vines. In addition to this, there were grown varying amounts of sunflowers, rice, tobac-

co, cotton, and other crops. In 1923 there was 9,000,000 pounds of redtop seed marketed, and in 1924 there were 15,630 acres of cotton, producing about 3,400 bales of lint. The acreage devoted to different crops varies from year to year and some particular crops may be omitted or receive very little attention for a period of years, however, the above serves to show the great variety and also the volume of agricultural production in southern Illinois.

Livestock production in southern Illinois is a vast industry in itself and this is the source of a large part of the farm incomes. According to the 1925 report, in 1924 there were on the farms in round numbers 202,000 horses, 80,000 mules, 425,000 cattle, 453,000 swine, and sufficient sheep (1919) to produce over 660,000 pounds wool. There is also to be included in this an enormous amount of poultry and poultry products. The eggs produced in 1919 amounted to about 32,729,000 dozens. The honey produced in this section for this year amounted to over 445,000 pounds.

SOIL INVESTIGATION WORK.

The outstanding fact about southern Illinois agriculture is that in a very large part of this area, the acre production is low. The volume of total production is relatively large; yet, the unit production is sometimes so low that the products from an acre of land may sell on the market for less than the cost of production when this cost includes an ample remuneration for labor, interest on the investment, depreciation and taxes.

A direct comparison of several counties in southern Illinois with counties in central Illinois shows the great difference in the productiveness of the soils of these two regions. The 14 year average (1911-24) corn yield for three central counties is as follows: Champaign 40.4 bushels, Logan 40 bushels, McLean 39.4 bushels, and three southern counties, Bond 23.2 bushels, Clay 22.7 bushels, and Marion 19.3 bushels. There are some southern counties that average a little higher than the above, however all of the counties named are representative of general soil areas. These comparative corn yields illus-

trate the fact that southern Illinois farm lands are far less productive than the lands to the north of this area.

The farm lands in the two sections represented by the above counties is that of glaciated areas, the distinguishing factor here in all probability is the difference in age of the glaciatons represented. The southern Illinois area representing the older glaciation has for a longer time been subject to the action of climatic conditions and other agencies which have depleted this soil of a large amount of its natural fertility. The problem of restoring this soil fertility is a question which has received a great deal of attention, and there are many aspects to its solution of this problem. At the present time the economic aspect seems to be one of the most formidable obstacles, however, this may in time cease to be a serious handicap as the country develops and conditions change. The scientific aspect of the southern Illinois soil problem has received very careful consideration and the progress made so far indicates some very encouraging results.

SOIL CLASSIFICATION AN CHEMICAL ANALYSIS.

The classification of soils includes the mapping out in a systematic manner all of the numerous types of soil to be found in each of the various counties. In this investigation the county is used as the unit of survey and soil maps and reports are published on this basis. This work reveals that Clay County (1911) which is in the glaciated area, has some 14 distinct types of soil. Of these types, Gray Silt Loam on Tight Clay makes up about 37 percent of the total area, and Brown-Gray Silt Loam makes up a fraction of one percent of the total. Bond County (1913) another in the glaciated area, has also 14 distinct types of soil. Here Gray Silt Loam on Tight Clay makes up 32.66 percent of the total and Brown-Gray Silt Loam on Tight Clay makes up additional 16.54 percent of the total. These two types make up practically half the soil of the county.

In the Ozark Ridge area, Hardin County (1912) has 10 distinct types of soil, with Yellow Silt Loam timbered soil making up 70.5 percent of the total area, and Yellow Gray Silt Loam making up an additional 6.17 percent

Johnson County (1925) also an Ozark Ridge county has 7 distinct types of soil. Here Yellow Silt Loam timbered soil makes up 61 percent of the total, and Yellow Gray Silt Loam timbered soil makes up an additional 13.15 percent of the total. These two types make up approximately three-fourths of these Ozark Ridge soils.

The comparative fertility of the above named types of soil as indicated by chemical analysis is illustrated in Table I. In this table is also shown the chemical composition of one of the best corn belt soil types known as Black Clay Loam (1915).

TABLE I.

Total Plant Food Elements in Various Soil Types. Surface Stratum About 6⅔ inches in depth. Figures represent average pounds per acre. (Two Million pounds of soil.)

	Organic Carbon.	Nitrogen.	Phosphorus.	Potassium.	Magnesium.	Calcium.
Corn Belt Soil..	57410	8160	2000	34210	16580	31240
Gray Silt Loam..	26970	2790	750	24830	4690	3420
Brown-Gray Loam	29490	2840	670	31040	4590	6210
Yellow Silt Loam	12880	1250	840	34200	7710	3980
Yellow-Gray Silt Loam	19470	1960	970	31420	4620	4010

The comparison based on chemical analysis shown in Table I, indicates very decidedly that the soil types which generally predominate in southern Illinois are deficient in organic carbon (organic matter) and consequently deficient in nitrogen. Based on this comparison there is also a decided shortage of phosphorus, magnesium, and calcium. Potassium is apparently abundant in the southern Illinois types, and the problem with this element is whether or not the natural supply can be made sufficiently available, or will additional soluble potassium have to be added to these soils?

In brief the problem of restoring the fertility to these soils is apparently a problem of replenishing the deficient elements as shown by the comparison in Table I. The scientific aspect of this may in all probability be quickly and thoroughly solved, but applying the solution to the 71,000 individual farms is in itself a vast and intricate problem.

FIELD EXPERIMENTS.

Probably among the most primitive yet effective methods of maintaining the productiveness of the land is that of crop rotation. The American Indian in his agricultural efforts practiced a system of rotation. On this point Carrier (1923) records, "The Indian in this land of boundless acres practiced a rotation of fields rather than a rotation of crops. A field was cropped until it no longer produced profitable yields, then it was abandoned and new land cleared." The present day farmer apparently would gladly follow the old Indian practice were it possible to do so, but he must confine his farming operations to the same set of fields year after year. This practice calls for a very careful study and a close application of some accepted and well balanced system of crop rotation.

The possibilities of crop rotations as one means of keeping land productive is illustrated by the long time results obtained on the Morrow Plots which are operated by the Illinois Experiment Station at Urbana. In this experiment there is a comparison of three distinct cropping systems which have been carried on since about 1879, and the results presented in Table II are most instructive.

TABLE II.

Corn Yields from the Morrow Plots. Figures Represent bushels per acre.

Cropping System.	1907.	1913.	1919.	1925.	Average.
Continuous corn	20.0	19.4	24.0	19.1	20.6
Corn—Oats	47.8	29.2	30.8	26.7	33.6
Corn—Oats—Clover	80.5	33.8	52.2	42.0	52.1

This test is composed of three plots lying adjacent to each other, and each plot through the years has carried the same cropping system. One plot has been continuously in corn, year after year, another plot had corn one year, and oats the next, and the third plot had corn, one year, then oats, and then clover. This plan gives a corn crop on all three plots every sixth year so that a direct comparison may be made for the years indicated in Table II. In this experiment the use of clover in the corn-oats rotation has increased the average corn yield 18.5

bushels per acre over the corn-oats rotation. The corn-oats-clover rotation has increased the average corn yield 31.5 bushels an acre over the continuous corn system. While this experiment is conducted under soil conditions not exactly similar to those of southern Illinois, yet it serves to illustrate the possibilities and value of crop rotation as a means of keeping up the productiveness of the land.

ADDING FERTILITY TO THE SOIL.

The New England settlers early adopted the Indians' plan of fertilizing their corn crop. Carrier (1923) cites the following as written by Morton in 1632. "You may see in one township a hundred acres together set with these fish, every acre taking 1,000 of them, and an acre thus dressed will produce and yield as much corn as three acres without fish." The fields thus fertilized were located near streams in which the fish were very abundant. In the decomposition of the fish there was supplied in a very available form a part of the plant food needed for the production of the corn crop.

Regarding the early use of limestone in this country, Carrier cites the two following instances: Kalm of New Jersey in 1748 mentions a red limestone which the farmers were using to manure their lands. William Logan in 1754 records putting 50 bushels of stone lime in small heaps to an acre. His farm was near Philadelphia, Pennsylvania. These references show that the fertilization and liming of farm lands is by no means a new practice in this country. Some of the early settlers in their efforts practiced more or less intelligently a few of the general principles of the science of soil fertility; however, today we have a more thorough understanding of these principles and can apply them more correctly and with greater economy than did the Indian and pioneer white man.

In discussing the fertility of Illinois soils, Hopkins (1908) says, "The productive capacity of practically all soils in good physical condition is measured by the available supply of limestone and the three elements, phosphorus, potassium, and nitrogen, because they are required by all crops in very considerable quantities, while

in most soils the supply of one or more of them is limited. If the supply of one of these elements is too limited, it must as a consequence, limit the yield of the crop, even though all other factors essential to crop production are well provided for. It is because of these facts that limestone, phosphorus, potassium, and nitrogen, in commercial form have recognized money values." Somewhat on this basis there was put in operation a system of experiment fields covering very thoroughly the principal soil types of southern Illinois. In these field experiments it was the aim to utilize fertilizing materials which would supply the soils need for certain elements at the lowest possible cost. It is very essential that low cost materials be used when farming operations are on an extensive scale and the margin of profit is narrow as in this region.

Ground limestone was used to correct the acidity of the soil and to supply calcium and magnesium. Nitrogen was supplied by manure, legumes, and other crop residues. Phosphorus was supplied by finely ground rock phosphate. Potassium was supplied by kainit or liberated from the large natural supply in the soil. All of these materials are such as to supply the desired elements at a very low cost.

The influence of manure alone as compared with manure and limestone is shown in Table III on the Enfield Experiment Field in White County.

TABLE III.

Crop Yields in Bushels and Pounds per acre. 12 year average—1914-25.

	Wheat Bu.	Corn Bu.	Oats Bu.	Hay Lbs.
Untreated land	5.4	18.1	11.6	520
Manured land	7.2	26.4	15.6	560
Manure and Limestone	16.1	39.7	25.0	2480

This table indicates that manure alone does increase the crop yields, but not until limestone is used with the manure is there any great progress made toward restoring the productivity of the land.

The value of legumes and other crop residues as a source of nitrogen is illustrated in Table IV. The legume

which has been found up to the present time to be best adapted to soil improvement is common sweet clover. This legume has been used in experimental work in southern Illinois since 1905, and its effect upon crop yields is remarkable. Table IV shows the influence of sweet clover on the Enfield Experiment Field when used with limestone, rock phosphate, and kainit.

TABLE IV.

Crop Yields in Bushels and Pounds per Acre as a 12 Year Average. 1914-25.

Soil Treatment.	Wheat Bu.	Corn Bu.	Oats Bu.	Hay Lbs.
No lime and no sweet clover.....	7.3	22.8	12.8	360
Lime, sweet clover	16.0	36.9	24.0	2280
Lime, sweet clover, rock phosphate....	20.6	39.9	27.2	2060
Lime, sweet clover, rock phosphate, kainit	20.9	43.3	29.6	2220

On this field the sweet clover was used as a green manure crop and results from its use as a source of nitrogen compares very favorably with the results from stable manure on this type of soil.

The sweet clover, limestone, rock phosphate, combination was apparently effective in restoring fertility on the unglaciated soils of the Ozark Ridge region. Table V shows crop yields from the Elizabethtown Experiment Field in Hardin County. This field has been in operation since 1917 and represents the Yellow Silt Loam soils of that region.

TABLE V.

Corn and Wheat Yields in Bushels per acre, 4 years Average—1922-25.

Soil Treatment.	Corn.	Wheat.
Untreated land	8.4	3.6
Limestone—sweet clover	33.7	11.4
Lime, sweet clover, rock phosphate.....	47.3	18.4
Lime, sweet clover, rock phosphate, kainit.....	47.7	19.8

The results in Table V shows that the soil treatment indicated is very effective in increasing crop yields and restoring the fertility of the soil.

Experimental soil improvement has been in progress in various parts of southern Illinois for a number of

years, and its practical possibilities may be determined with a fair degree of accuracy. While experimental success does not always assure practical success, yet it is a fair indication of what may be reasonably expected. The following plates show some graphs prepared by Hein (1926) indicating the trend of crop yields on treated land as compared with those on untreated land. These drawings visualize experimental results and aid materially in their interpretation.

In Text, Figure1, the curved lines represent the annual corn yields. The Heavy straight line indicates the trend of corn yields on the untreated land (O) and the broken straight line indicates the trend of corn yields on treated land (RL). The treatment in this case consists of limestone and sweet clover as a green manure. The figures represent a 13 year average (1913-25) and are taken from two experiment fields, Enfield (White County) and Raleigh (Saline County). Here the corn yield on the untreated land, has gone down from 21.4 bushels to 19.2 bushels an acre during the 13 year period. On the treated land however, the yields have gone up from 30.6 bushels to 39.9 bushels an acre, and in 1925 the trend of the treated land yield is over 20 bushels an acre higher than that of the untreated land. Text Figure 2, shows the trends of the lime-sweet clover treatment (solid line) compared with the lime-sweet clover-rock phosphate treatment (broken line RLP). In this comparison the addition of rock phosphate has given a decided upward trend to the corn yield which is 8 bushels an acre above the lime-sweet clover treatment and about 28 bushels an acre above the untreated land.

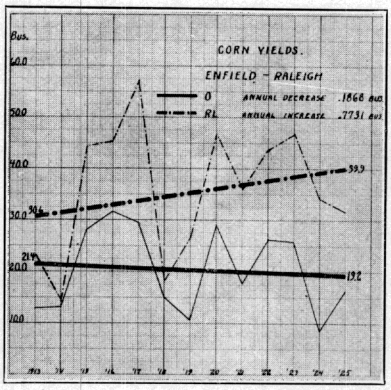
In Text Figure 3 is shown the annual acre production and trend of wheat yields on three experiment fields located, respectively, at Toledo, Oblong, and Ewing. These fields are representative of the Gray Silt Loam prairie soils. The straight heavy line represents the trend of wheat yields on untreated land (O) which has been slightly upward during the past 13 years. The broken heavy line represents the trend of wheat yields on the sweet clover-limestone treatment and shows the yield has gone up from 13.8 bushels to 19.6 bushels an

acre and is 12 bushels an acre higher than the untreated land. Text Figure 4, shows in the broken straight line the influence of the addition of rock phosphate (RLP) over the lime-sweet clover treatment (RL). Here the addition of rock phosphate has sent the wheat yield up to 28.3 bushels an acre as compared to 19.6 bushels on the lime-sweet clover treatment and 7.6 bushels on the untreated land.

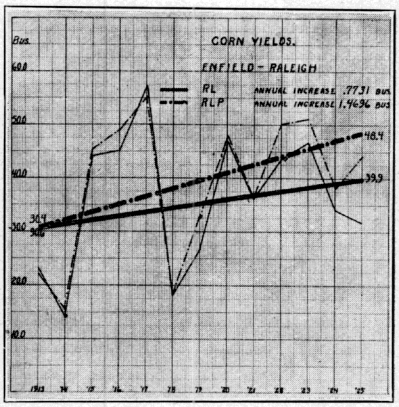
These experimental results show very favorable acre yields, and they show very good indications that southern Illinois soils are very responsive to certain fertility treatment. Since these experimental results are sufficiently reliable to place before the farmer it is interesting to note how he responds to them. In 1906 there were approximately 120 tons of limestone used on southern Illinois farms, while according to Bent (1926) in 1925 about 20 years later there were used in this region in a single year 322,650 tons of agricultural limestone. In 1924 there were 26,650 acres of sweet clover seeded, while 10 to 12 years previous there was scarcely any seeded. A great deal of the credit for this educational work belongs to the local farm bureau organizations, and these results show that a great deal of progress is being made toward restoring the fertility to southern Illinois farm lands.

REFERENCES.

Mosier, J. G. 1918. Climate of Illinois Bul. 208. Ill. Agr. Exp. Sta.
Curtiss, D. C. 1852. Western Portraiture, page 238.
Woodward, John. 1923. Origin of Prairie in Illinois. Trans. Ill. Acad. Sci. 16th Annual Meeting. Vol. XVI, page 259.
Waters, H. J. 1911. The Role of the Farmer. Wallace's Farmer. March 3.
Weller, Stuart. 1921. Some Events in the Geological History of Southern Illinois. Trans. Ill. Acad. Sci. Vol. XIV, pages 21-35.
Carrier, Lyman. 1923. Beginners of Agriculture in America. McGraw-Hill Book Company, New York.
Peck, J. M. 1837. A Gazateer of Illinois.
Fourteenth Census of the United States. 1920.
Farm Census of U. S. 1925. Dept. of Commerce, Washington, D. C.
Clay County Soils. 1911. Soil Rpt. No. 1, Ill. Agr. Exp. Sta.
Bond County Soils. 1913. Soil Rpt. No. 8. Ill. Agr. Exp. Sta.
Hardin County Soils. 1912. Soil Rpt. No. 3. Ill. Agr. Exp. Sta.
Johnson County Soils. 1925. Soil Rpt. No. 30. Ill. Agr. Exp. Sta.
McLean County Soils. 1915. Soil Rpt. No. 10. Ill. Agr. Exp. Sta.
Hopkins, C. G., Pettit, J. H. 1908. The Fertility of Illinois Soils. Bul. 123. Ill. Agr. Exp. Sta.
Hein, M. A. 1926. Unpublished data. Ill. Agr. Exp. Sta.
Bent, J. R. 1926. Official Report Ill. Agr. Association

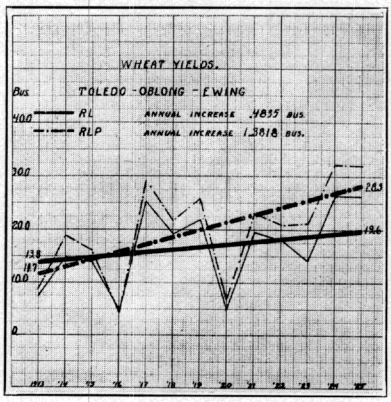


Text Fig. 1.

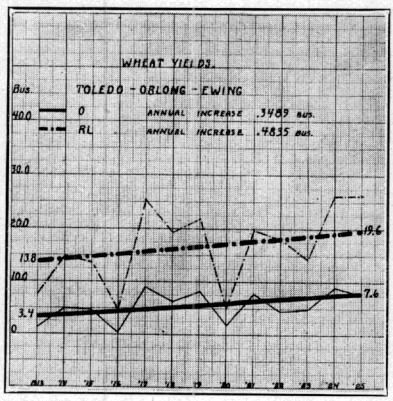


Text Fig. 2.

Curves and straight line trends illustrating the influence of soil treatment upon corn yields on the Enfield and Raleigh Experiment Fields. Comparison between untreated land (O), limestone, sweet clover, green manure (RL), and limestone, rock phosphate, sweet clover, green manure (RLP).



Text Fig. 3.



Text Fig. 4.

Curves and straight line trends illustrating the influence of soil treatment upon wheat yields on the Toledo, Oblong, and Ewing Experiment Fields. The comparison is with untreated land (O), limestone, sweet clover, green manure (RL), and limestone, rock phosphate, sweet clover, green manure (RLP).