# SOIL SURVEY OF IOWA

## PLYMOUTH COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

**Agronomy Section**

**Soils**



**Soil Survey Report No. 54**

**April, 1929**

**Ames, Iowa**

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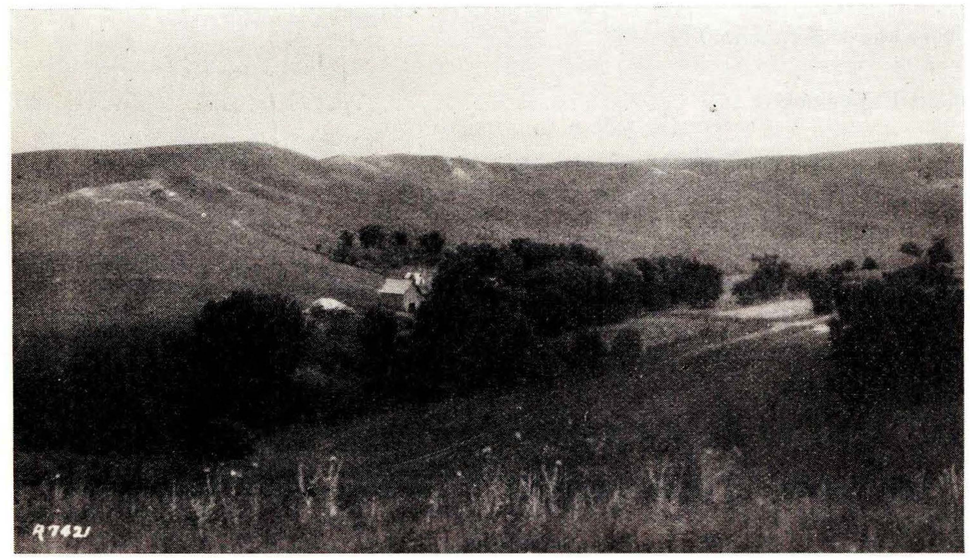
## Report No. 54—PLYMOUTH COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of D. S. Gray, L. W. Forman and H. R. Meldrum



A typical topography of Knox silt loam in Plymouth County.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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# PLYMOUTH COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of D. S. Gray, L. W. Forman and H. R. Meldrum

Plymouth County is located in western Iowa, being separated by the Big Sioux River from South Dakota on the west, and is in the third tier of counties south of the Minnesota State line. It lies entirely in the Missouri loess soil area and hence the soils of the county are mainly loessial in origin.

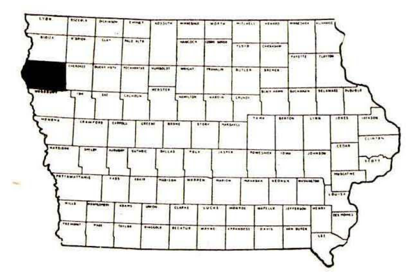

Fig. 1. Map showing the location of Plymouth County.

The total area of the county is 860 square miles or 550,400 acres. Of this area 531,985 acres or 96.6 per cent are in farm lands. The total number of farms is 2,185, and the average size of the farms is 189 acres. Thirty-five per cent of the total farm land is operated by owners, the remaining area in farm land being operated by renters. The following figures taken from the Iowa Yearbook of Agriculture for 1927 show the utilization of the farm land of the county:

| | |
|---|---|
| Acreage in general farm crops | 388,706 |
| Acreage in farm buildings, public highways and feed lots | 27,994 |
| Acreage in pasture | 113,720 |
| Acreage in waste land not utilized for any purpose | 952 |
| Acreage in farm woodlots used for timber only | 716 |
| Acreage in farm land lying idle | 2,232 |
| Acreage in crops not otherwise listed | 186 |

## THE TYPE OF AGRICULTURE IN PLYMOUTH COUNTY

The type of agriculture followed in Plymouth County at the present time consists of a system of general farming which includes the growing of corn and other grains and some hay crops, the breeding and feeding of hogs and beef cattle and, to a limited extent, of dairy farming. On most of the farms the major portion of the income is derived from the livestock industry, particularly from the sale of hogs and cattle. Dairying is important and there are many farms operating on a dairy basis. The income from dairying is considerable in the county as a whole. The sale of corn, wheat and other crops produced adds to the total income. The chief crops are corn, oats, hay, wheat and barley. A large portion of these crops, with the exception of the wheat, is used for feeding purposes on the farms; the remainder is sold. The wheat serves as a cash crop on the farms on which it is produced. Some income is derived on many farms from orchard fruits, small fruits, potatoes and certain garden crops.

The acreage in waste land is small in proportion to the total area in farm land. Much of the waste area might be reclaimed and made productive if proper methods of soil treatment were adopted. It is impossible to give general recommendations for the reclamation of infertile areas because of the fact that the

* See Soil Survey of Plymouth County, Iowa, by D. S. Gray of the Iowa Agricultural Experiment Station, in charge, and A. L. Gray of the U. S. Department of Agriculture. Field operations of the Bureau of Soils, 1923.

causes of infertility of land are so variable. In a later section of this report suggestions will be offered regarding treatments which would be most desirable for areas of waste land in various parts of the county. Advice regarding the handling of soils in special cases where the conditions are more or less abnormal, will be given by the Soils Section of the Iowa Agricultural Experiment Station upon request.

## CROPS GROWN IN PLYMOUTH COUNTY

The general farm crops grown in Plymouth County in the order of their importance are corn, oats, alfalfa, barley, wheat, hay, potatoes and rye. The average yield and value of these crops are given in table I.

Corn is the most important crop both in acreage and value. In 1927 it was grown on 40.2 per cent of the total farm land. Average yields of corn amounted to 37.5 bushels per acre. The most popular varieties grown are Reid Yellow Dent, Wimple Yellow Dent, Silver King and Iowa Silvermine. There is also some Iowa Goldmine, and a considerable acreage of an unknown variety. Usually more than one-half of the corn crop is used for feeding purposes on the farms, the remainder being sold for local consumption or to elevators in nearby towns where it is shipped to the markets. It is the chief cash crop produced in the county.

Oats are second in importance, being grown on 20.1 per cent of the total farm land. Average yields of this crop in 1927 amounted to 29.7 bushels per acre. The varieties most commonly grown include Iowa 103, Iowa 105, Kherson and Iowar. The Big Four, a midseason white oat, is also grown to some extent. A large portion of the oat crop is grown for feed for the work stock, and serves as a nurse crop for clover and alfalfa. The surplus is sold as grain.

TABLE I. AVERAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN PLYMOUTH COUNTY, IOWA*

| Crop | Acreage | Percent of total farm land of county | Bushels or tons per acre | Total bushels or tons | Average price | Total value of crops |
|---|---|---|---|---|---|---|
| Corn | 213,697 | 40.2 | 37.5 | 8,013,638 | $0.69 | $5,529,410 |
| Oats | 106,602 | 20.1 | 29.7 | 3,168,771 | 0.42 | 1,330,884 |
| Winter wheat | 2,547 | .5 | 21.9 | 55,895 | 1.17 | 65,397 |
| Spring wheat | 4,410 | .8 | 12.0 | 52,877 | 1.15 | 60,809 |
| Barley | 14,950 | 2.8 | 28.6 | 427,751 | 0.66 | 282,316 |
| Rye | 538 | .1 | 22.4 | 12,056 | 0.86 | 10,368 |
| Clover hay† | 1,561 | .3 | 1.95 | 3,044 | 12.50 | 38,050 |
| Timothy hay | 3,138 | .6 | 1.23 | 3,860 | 10.50 | 40,530 |
| Clover and timothy hay (mixed) | 5,405 | 1.0 | 1.43 | 7,729 | 11.77 | 90,970 |
| All other tame hay | 1,480 | .3 | 2.64 | 3,907 | 11.77 | 45,985 |
| Alfalfa | 16,537 | 3.1 | 3.47 | 57,383 | 16.00 | 918,128 |
| Wild hay | 13,761 | 2.6 | 1.33 | 18,302 | 10.00 | 183,020 |
| Soybeans | 77 | .01 | ------ | -------- | ------ | ---------- |
| Potatoes | 1,172 | .2 | 127.00 | 148,844 | 1.00 | 148,844 |
| Flax seed | 25 | .01 | 10.4 | 260 | 1.95 | 507 |
| Timothy seed | 85 | .01 | 5.3 | 453 | 1.65 | 747 |
| Clover seed† | 45 | .01 | 1.96 | 88 | 16.10 | 1,417 |
| Sweet clover seed | 236 | .04 | 3.8 | 904 | 5.50 | 4,972 |
| Sweet clover‡ | 2,404 | .5 | ------ | -------- | ------ | ---------- |

* Iowa Yearbook of Agriculture, 1927.
† Sweet Clover not included.
‡ All varieties, for all purposes.



Alfalfa ranks third in acreage and value, being produced on 3.1 per cent of the total farm land. Average yields of this crop amount to 3.47 tons per acre. It is considered a very valuable crop and may be grown very successfully thruout the uplands and on many of the bottomland types. By the addition of lime when the soil is acid in reaction and by inoculation of the crop, very successful yields may be secured.

Hay crops are grown to a considerable extent, clover being produced on a rather limited acreage and timothy somewhat more extensively. The mixture of clover and timothy is the most popular hay crop. Yields of the mixture amount to 1.43 tons per acre. Wild hay is grown on the bottomlands which are subject to overflow and on depressed areas in the uplands and yields of this crop amount to 1.33 tons per acre. Wild hay is produced on 2.6 per cent of the total farm land.

Some clover and timothy are grown for seed. There is a limited area of sweet clover some of which is utilized for the production of seed.

Barley is an important crop, being grown on 2.8 per cent of the total area. It is a cash crop and is sometimes used in the rotation in place of oats. Wheat growing is limited, both winter wheat and spring wheat being used. The Turkey variety is the chief winter wheat grown; the popular spring wheats are the Marquis, Bluestem and Velvet Chaff. There is a limited area in rye and in soybeans. A small acreage is devoted to the growing of flax for seed.

Potatoes are grown chiefly to supply the home demand and satisfactory yields are secured. The value of the crop is considerable. Other truck crops are grown to a limited extent but usually merely to supply the home demand. There is no development of this industry on a commercial scale. There are a few orchards, and a few farms produce apples in sufficient quantities to sell on the market. Some small fruits are produced on nearly every farm. The fruit industry as a whole is not developed to any large extent, however, in Plymouth County, altho on a few farms considerable income is derived from the sale of the fruit crop.

## THE LIVESTOCK INDUSTRY IN PLYMOUTH COUNTY

The livestock industry of the county includes the raising and feeding of hogs and beef cattle and some dairying. The following figures taken from the Iowa Monthly Crop Report for July 1, 1928, giving the January 1, 1928, estimates of the Bureau of Agricultural Economics in co-operation with the Iowa State Department of Agriculture, show the extent of the livestock industries:

| | |
|---|---|
| Horses | 16,300 |
| Mules | 1,110 |
| Cattle, all | 59,400 |
| Hogs | 223,900 |
| Sheep | 8,500 |

The most extensive livestock industry is hog raising. The total number of hogs on the farms on January 1, 1928, was 223,900, and the number per farm ranged from 50 to over 150. The more popular breeds are the Poland China, Duroc Jersey, Spotted Poland China and Chester White, with some Hampshire and many grade hogs. The principal markets are Sioux City, Chicago, Omaha, Minneapolis and St. Paul.

The feeding and breeding of beef cattle is important and there are many purebred herds, including Shorthorn, Hereford and Angus cattle and many nitrogen to the soil in considerable quantities, if proper precautions are taken in the handling of the crop and, therefore, green manuring may be considered the most desirable means of nitrogen fertilization. At the present time there seems to be no immediate need for the use of commercial nitrogen on the land in this county, as leguminous crops may be successfully and profitably grown and utilized as nitrogen fertilizers.

The phosphorus supply is rather low in most of the soils. It is evident, therefore, that phosphorus fertilizers will be needed on these soils in the near future if crop production is to continue to be satisfactory, but it seems probable, from some experimental work and from much farm experience, that the use of a phosphate fertilizer might prove of large value in many cases at the present time. Experiments with phosphate fertilizers have been carried out in the field and in the greenhouse and comparisons have been made of the use of rock phosphate and superphosphate, the two common commercial forms of phosphorus. In general very desirable results have followed the application of these phosphate fertilizers to the various soils which have been tested. In some cases the superphosphate has proven superior but in other instances the rock phosphate has seemed to be as good. Definite conclusions regarding the relative value of the two phosphates cannot, therefore, be drawn at the present time. It is recommended that both phosphates be tested on small areas on individual farms to determine their relative value under the particular conditions pertaining there. By making such tests farmers may determine the response of their particular soils to a phosphorus fertilizer and may also learn which of the phosphorus carriers will bring about the most desirable and profitable effects on crop growth.

Tests have been carried out on a number of co-operative soil experiment fields, using a complete commercial fertilizer in comparison with superphosphate and rock phosphate. In none of these tests has the complete commercial fertilizer brought about any pronouncedly greater beneficial results than the superphosphate. In fact the increases in crop yields from the two fertilizers are very similar in most cases. The use of a complete commercial fertilizer would, therefore, not be as economically desirable, owing to the fact that the superphosphate is cheaper. Hence it is not recommended that complete commercial fertilizers be used on the soils of this county at the present time where general farm crops are to be grown. One of the phosphorus carriers will undoubtedly prove more profitable. Where special crops, and particularly truck crops are grown, however, the use of a complete commercial fertilizer may be distinctly profitable.

There is considerable erosion occurring in this county, particularly on the rougher uplands. The areas of the Clarion silt loam and the Dickinson loam are somewhat eroded. There is also considerable erosion in the Knox silt loam on the steeper slopes and in the areas of the Marshall, where the topography is more strongly rolling and conditions have been favorable for the washing action of water. On all of these soils there has been considerable washing away of the surface soil and gullies have been formed and in many cases the land has been seriously injured. In all instances where erosion occurs, some method should be followed to prevent or control the destructive action. Suggestions are offered

# WEST SECTION

# SOIL MAP OF PLYMOUTH COUNTY IOWA

Thomas D. Rice, Inspector Northern Division. Soils surveyed by D. S. Gray of the Iowa Agricultural Experiment Station, and A. L. Gray of the U. S. Dept. of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
H. G. Knight, Chief. Curtis F. Marbut, in charge Soil Survey

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P. E. Brown, Associate in Charge

## LEGEND

*Swamp and Bottomland Soils*

- 26 Wabash silt loam
- 48 Wabash silty clay loam
- 72 Wabash clay
- 153 Lamoure silt loam
- 111 Lamoure silty clay loam
- 130 Cass fine sandy loam

*Terrace Soils*

- 108 O'Neill loam
- 126 O'Neill sandy loam

*Drift Soils*

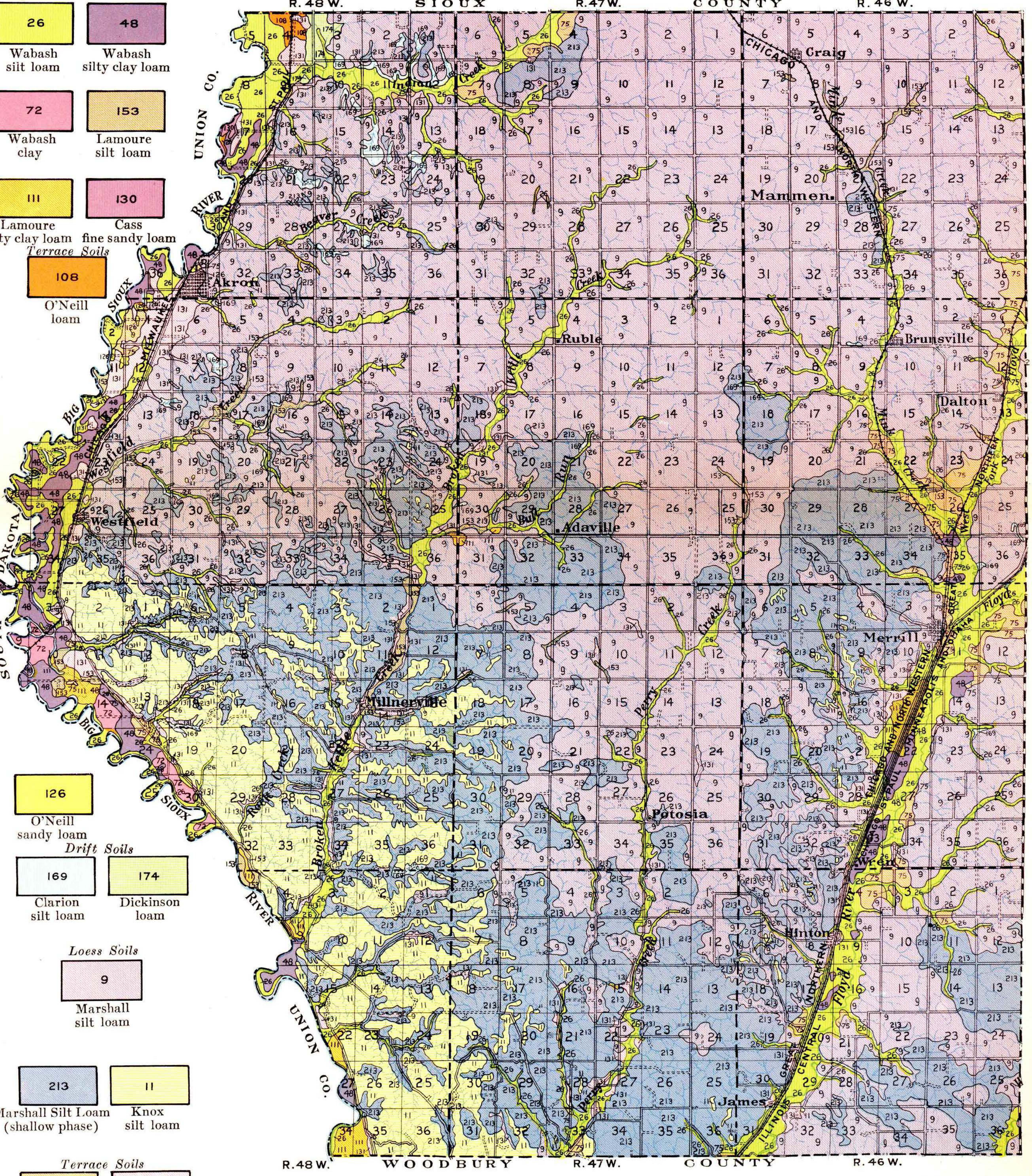
- 169 Clarion silt loam
- 174 Dickinson loam

*Loess Soils*

- 9 Marshall silt loam
- 213 Marshall Silt Loam (shallow phase)
- 11 Knox silt loam

*Terrace Soils*

- 75 Waukesha silt loam
- 131 Judson silt loam




SCALE: 1 INCH TO 2½ MILES

AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA

coarse silty material rather retentive of moisture and having the characteristic of standing in vertical cuts.

Where erosion has occurred to some extent on many of the steeper slopes, the surface covering has been washed away and the lighter brown loess subsoil is exposed, or there has even been an exposure of the underlying drift material.

In the areas where the color is lighter and the original loess material appears close to the surface the soil is known as the Knox silt loam. It is most extensively developed on the steeper areas of the loessial sections. On the extensive uplands where the topography is more gently rolling to undulating, more organic matter has accumulated and less erosion has occurred. This soil is mapped as the Marshall silt loam. Where erosion has occurred on the more strongly undulating areas of Marshall, the shallow phase of the type has been mapped. This merely indicates a shallower surface soil.

The terrace and bottomland soils have been formed mainly from the loessial material carried down from the uplands. However, they are frequently made up of mixtures of glacial and loessial material, but most of them may be considered to have come from the loessial deposits.

## PHYSIOGRAPHY AND DRAINAGE

The topographic conditions in different parts of the county are variable, depending in part upon the features which were developed by the deposition of the thick loessial deposit and to a much greater extent by the erosion which has occurred in the years which have elapsed since the deposit was made. There are two rather definite types of topography in the county, one which is characteristic of the entire area except the extreme southwestern part, is that of a gently eroded plain. In this section the hills are smooth and rounded with wide shallow valleys intervening. Here the streams and intermittent drainageways extend into all parts of the upland and there are no flat, undrained areas or depressions. The valleys are well developed, the slopes long and gentle and the bottomlands relatively wide. In only a few areas has there been any development of steeper slopes due to more rapid erosion in the surface soil. A few such areas are found along Broken Kettle Creek and Bull Run in Westfield and Johnson Townships, south of Indian Creek in northwestern Creston Township, for several miles west of the bottomlands along Floyd River in southern Washington Township, and along the larger streams in eastern Hungerford, Lincoln and Elk Horn Townships. Along the West Fork Little Sioux River south of Kingsley and the lower part of Whiskey and Mud Creeks, there are rougher and steeper lands bordering the bottoms. Here the valleys are from 90 to 170 feet below the surrounding hills.

In the southwestern part of the county, chiefly southwest of a line between Westfield and James and including the greater part of Sioux and Hancock Townships and a portion of Perry Township, the topography is much rougher. Here the surface is strongly rolling to hilly, the valley slopes are steep and in some places rise to abrupt bluffs 150 to 250 feet above the adjacent bottomland. There are sharp hills and ridges thruout this region. Along the Big Sioux River the hills rise above the bottomlands in steep slopes or bluffs, but a few miles back from the river they become smoother and gradually grade into the gently undulating topography of the typical upland areas.



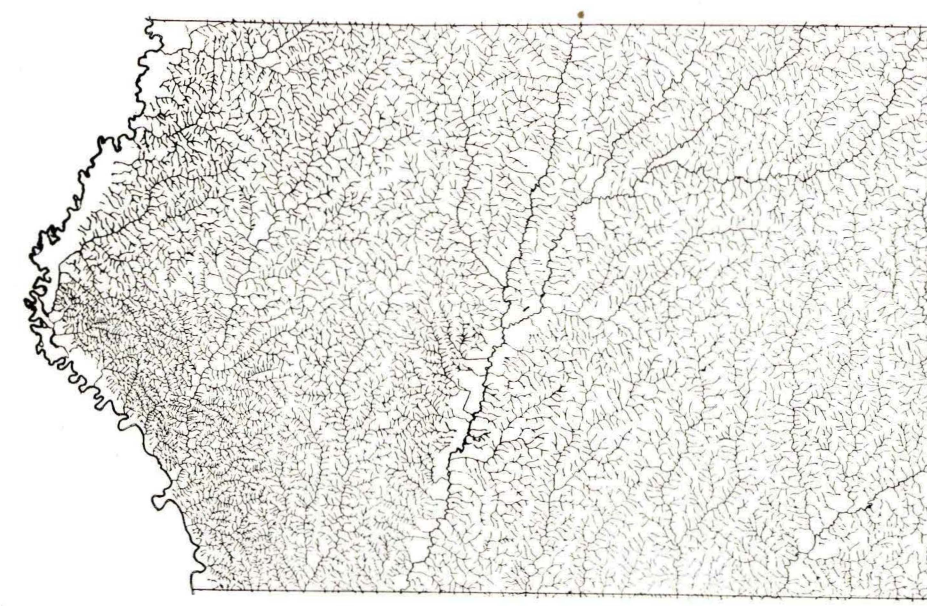


Fig. 2. Drainage map of Plymouth County.

Extensive areas of terrace or second bottomlands are developed along all of the larger streams and most extensively along the Floyd, Big Sioux and West Fork Little Sioux Rivers. The terraces range in extent from 40 to 500 acres and vary in width from one-fourth to one-half mile. They are all well above overflow. The first bottomlands are found along all the larger streams, and narrow strips extend for miles along the smaller drainageways.

The drainage of the county is brought about by the Big Sioux River, Broken Kettle Creek, Perry Creek, the Floyd River, with its various branches, Mud Creek, West Fork Floyd River, Willow Creek, Deep Creek, Plymouth Creek, Whiskey Creek, Elliott Creek, Mud Creek, Clear Creek, the West Fork Little Sioux River, Deer Creek and various tributaries of these larger streams.

The various streams with their tributaries and intermittent drainageways extend into practically all parts of the uplands, and the natural drainage system is adequate. Very seldom, and only in limited areas, is there any need for artificial drainage in the upland portions. On the terraces and bottomlands are small areas where drainage is needed, this being particularly true of the level to flat bottomlands where the soil conditions are such that the removal of excess moisture is slow. The Wabash and Lamoure soils are the types which are chiefly in need of drainage. The accompanying map indicates the extensive drainage system of the upland areas. It is evident that the need for drainage is not great.

# THE SOILS OF PLYMOUTH COUNTY

The soils of Plymouth County are grouped into four classes, according to their origin and location. These are drift soils, loess soils, terrace soils, and swamp and bottomland soils. Drift soils are formed from the deposits left by

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN PLYMOUTH COUNTY

| Soil Group | Acres | Percent of total area of County |
|---|---|---|
| Drift soils | 4,480 | 0.8 |
| Loess soils | 470,144 | 85.4 |
| Terrace soils | 18,432 | 3.5 |
| Swamp and bottomland soils | 57,344 | 10.3 |
| Total | 550,400 | ---- |

retreating glaciers and they consist of mixtures of sand, gravel and clay and frequently contain pebbles and boulders. Loess is a fine dust-like deposit laid down over the surface of the land by the wind, presumably at a time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a depression of the river channels. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams, and often they are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Plymouth County are shown in table II.

Drift soils occur to only a very limited extent, covering 0.8 per cent of the total area. By far the largest portion of the county is covered by the loess types; 85.4 per cent of the total area is loessial. Terrace soils are developed along the major streams flowing thru the county and together they cover 3.5

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN PLYMOUTH COUNTY

| Soil No. | Soil Type | Acres | Percent of total area of county |
|---|---|---|---|
| | DRIFT SOILS | | |
| 169 | Clarion silt loam | 4,096 | 0.7 |
| 174 | Dickinson loam | 384 | 0.1 |
| | LOESS SOILS | | |
| 9 | Marshall silt loam | 369,344 | 81.3 |
| 213 | Marshall silt loam (shallow phase) | 78,016 | |
| 11 | Knox silt loam | 22,784 | 4.1 |
| | TERRACE SOILS | | |
| 75 | Waukesha silt loam | 11,968 | 2.2 |
| 131 | Judson silt loam | 6,016 | 1.1 |
| 126 | O'Neill sandy loam | 192 | 0.1 |
| 108 | O'Neill loam | 256 | 0.1 |
| | SWAMP AND BOTTOMLAND SOILS | | |
| 26 | Wabash silt loam | 46,784 | 8.5 |
| 48 | Wabash silty clay loam | 4,480 | 0.8 |
| 72 | Wabash clay | 832 | 0.1 |
| 153 | Lamoure silt loam | 3,712 | 0.6 |
| 111 | Lamoure silty clay loam | 1,472 | 0.2 |
| 130 | Cass fine sandy loam | 64 | 0.1 |
| | Total | 550,400 | ---- |



per cent of the total area. There is a considerable area of bottomland soils, together covering 10.3 per cent of the total area.

There are 14 individual soil types and these with the shallow phase of the Marshall silt loam make a total of 15 soil areas. There are two drift soils, two loess types, four terrace soils and six areas of swamp and bottomland soils. The various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report, and the names indicate certain group characteristics. The areas covered by the various soil types in the county are shown in table III.

The Clarion silt loam is the most extensive of the two drift soils, covering 0.7 per cent of the county. The Dickinson loam, the second drift soil, is of very limited extent, covering only 0.1 per cent of the county. The Marshall silt loam is the most extensively developed loess soil. Together with the shallow phase which is more limited in extent, this type covers 81.3 per cent of the total area. The Knox silt loam, the second of the loess types, is more limited in extent, covering only 4.1 per cent of the county. The Waukesha silt loam is the largest of the terrace soils, and covers 2.2 per cent of the county. The Judson silt loam is second in area, covering 1.1 per cent of the total area. The O'Neill sandy loam and the O'Neill loam are very minor in extent, each covering 0.1 per cent of the county. The Wabash silt loam is the largest of the bottomland types and the second largest soil type. It covers 8.5 per cent of the total area. The Wabash silty clay loam is the second largest bottomland soil, covering 0.8 per cent of the county. The Lamoure silt loam is the third largest bottomland soil, covering 0.6 per cent of the total area. The Lamoure silty clay loam, Wabash clay and Cass fine sandy loam, are all minor in extent, covering 0.2, 0.1 and 0.1 per cent of the total area of the county, respectively.

The topography is variable among the individual soil types and while some differences occur within soil types, there is a rather general relationship between topographic position and the soil type which is mapped. In topography the Marshall silt loam ranges from gently undulating to rolling. The drift soils, the Clarion silt loam and the Dickinson loam, are usually more rolling than the Marshall. The Knox silt loam occurs on the steep bluffs along the borders of the uplands where these join the bottomlands, or adjacent to the river, and the topography of this type is steep to rough and abrupt. The terrace soils and swamp and bottomland types are generally level to flat and present no distinct topographic features.

## THE FERTILITY IN PLYMOUTH COUNTY SOILS

Samples were taken for analysis from each soil in the county, to determine its plant food content. The extensively developed types were sampled in triplicate, while only one sample was taken from each of the minor types. All samples were carefully secured to insure their being representative of the individual types and to eliminate all variations due to previous treatments. Samples were taken to three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches, and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were followed in the determination of the phosphorus, nitrogen and carbon. The Truog qualitative test was used in the determination of the limestone requirement. The figures given in the tables are the averages of the results of duplicate determinations of all samples of each type and they represent, therefore, the averages of two or six determinations.

## THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the soils varies but not widely. The Dickinson loam which is the lowest in phosphorus shows a content of 1,010 pounds per acre, while the Wabash silty clay loam, which is the highest, shows a content of 1,884 pounds per acre.

No definite relationship between the phosphorus content of the soils and the different soil groups is evident. On the average the bottomland types are a little better supplied than the upland soils, which might be expected from the fact that there has been less plant growth on these types and hence a smaller removal of phosphorus.

A few comparisons may be made, however, among the various soil series which are mapped. On the drift uplands the Clarion silt loam is richer in phosphorus than the Dickinson loam. On the loessial uplands the Marshall silt loam is much better supplied than the Knox silt loam. On the terraces the Judson silt loam is richer than the other terrace types, while there is little difference between the Waukesha and the O'Neill soils. On the bottomlands the Wabash and Lamoure types are higher in phosphorus on the average than the Cass soils. There is little difference between the Wabash and Lamoure types, however. It seems probable that some relationship exists between the phosphorus content of soils and the characteristics which serve as a basis for distinguishing the various series. Thus differences in topography, the color of the soil and the subsoil characteristics influence the amount of phosphorus to a considerable extent. The soils which are darker in color, more level in topography and have heavier subsoils, are usually higher in phosphorus. These relationships appear in the comparisons which have been made of the various soil series. The Clarion soils are darker and have heavier subsoils than the Dickinson types. The Marshall soils are darker than the Knox and more level in topography. The Judson soils are darker than the other terrace types. The Wabash and Lamoure types on the bottoms are darker and have heavier subsoils than the Cass types.

Usually a rather definite relationship exists between the phosphorus content of soils and the texture of the types. It is not possible to make many comparisons along this line in Plymouth County, as in only one or two cases is there more than one type of a series mapped. On the bottomlands the Wabash silty clay loam is much higher than the clay or the silt loam and the Lamoure silty clay loam is much higher than the Lamoure silt loam. On the terraces the O'Neill loam is slightly higher than the O'Neill sandy loam. These differences reflect the variations in texture which occur. Previous observations along this line are very largely confirmed. Evidently, fine textured types are better supplied with phosphorus than coarse textured soils. Silty clay loams are usually



TABLE IV. PLANT FOOD IN PLYMOUTH COUNTY, IOWA, SOILS

Pounds per acre of 2 million pounds of surface soil (0-6⅔")

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | **DRIFT SOILS** | | | | | |
| 169 | Clarion silt loam | 1,252 | 2,400 | 30,301 | ------ | 2,000 |
| 174 | Dickinson loam | 1,010 | 3,000 | 33,482 | ------ | 2,000 |
| | **LOESS SOILS** | | | | | |
| 9 | Marshall silt loam | 1,329 | 2,467 | 49,619 | ------ | 2,000 |
| 213 | Marshall silt loam (shallow phase) | 1,589 | 2,000 | 36,198 | ------ | ------ |
| 11 | Knox silt loam | 1,279 | 2,640 | 21,888 | 27,538 | ------ |
| | **TERRACE SOILS** | | | | | |
| 75 | Waukesha silt loam | 1,266 | 4,800 | 49,409 | ------ | 2,000 |
| 131 | Judson silt loam | 1,441 | 3,660 | 40,795 | ------ | ------ |
| 126 | O'Neill sandy loam | 1,225 | 3,440 | 38,386 | ------ | 2,000 |
| 108 | O'Neill loam | 1,266 | 2,200 | 38,168 | ------ | ------ |
| | **SWAMP AND BOTTOMLAND SOILS** | | | | | |
| 26 | Wabash silt loam | 1,427 | 3,920 | 60,544 | ------ | 1,000 |
| 48 | Wabash silty clay loam | 1,884 | 2,160 | 61,493 | ------ | ------ |
| 72 | Wabash clay | 1,711 | 5,080 | 51,960 | ------ | ------ |
| 153 | Lamoure silt loam | 1,185 | 6,440 | 65,216 | 234 | ------ |
| 111 | Lamoure silty clay loam | 1,872 | 3,120 | 61,415 | ------ | ------ |
| 130 | Cass fine sandy loam | 1,495 | 1,800 | 32,054 | 2,850 | ------ |

richer than silt loams, loams and sandy loams. Silt loams generally show a higher content of phosphorus than sandy types, and loams are generally higher in phosphorus than sandy loams or sand of the same series.

Considering the analyses as a whole, it is evident that there is no large supply of phosphorus in the soils of this county. It is certain, therefore, that phosphorus fertilizers will be needed on these soils in the very near future. It seems probable, from the greenhouse experiments and field tests which have been carried out on these soil types and from the experiences of farmers who have tested the value of phosphorus fertilizers under their own conditions, that phosphorus fertilizers might be applied in many cases in this county with profit now. Farmers should test the value of rock phosphate and superphosphate on their soils at the present time. Thus they may determine for their particular conditions whether or not phosphorus will bring about profitable crop increases and which form of phosphorus fertilizer is the more desirable for use.

The nitrogen content of the soils varies from 1,800 pounds in the Cass fine sandy loam on the bottomlands up to 6,440 pounds in the Lamoure silt loam, also on the bottomlands. In general the various soils are fairly well supplied with nitrogen but in a few cases the content is rather low. No definite relationship is evident between the nitrogen content of the soil and the various soil groups. On the average the bottomland types are somewhat richer in nitrogen than the upland soils, because of the lower plant growth on these soils and hence the smaller removal of the element. The differences, however, between the drift soils, the loess soils and the terrace types are not of great significance.

There is some evidence, however, of the relationship of soil series to the nitrogen content of these soils. On the drift and loessial uplands there is no great difference in the nitrogen content of the soils of the different soil series which are represented. The Dickinson soil seems to be a little better supplied than the Clarion, but this is contrary to the usual results and is probably due to some abnormal condition in the individual sample of the Dickinson. On the loessial upland the Marshall and the Knox are very similar in nitrogen content. Ordinarily the Knox will run somewhat lower than the Marshall in content of this constituent. On the terraces the Waukesha and Judson soils are richer in nitrogen than the O'Neill types and on the bottomlands the Wabash and Lamoure soils are richer than the Cass types. Again there seems to be some relationship between the characteristics which serve to determine the soil series and the content of nitrogen.

The relationship between nitrogen and the texture of the soil is shown in a few cases. The O'Neill sandy loam is somewhat higher than the loam, but ordinarily the sandy loam would not be as well supplied as the loam. The Wabash clay is higher in nitrogen than the Wabash silt loam, but the silty clay loam of this series is slightly lower than the silt loam, which is contrary to the usual results. The Lamoure silt loam is higher than the Lamoure silty clay loam in these results and this, too, is contrary to the usual trend of results. These discrepancies are undoubtedly due to variations in the particular samples. Ordinarily coarse textured types are lower in nitrogen than fine textured soils. No wide differences occur in the textures of the soils in the various series which have been mentioned and this probably accounts for the fact that the nitrogen content is not widely different.

While the nitrogen content of the soils is not strikingly deficient, there are a few cases where the supply is rather low. In all instances, however, this element must be considered when systems of permanent fertility are planned. It is very necessary that some nitrogenous fertilizing material be employed on these soils at regular intervals, if the supply of this constituent is to be kept up. The most important material for supplying nitrogen is farm manure. The proper preservation and application of all the manure produced on the farm will aid materially in keeping up the nitrogen supply of the soil. The turning under of leguminous crops as green manures will also be of value in increasing the content of nitrogen in the soil. Green manuring is a very desirable practice on many of the soils in Plymouth County. The thoro utilization of all crop residues is likewise an aid in keeping up the supply of nitrogen. By the use of these natural fertilizing materials it seems unlikely that there should be any need for commercial nitrogenous fertilizers.

The supply of organic carbon or organic matter in the soils varies in much the same way as does the nitrogen. The bottomland soils are somewhat better supplied than are the upland and terrace types. The loessial uplands seem to be somewhat richer than are the drift uplands. The terrace types are a little higher on the average than the loessial soils. However, the differences are not great in any case. The Knox silt loam on the loessial upland is the lowest in organic carbon, containing 21,880 pounds per acre. The Lamoure silt loam on the bottomlands is the highest in this constituent, showing a content of 65,216

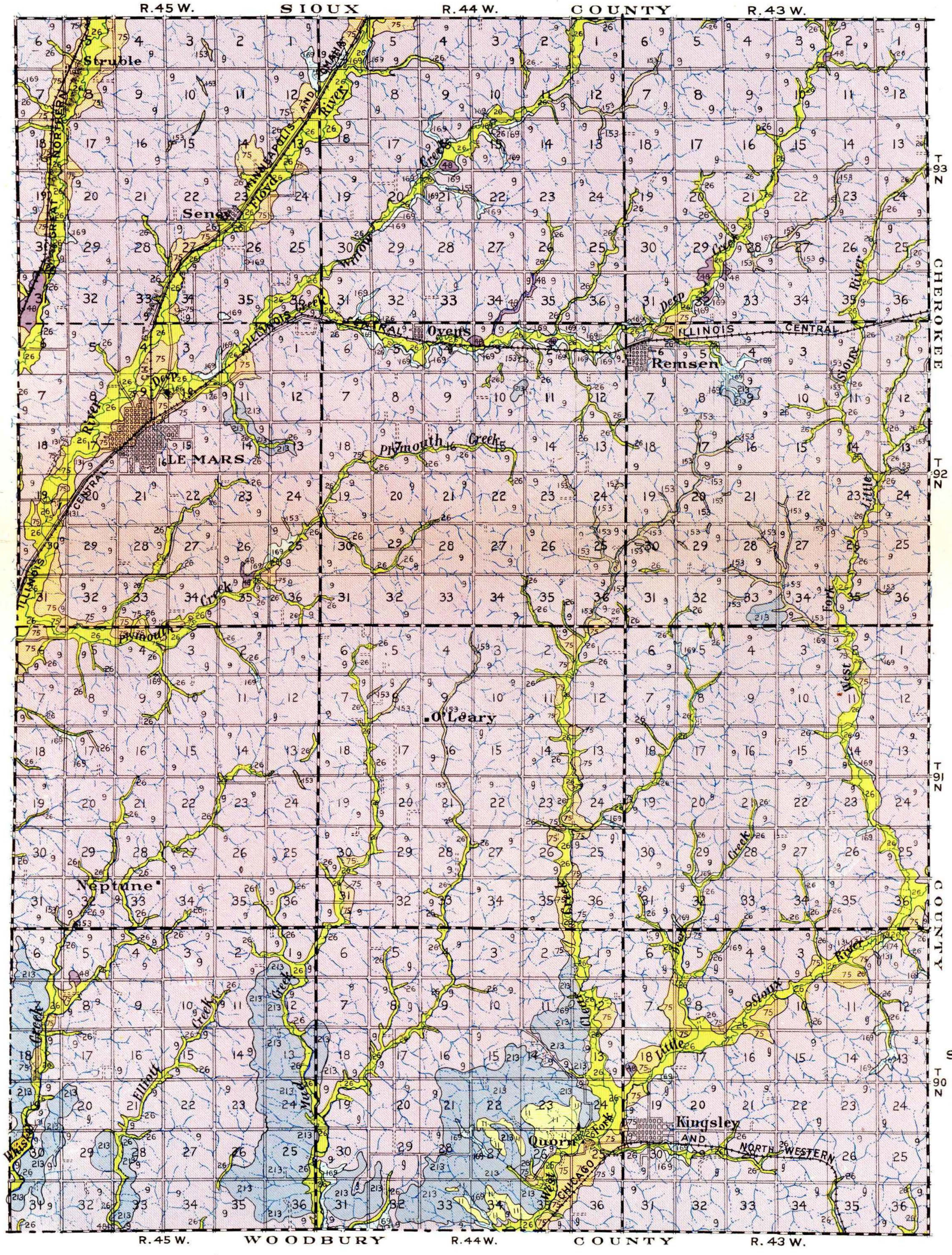
# EAST SECTION

# SOIL MAP OF PLYMOUTH COUNTY IOWA

Thomas D. Rice, Inspector Northern Division. Soils surveyed by D. S. Gray of the Iowa Agricultural Experiment Station, and A. L. Gray of the U. S. Dept. of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
H. G. Knight, Chief. Curtis F. Marbut, in charge Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in Charge




## LEGEND

*Drift Soils*

- 169 Clarion silt loam
- 174 Dickinson loam

*Loess Soils*

- 9 Marshall silt loam
- 213 Marshall Silt Loam (shallow phase)
- 11 Knox silt loam

*Terrace Soils*

- 75 Waukesha silt loam
- 131 Judson silt loam
- 126 O'Neill sandy loam
- 108 O'Neill loam

*Swamp and Bottomland Soils*

- 26 Wabash silt loam
- 48 Wabash silty clay loam
- 72 Wabash clay
- 153 Lamoure silt loam
- 111 Lamoure silty clay loam
- 130 Cass fine sandy loam

SCALE: 1 INCH TO 2½ MILES

AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA

pounds per acre. Some relationships of the various series to content of organic carbon, are shown. Thus the Knox silt loam is much lower in organic matter than the Marshall silt loam on the loessial uplands. The O'Neill types on the terraces are lower in this constituent than the Waukesha and Judson soils, and on the bottomlands the Wabash and Lamoure types are richer in organic matter than the Cass soils.

There is also some relationship of texture to organic carbon content. The Wabash silty clay loam is higher than the Wabash silt loam but the latter contains more organic matter than the Wabash clay which is somewhat different than the usual results. The Lamoure silt loam is slightly higher than the Lamoure silty clay loam which is also somewhat different than the usual results. These differences are probably due to the characteristics of the particular soil samples analyzed. The O'Neill sandy loam and O'Neill loam on the terraces show almost the same content of organic carbon, no effect of texture being evident. In general these results indicate that the characteristics which serve to determine the soil series have some effect on the organic matter content. Those types which are dark in color, level in topography and with heavy subsoils are richer in organic matter than those which are light colored, rolling to rough in topography and have coarse textured subsoils. These differences are evident in the comparisons between the Knox silt loam and the Marshall silt loam, between the Waukesha and Judson types on the terraces, with the poorer O'Neill soils and between the Wabash and Lamoure types on the bottoms with the poorer Cass soils.

Usually a rather definite relationship is evident between the nitrogen content of the soil and its content of organic carbon or organic matter. Types low in nitrogen are apt to be in need of organic matter. Soils deficient in organic matter are generally lacking in nitrogen. The amount of both these constituents in soils is usually definitely shown by the color. Types which are dark in color are well supplied with organic matter and usually have plenty of nitrogen. If the types are light colored the supply of both constituents is generally inadequate. The actual relationship between the carbon and nitrogen in soils generally indicates something of the rapidity with which the plant food in the soil is being changed into an available form. In many Plymouth County soils this relationship is such that it is apparent that the decomposition processes are not proceeding as rapidly as they should and there is certainly an inadequate production of available plant food constituents in some cases. On such soils the application of farm manure is of especially large value, as it stimulates the production of available plant food. On practically all of the soils of the county, however, the use of farm manure is very desirable for increasing and maintaining the fertility of the land. It supplies considerable amounts of organic matter and will build up the soil in this constituent. It also supplies plant food constituents and increases the supply of available plant food. Crop residues also aid in maintaining the organic matter content, and leguminous crops used as green manures will prove very valuable in providing more of the necessary organic matter in soils and permitting of greater crop production.

The Knox silt loam on the upland shows a high content of inorganic carbon. This type is, therefore, basic in reaction and not in need of lime. All the other upland types are slightly acid in reaction and show a low lime requirement. The terrace soils are all acid and show some lime requirement. On the bottomlands the Lamoure and Cass soils show a small content of inorganic carbon and are not in need of lime. The Wabash types are acid and need lime.

Wherever soils are acid, most satisfactory yields of crops cannot be secured, this being especially true with legumes. Where alfalfa and sweet clover are to be seeded, the testing of soils to determine their reaction or need of lime and the applying of the proper amount of lime is essential to insure satisfactory yields. The amount of lime needed by the various soil types can only be determined by special tests. Farmers should see to it that their soils are tested and that lime is applied as needed in order to insure the best crop returns.

### THE SUBSURFACE SOILS AND SUBSOILS

Tables V and VI give the results of the analyses of the subsurface soils and subsoils calculated on the basis of 4,000,000 pounds of subsurface soil per acre and 6,000,000 pounds of subsoil per acre.

The content of plant food in the lower soil layers shows little effect on the fertility of the soil unless a very large amount of some constituent or a striking deficiency in any element is present. Analyses of the surface soils usually indicate fairly accurately the plant food content and crop producing power of the soils, and thus indicate the needs. The lower soil layers in Plymouth County are not particularly high in any constituent nor are they strikingly deficient. It is not necessary, therefore, to discuss these analyses in detail.

TABLE V. PLANT FOOD IN PLYMOUTH COUNTY, IOWA, SOILS

Pounds per acre of 4 million pounds of subsurface soil (6⅔″-20″)

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 169 | Clarion silt loam | 2,236 | 4,640 | 41,491 | 25,691 | ------ |
| 174 | Dickinson loam | 2,154 | 3,760 | 48,505 | ------ | 1,000 |
| | LOESS SOILS | | | | | |
| 9 | Marshall silt loam | 2,594 | 4,960 | 59,895 | ------ | 1,000 |
| 213 | Marshall silt loam (shallow phase) | 2,882 | 3,360 | 27,574 | 53,332 | ------ |
| 11 | Knox silt loam | 2,559 | 4,120 | 10,516 | 64,788 | ------ |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 2,558 | 4,720 | 51,249 | ------ | 2,000 |
| 131 | Judson silt loam | 2,895 | 7,200 | 83,776 | ------ | ------ |
| 126 | O'Neill sand loam | 1,830 | 2,080 | 27,240 | ------ | 1,000 |
| 108 | O'Neill loam | 1,992 | 4,160 | 39,482 | ------ | ------ |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam | 1,992 | 5,360 | 81,342 | ------ | ------ |
| 48 | Wabash silty clay loam | 2,236 | 6,160 | 76,684 | ------ | ------ |
| 72 | Wabash clay | 2,046 | 5,050 | 59,732 | ------ | ------ |
| 153 | Lamouro silt loam | 2,370 | 7,680 | 111,058 | 626 | ------ |
| 111 | Lamoure silty clay loam | 3,796 | 5,050 | 74,615 | 4,224 | ------ |
| 130 | Cass fine sandy loam | 2,558 | 1,600 | 51,087 | 12,551 | ------ |



TABLE VI. PLANT FOOD IN PLYMOUTH COUNTY, IOWA, SOILS

Pounds per acre of 6 million pounds of subsoil (20″-40″)

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 169 | Clarion silt loam | 4,443 | 3,720 | 53,109 | 104,728 | ------ |
| 174 | Dickinson loam | 1,616 | 2,880 | 25,197 | ------ | ------ |
| | LOESS SOILS | | | | | |
| 9 | Marshall silt loam | 5,798 | 1,840 | 19,249 | 51,483 | ------ |
| 213 | Marshall silt loam (shallow phase) | 4,080 | 2,400 | 17,504 | 91,944 | ------ |
| 11 | Knox silt loam | 3,899 | 3,480 | 41,073 | 43,455 | ------ |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 3,594 | 3,480 | 31,068 | ------ | ------ |
| 131 | Judson silt loam | 4,059 | 5,280 | 116,632 | ------ | ------ |
| 126 | O'Neill sandy loam | 3,513 | 2,160 | 70,148 | ------ | 2,000 |
| 108 | O'Neill loam | 3,798 | 3,120 | 27,546 | ------ | ------ |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam | 2,868 | 6,360 | 80,130 | ------ | ------ |
| 48 | Wabash silty clay loam | 2,826 | 6,000 | 85,836 | ------ | ------ |
| 72 | Wabash clay | 3,756 | 5,640 | 46,259 | ------ | ------ |
| 153 | Lamoure silt loam | 2,019 | 5,640 | 75,880 | 633 | ------ |
| 111 | Lamoure silty clay loam | 4,848 | 6,840 | 83,454 | 16,665 | ------ |
| 130 | Cass fine sandy loam | 4,404 | 2,640 | 53,109 | 23,240 | ------ |

The conclusions reached from the discussion of the analyses of the surface soil are very largely confirmed by the analyses of the subsurface soils and subsoils. It is evident that phosphorus fertilizers will be needed on these soils in the near future and they might prove profitable for use at the present time. It is important that the supply of organic matter and nitrogen be maintained in all the soils and in some instances the content of these constituents should be increased. By the proper use of farm manure and crop residues and the turning under of leguminous crops as green manures this may be readily accomplished.

Some soils which showed an acidity in the surface layer were not acid in the lower soil layers. This was true of the Clarion silt loam on the drift uplands and of the Marshall silt loam on the loessial upland, but in the other types the acidity shown in the surface soil extends down thru the soil section. A supply of lime in the lower soil layers, however, does not necessarily mean that the surface soil will not respond to an application of lime when it is acid, especially when such legumes as sweet clover and alfalfa are seeded. There is very little movement of lime in the soil except that due to losses by leaching in the drainage water, and hence if the surface soil is acid it is very often desirable to supply lime to insure the best early growth of legume crops. The soil types in Plymouth County, which are acid, should be tested for their lime needs and lime should be applied as necessary for such crops as sweet clover and alfalfa.

## GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the Marshall silt loam and on the Knox silt loam from Plymouth County to secure some information regarding the fertilizer needs of these soils and regarding the value of the application of certain fertilizing materials. Experiments are also included on the Marshall silt loam and the Knox silt loam from Harrison County, on the Marshall silt loam from Fremont County, from Crawford County and from Woodbury County, inasmuch as these are the same soil types which occur in Plymouth County. The results are certainly directly applicable to conditions in that county.

The fertilizer treatments employed included superphosphate, rock phosphate, limestone, manure, a complete commercial fertilizer and muriate of potash. These materials were applied in the amounts in which they are usually employed in the field and the results are, therefore, indicative of what may be expected on the farm. Manure was applied at the rate of 10 tons per acre, lime was added in sufficient amounts to neutralize the acidity of the soil, superphosphate was applied at the rate of 250 pounds per acre, rock phosphate at the rate of one ton per acre, the complete fertilizer at the rate of 300 pounds per acre, and the muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown, the clover being seeded about one month after the wheat was up. In the experiments on the Marshall silt loam from Plymouth and Harrison counties, only the clover yields were obtained.

### THE RESULTS ON THE MARSHALL SILT LOAM

The results secured in the greenhouse experiment on the Marshall silt loam are given in table VII. The superphosphate greatly increased the clover yield, and the limestone with the phosphate gave a further increase. Manure alone gave a large increase in the clover, an effect that was about the same as that brought about by the superphosphate and limestone. When superphosphate was added with the manure, however, there was a further gain in the clover yield. The use of limestone with the manure and superphosphate had no further effect. The addition of the muriate of potash with the manure, limestone and superphosphate brought about a considerable increase in the clover.

It is evident from these results that this soil will respond to applications of manure, limestone and a phosphate fertilizer. The liberal use of manure is very desirable; the addition of lime is necessary when the soil is acid; and the use of superphosphate may bring about large crop increases. The application of muriate of potash may be of value in some cases, but tests should be carried out on small areas before applications are made extensively.

TABLE VII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, PLYMOUTH COUNTY

| Pot No. | Treatment | Weight of clover in grams |
|---|---|---|
| 1 | Check | 21.1 |
| 1 | Superphosphate. | 33.4 |
| 3 | Limestone+superphosphate | 37.8 |
| 4 | Manure | 38.2 |
| 5 | Manure+superphosphate | 40.0 |
| 6 | Manure+superphosphate+limestone | 40.0 |
| 7 | Manure+superphosphate+limestone+potassium | 49.4 |



Fig. 3. Clover on Marshall silt loam, greenhouse experiment.

### THE RESULTS ON THE KNOX SILT LOAM

The results secured in the experiment on the Knox silt loam are given in table VIII. The superphosphate increased the yield of wheat and brought about an enormous increase in the yield of the clover. Manure alone gave about the same effect as the superphosphate with wheat but showed less effect on clover. Superphosphate with the manure greatly increased the yields of wheat and clover. When the muriate of potash was added with the manure and superphosphate, the largest increase in the yield of wheat was secured but the effect was not evidenced on the yields of clover.

TABLE VIII. GREENHOUSE EXPERIMENT, KNOX SILT LOAM, PLYMOUTH COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 5.8 | 7.7 |
| 2 | Superphosphate | 7.1 | 33.7 |
| 3 | Manure | 7.8 | 29.1 |
| 4 | Manure+superphosphate | 9.2 | 51.1 |
| 5 | Manure+superphosphate+potassium | 10.4 | 42.8 |

It is apparent from this test that the Knox silt loam will respond to applications of manure and a phosphate fertilizer in a very profitable way. The use of manure is especially desirable on the type and large increases in the yields of general farm crops may be expected. The application of superphosphate is strongly recommended and it will undoubtedly prove profitable in most cases. The use of potassium fertilizers may be desirable in individual cases, but tests

Fig. 4. Clover on Knox silt loam, greenhouse experiment.

TABLE IX. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, HARRISON COUNTY

| Pot No. | Treatment | Weight of clover in grams |
|---|---|---|
| 1 | Check | 7.4 |
| 2 | Superphosphate | 20.3 |
| 3 | Limestone+superphosphate | 28.0 |
| 4 | Manure | 25.9 |
| 5 | Manure+superphosphate | 39.2 |
| 6 | Manure+limestone+superphosphate | 44.9 |
| 7 | Manure+limestone+superphosphate+potassium | 45.9 |

are recommended before any extensive application of this fertilizing constituent is made.

### THE RESULTS ON THE MARSHALL SILT LOAM FROM HARRISON COUNTY

The results of the experiment on the Marshall silt loam from Harrison County are given in table IX. The application of the superphosphate brought about a very large increase in the yield of clover. Limestone applied with the superphosphate gave a further considerable increase in the yields. Manure alone increased the yield over the check and gave a somewhat greater increase than the superphosphate alone. The superphosphate applied with the manure brought about a very large increase over that occasioned by the manure alone. Limestone applied with the manure and superphosphate showed a further increase in yield. The muriate of potash applied with the manure, limestone and superphosphate showed a very slight increase in the clover.

Apparently this soil will respond in a very profitable way to applications of manure, lime and superphosphate. Manure may be considered a basic treatment and will have large value on all general farm crops. Lime is very desirable when legumes are to be grown and it will show its largest effect on these crops. The use of superphosphate in addition to manure and limestone is apparently very desirable on this soil. Tests of this phosphate fertilizer on individual farms are strongly recommended.

### THE RESULTS ON THE KNOX SILT LOAM FROM HARRISON COUNTY

The results secured on the greenhouse experiment on the Knox silt loam from Harrison County are given in table X. The application of superphosphate increased the yield of wheat and brought about an enormous increase in the yield of clover. The manure alone increased the yield of wheat considerably over the check, and gave about the same results as the superphosphate except on the clover, on which, it brought about a larger increase than did the superphosphate. When the superphosphate was applied with the manure a gain was noted in the yield of wheat and also in the yield of clover. Muriate of potash applied with the manure and superphosphate showed no further increase in the clover. The yield of wheat was not secured.

TABLE X. GREENHOUSE EXPERIMENT, KNOX SILT LOAM, HARRISON COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 3.8 | 3.5 |
| 2 | Superphosphate | 5.2 | 22.6 |
| 3 | Manure | 5.2 | 31.6 |
| 4 | Manure+superphosphate | 5.7 | 34.2 |
| 5 | Manure+superphosphate+potassium | ---- | 31.0 |



On this soil type the effects of manure and superphosphate are clearly shown. The type is low in organic matter and additions of farm manure are desirable. If farm manure is not available, the turning under of a leguminous crop as a green manure is strongly recommended. The use of superphosphate may be very desirable on the soil and may bring about highly profitable increases in the yields of general farm crops. Tests on individual farms are strongly recommended.

### THE RESULTS ON THE MARSHALL SILT LOAM FROM FREMONT COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Fremont County are given in table XI. The superphosphate increased the yield of wheat on this soil and gave a very large increase in the yield of clover. Limestone with the superphosphate had no effect on the wheat and but a slight influence on the clover. The manure alone showed about the same effect on the wheat as that shown by the superphosphate, with a much smaller effect on the clover. When the superphosphate was applied with the manure, it showed no effect on the wheat but brought about a very large increase in the yield of clover. Limestone applied with the manure and superphosphate showed a gain in the yield of the wheat crop and a slight increase on the clover. Muriate of potash applied with the manure, limestone and superphosphate had no effect on the wheat or on the clover.

These results largely confirm those previously secured on the same soil type, indicating that this soil will respond profitably to applications of manure, limestone and superphosphate. The use of lime is particularly desirable in connection with the growing of a legume crop and the addition of superphosphate is strongly recommended. There is no evidence of value from the use of a potash fertilizer.

### THE RESULTS SECURED ON THE MARSHALL SILT LOAM FROM CRAWFORD COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Crawford County are given in table XII. Manure brought about a large increase in the yields of wheat and clover. Limestone with the manure showed a slight effect on the wheat crop and a pronounced effect on the clover. Super-

TABLE XI. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, FREMONT COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 12.2 | 10.4 |
| 2 | Superphosphate | 14.5 | 43.2 |
| 3 | Limestone+superphosphate | 13.8 | 43.5 |
| 4 | Manure | 14.6 | 30.4 |
| 5 | Manure+superphosphate | 14.2 | 51.9 |
| 6 | Manure+limestone+superphosphate | 15.4 | 52.5 |
| 7 | Manure+limestone+superphosphate+potassium | 15.4 | 49.7 |

TABLE XII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, CRAWFORD COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 8.66 | 16.16 |
| 2 | Manure | 12.56 | 30.66 |
| 3 | Manure+limestone | 13.20 | 38.00 |
| 4 | Superphosphate | 11.70 | 43.33 |
| 5 | Manure+superphosphate | 11.96 | 56.83 |
| 6 | Limestone+superphosphate | 12.23 | 43.50 |
| 7 | Manure+limestone+superphosphate | 14.26 | 51.66 |
| 8 | Manure+limestone+superphosphate+potassium | 13.25 | 64.16 |

phosphate alone had less effect on the wheat than did the manure alone but it showed a much larger effect on the clover. Manure and superphosphate showed a larger effect than the phosphate alone on the wheat and brought about a much larger effect on the clover. Limestone and superphosphate showed a greater effect on the wheat than did the superphosphate alone and about the same influence on the clover. Manure, lime and superphosphate gave the largest increase in the yields of wheat and only a slightly smaller effect on the clover than that brought about by the manure and phosphate without lime. When the muriate of potash was added with the manure, limestone and superphosphate, a smaller effect was brought about on the wheat than without the muriate, but on the clover there was a large increase in the yields.

These results are largely confirmatory of those previously secured. The value of manure is definite. The use of limestone is certainly of value in connection with the growing of a legume crop, and the addition of superphosphate is highly desirable for general farm crops, especially when applied in addition to the basic treatments of manure and limestone. The addition of a potash fertilizer cannot be recommended until tests have been carried out and beneficial effects of the treatment definitely shown.

### THE RESULTS SECURED ON THE MARSHALL SILT LOAM FROM WOODBURY COUNTY

The results of the experiment on the Marshall silt loam from Woodbury County are given in table XIII. Manure increased the yield of wheat and had a small effect on the clover. Lime, in addition to manure, increased the wheat crop considerably but showed no effect on the clover, which is contrary to the usual results. Ordinarily the application of lime will show up particularly well on the legume crop of the rotation and, in many cases, the beneficial effects of lime are not apparent on the corn and small grain crops. In this case, the effect was very large on the wheat and not so definite on the clover. The rock phosphate had a very slight effect on the yields of wheat and little or no effect on the clover. Superphosphate, however, brought about a very distinct effect on the wheat and a large increase in the yield of clover. The complete commercial fertilizer exerted a greater effect than the superphosphate in the case of the wheat crop but had a slightly less effect on the clover.

Apparently this soil will respond profitably to applications of manure, lime and phosphorus. The addition of manure seems to be of considerable value and lime along with manure may have a considerable effect not only on the legume



TABLE XIII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, WOODBURY COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 7.051 | 35.0 |
| 2 | Manure | 7.850 | 39.0 |
| 3 | Manure+lime | 8.946 | 35.0 |
| 4 | Manure+lime+rock phosphate | 9.023 | 39.0 |
| 5 | Manure+lime+superphosphate | 9.247 | 48.5 |
| 6 | Manure+lime+complete commercial fertilizer | 10.216 | 45.0 |

but on the grain crops of the rotation. Superphosphate seems to have a greater effect than rock phosphate in this particular case, and in general it would seem that the use of superphosphate might be more desirable than rock phosphate. The complete commercial fertilizer was more effective than the superphosphate with the wheat but had less effect on the clover. Probably superphosphate would generally prove more profitable than the complete fertilizer because of its lower cost.

## FIELD EXPERIMENTS

No field experiments are located in Plymouth County, but as a number of experiments have been under way in other counties for a period of years on the same soil types as those occurring in Plymouth County, the results will be given in this report. The tests indicate definitely the results which may be secured on the same soil types in this county. Experiments on the Marshall silt loam on the Avoca Field in Pottawattamie County; on the same soil type on the Red Oak and Villisca fields in Montgomery County; on the Waukesha silt loam on the Clarinda Field in Page County; and on the Lamoure silty clay loam on the Everly Field in Clay County are included.

These experiments are planned to determine the value of various soil treatments and are laid out on land which is representative of the particular soil type. The fields include 13 plots 155 feet 7 inches long by 28 feet wide and are one-tenth of an acre in size. They are permanently located by the installation of corner stakes, and precautions are taken in the application of fertilizers and in the harvesting of the plots to insure accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former, manure is applied as the basic treatment, while in the latter, crop residues are employed to supply the organic matter. The other fertilizing materials tested include limestone, rock phosphate, superphosphate, muriate of potash and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residue treatment consists in plowing under the corn stalks, which have been cut with a disk or stalk cutter, and the plowing under of at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a four-year rotation. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in four years. Superphosphate is applied at the rate of 150 pounds per acre annually three years out of a four-year rotation. Until 1923 this material was applied at the rate of 200 pounds per acre annually. Muriate of potash was applied at the rate of 50 pounds per acre. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being employed the applications being made at the rate of 202 pounds per acre annually, thus applying the same amount of phosphorus that is contained in the superphosphate.

### THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca Field in Pottawattamie County are given in table XIV. The beneficial effect of manure on this soil is shown in practically all cases. The influence on the oats may be noted particularly and also the large effects on the clover and sweet clover. The corn yield in 1926 was very largely increased by the addition of manure. In other years the effects on the corn were much smaller. The influence of lime was particularly evident on the sweet clover crop in 1924 on which a very large increase in yield resulted from the application. There was also an effect noted on the oats in 1927. No beneficial effects were shown on the clover crop in 1921.

The application of rock phosphate and superphosphate along with the manure and lime showed large beneficial effects on the crops grown in some seasons. The corn in 1919, 1922 and 1928 showed pronounced effects from the use of the superphosphate, and slightly less effects from the rock phosphate. There was

TABLE XIV. FIELD EXPERIMENT, MARSHALL LOAM, POTTAWATTAMIE COUNTY, AVOCA FIELD

| Plot No. | Treatment | (1) 1919 Corn bu. per A. | (2) 1920 Oats bu. per A. | (3) 1921 Clover tons per A. | (4) 1922 Corn bu. per A. | 1923 Oats bu. per A. | 1924 Sweet Clover tons per A. | (5) 1925 Corn bu. per A. | 1926 Corn bu. per A. | 1927 Oats bu. per A. | 1928 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 72.9 | 62.2 | 2.0 | 58.1 | 48.7 | 0.36 | 62.2 | 54.6 | 45.7 | 64.5 |
| 2 | Manure | 72.1 | 69.0 | 2.7 | 53.6 | 56.7 | 0.63 | 63.9 | 63.7 | 56.0 | 67.5 |
| 3 | Manure+lime | 74.0 | 72.3 | 2.6 | 53.9 | 53.2 | 1.82 | 61.6 | 64.0 | 64.0 | 68.3 |
| 4 | Manure+lime+rock phosphate | 77.8 | 58.8 | 2.7 | 65.5 | 60.0 | 1.52 | 58.1 | 61.3 | 69.8 | 66.4 |
| 5 | Manure+lime+ superphosphate | 79.3 | 69.0 | 2.5 | 56.5 | 60.0 | 1.68 | 52.3 | 64.8 | 75.0 | 70.9 |
| 6 | Manure+lime+complete commercial fertilizer | 77.5 | 61.2 | 2.8 | 57.5 | 66.8 | 1.92 | 51.4 | 65.6 | 79.1 | 65.6 |
| 7 | Check | 71.5 | 56.8 | 2.0 | 44.8 | 47.6 | 0.85 | 39.8 | 61.0 | 50.0 | 64.3 |
| 8 | Crop residues | 78.9 | 63.9 | 2.0 | 44.8 | 49.8 | 0.90 | 51.0 | 66.4 | 57.1 | 66.7 |
| 9 | Crop residues+lime | 80.7 | 68.1 | 2.1 | 50.0 | 56.7 | 1.92 | 58.7 | 64.5 | 66.7 | 66.4 |
| 10 | Crop residues+lime +rock phosphate | 78.5 | 68.6 | 2.8 | 54.8 | 59.0 | 1.83 | 56.8 | 69.6 | 66.6 | 62.1 |
| 11 | Crop residues+lime +superphosphate | 81.1 | 75.1 | 2.2 | 54.1 | 64.5 | 1.50 | 57.1 | 66.6 | 64.7 | 66.1 |
| 12 | Crop residues+lime +complete commercial fertilizer | 80.4 | 68.6 | 2.9 | 52.0 | 52.1 | 1.44 | 58.4 | 65.8 | 70.0 | 64.8 |
| 13 | Check | 80.0 | 68.6 | 2.2 | 46.3 | 50.9 | 1.12 | 51.8 | 60.8 | 60.6 | 61.6 |

(1) Field slopes toward plot 13.
(2) Not limed until October 1, 1920. Three tons per acre.
(3) Field pastured until June 1.
(4) Corn injured by hail in August and by rainy spring.
(5) Strong winds and wireworms cut down stand considerably.



considerable influence from both phosphates on the oats in 1923 and a large effect in 1927. The crop in 1920 was not materially benefited. No effects from the phosphates were evidenced on the clover crops in 1921 and 1924. The complete commercial fertilizer had about the same effects as the phosphates on most of the crops grown. In some cases it showed a slightly larger influence, as for example on the sweet clover in 1924 and on the oats in 1927. In other years, as on the corn in 1928, there was less influence from the complete fertilizer.

The crop residues treatment generally had but small influence. Lime with the crop residues increased crop yields, with the exception of the corn crops in 1926 and 1928. The largest influence of the lime was evident on the sweet clover in 1924. Considerable increases were noted, however, on the corn in 1922, on the oats in 1923 and on the corn in 1925. The rock phosphate and the superphosphate brought about increases in crop yields in several cases, the effect of the superphosphate being particularly large on the oats in 1920 and in 1923. The effects on the corn crop were not large from either of the phosphates. The complete commercial fertilizer had about the same effect as the superphosphate except on the oats in 1927 where a larger influence was noted, and on the clover in 1921 where it brought about a greater effect.

The Marshall silt loam responds very profitably to applications of farm manure, and this material should be applied in liberal amounts to the soil. The type is generally slightly acid in reaction, and additions of lime are desirable, especially where legumes are to be grown. Sweet clover is particularly sensitive to acidity, and an adequate content of lime in the soil is essential for this crop. The type should be tested and the necessary additions should be made, if sweet clover or alfalfa are to be grown. Beneficial effects from phosphate fertilizers have been secured, both with the manure and lime, and under the grain systems of farming with crop residues and lime. The complete commercial fertilizer generally had no greater effect than the superphosphate and hence it is not recommended for general use. Complete fertilizers will probably prove less economical than superphosphate. Tests of superphosphate and rock phosphate should be carried out on this soil on individual farms to determine the relative value of the two materials.

### THE RED OAK FIELD

The results secured on the Red Oak Field on the Marshall silt loam in Montgomery County are given in table XV. Benefits from the application of manure to this soil are shown definitely by the data in this table. The increased yield of winter wheat in 1918 is particularly noteworthy. The corn crops were increased to a large extent in every case, and increases were also noted with the oats in 1921, the winter wheat in 1922 and 1925, the soybeans in 1924 and the alfalfa in 1927 and 1928. The largest beneficial effects from lime were shown, as would be expected, on the alfalfa in 1927 and 1928, but increases were also secured on the corn in 1920, the oats in 1921, the wheat in 1922 and the corn in 1923. The soybeans in 1924 also showed a considerable beneficial effect of the lime.

Rock phosphate or the superphosphate used along with the manure and lime brought about many increases in crop yields, particularly on the wheat in 1922 and 1925, and on the alfalfa in 1927 and 1928. In some seasons, as in 1919 and

TABLE XV. FIELD EXPERIMENT, MARSHALL SILT LOAM, MONTGOMERY COUNTY, RED OAK FIELD

| Plot No. | Treatment | (1) 1918 Winter Wheat bu. per A. | (2) 1919 Corn bu. per A. | 1920 Corn bu. per A. | (3) 1921 Oats bu. per A. | (4) 1922 Winter Wheat bu. per A. | 1923 Corn bu. per A. | 1924 Soybeans bu. per A. | 1925 Winter Wheat bu. per A. | (5) 1926 Clover tons per A. | (6) 1927 Alfalfa tons per A. | (7) 1928 Alfalfa tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 13.6 | 52.0 | 56.0 | 28.2 | 13.2 | 54.5 | 11.2 | 10.4 | --- | 1.84 | 3.36 |
| 2 | Manure | 34.1 | 57.2 | 61.6 | 36.9 | 15.5 | 57.8 | 12.4 | 11.6 | --- | 2.20 | 3.70 |
| 3 | Manure+lime | 31.8 | 59.2 | 66.0 | 37.8 | 18.6 | 64.7 | 14.2 | 11.3 | --- | 3.09 | 3.85 |
| 4 | Manure+lime+rock phosphate | 27.7 | 60.0 | 63.0 | 35.6 | 28.6 | 64.6 | 13.7 | 13.6 | --- | 3.57 | 4.67 |
| 5 | Manure+lime+superphosphate | 31.8 | 58.5 | 62.7 | 39.4 | 30.7 | 62.9 | 13.1 | 13.1 | --- | 3.32 | 4.35 |
| 6 | Manure+lime+complete commercial fertilizer | 29.5 | 56.2 | 64.2 | 36.4 | 25.4 | 61.3 | 14.6 | 10.6 | --- | 3.75 | 4.18 |
| 7 | Check | --- | 54.2 | 56.6 | 31.8 | 17.4 | 50.6 | 10.5 | 9.4 | --- | 2.18 | 3.69 |
| 8 | Crop residues | 29.5 | 51.0 | 54.1 | 31.3 | 16.4 | 52.9 | 9.9 | 8.6 | --- | 2.34 | 3.13 |
| 9 | Crop residues+lime | 25.0 | 53.7 | 60.2 | 31.2 | 19.5 | 55.0 | 13.2 | 10.2 | --- | 2.30 | 4.14 |
| 10 | Crop residues+lime+rock phosphate | 18.1 | 57.7 | 59.2 | 35.0 | 23.8 | 55.7 | 12.3 | 13.0 | --- | 2.54 | 4.21 |
| 11 | Crop residues+lime+superphosphate | 27.2 | 53.7 | 61.6 | 36.9 | 22.3 | 52.7 | 12.1 | 11.6 | --- | 2.53 | 4.26 |
| 12 | Crop residues+lime+complete commercial fertilizer | 26.1 | 57.0 | 57.3 | 37.8 | 22.2 | 56.8 | 14.0 | 12.5 | --- | 1.97 | 3.79 |
| 13 | Check | 13.6 | 48.2 | 51.4 | 29.0 | 15.2 | 52.0 | 8.9 | 9.9 | --- | 1.53 | 3.78 |

(1) Clover killed and plowed up. Yield on plot 7 an error.
(2) 3½ tons lime applied May 15.
(3) 2½ tons of lime applied in September.
(4) Dry weather killed out clover.
(5) Clover stand very poor due to dry weather. Field was plowed and seeded to alfalfa in August.
(6) Results of first and second cuttings combined. No results taken on third cutting.
(7) Three cuttings.

1920, there was very little evidence of beneficial effects from the phosphates. Superphosphate benefited the oat crop in 1921, but the rock phosphate had no effect. The corn in 1923 showed no effect from the phosphates, and the soybeans in 1924 were not benefited. The complete commercial fertilizer had about the same effect as the superphosphate in practically all cases, showing up a little better in one or two instances but in other cases having a lesser effect.

The crop residues treatment had little effect on the crop yields, as would be expected. Lime with the residues usually increased the yields, particularly of the alfalfa in 1928, the soybeans in 1924, the corn in 1920 and the wheat in 1922 and in 1925. The phosphate fertilizers, when applied with the crop residues and lime, increased crop yields in several instances, particularly the wheat in 1922 and 1925, and the alfalfa in 1927 and 1928. The oats were materially benefited in 1921, and the superphosphate increased the wheat yields in 1918. No large beneficial effects of the phosphates were shown on the corn either in 1920 or in 1923, but the rock phosphate showed an increase in 1919. The complete commercial fertilizer again had about the same effect as that brought about by the use of the phosphates. In one or two instances the complete fertilizer gave larger effects as for example on the soybeans in 1924, on the corn in 1923 and on the oats in 1921; but in other cases, as with the alfalfa in



1927 and 1928 and the corn in 1920, the influence of the complete fertilizer was less than that of the phosphates.

These results confirm those secured on the Avoca Field on the same soil type and indicate the value of applications of manure and lime and in many cases the possible profit which may result from the application of a phosphate fertilizer. It seems that the addition of lime is of particular value on this soil when it is acid if legumes are to be grown. The effect of phosphate fertilizers may be very large in the case of some crops in the rotation and the influence may be exerted on all the crops grown. Tests on individual farms are very desirable to determine the value from the use of a phosphorus carrier.

### THE VILLISCA FIELD

The results secured on the Marshall silt loam on the Villisca Field in Montgomery County are given in table XVI. The application of manure increased the crop yields in each year as shown in the table. Large increases were noted on the clover in 1918 and on the corn in 1922. Lime was not applied to this field until the fall of 1920. In the succeeding years the effect of lime was evidenced on the clover and the corn crops. Evidently the soil was in need of the addition in order to yield the largest crops.

The addition of rock phosphate or superphosphate with the manure and lime increased the crop yields in practically all cases, the gain being definitely

TABLE XVI. FIELD EXPERIMENT, MARSHALL SILT LOAM, MONTGOMERY COUNTY, VILLISCA FIELD

| Plot No. | Treatment | (1) 1918 Clover tons per A. | (2) 1919 Corn bu. per A. | 1920 Oats bu. per A. | 1921 Clover tons per A. | 1922 Corn bu. per A. | 1923 Corn bu. per A. | (3) 1924 Corn bu. per A. | (4) 1925 Oats bu. per A. | (5) 1926 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 1.0 | 49.3 | 46.2 | 0.73 | 64.1 | 37.7 | ---- | 15.0 | ---- |
| 2 | Manure | 1.2 | 51.0 | 52.1 | 0.88 | 73.9 | 38.8 | ---- | 15.6 | ---- |
| 3 | Manure+limestone | 1.3 | 50.3 | 52.7 | 0.99 | 76.6 | 43.2 | ---- | 16.3 | ---- |
| 4 | Manure+limestone+rock phosphate | 1.5 | 52.0 | 54.7 | 1.12 | 81.1 | 44.1 | ---- | 18.2 | ---- |
| 5 | Manure+limestone+superphosphate | 1.4 | 49.0 | 72.7 | 0.80 | 80.3 | 45.3 | ---- | 17.6 | ---- |
| 6 | Manure+limestone+complete commercial fertilizer | 1.6 | 48.7 | 58.1 | 1.04 | 82.4 | 45.8 | ---- | 18.1 | ---- |
| 7 | Check | 1.6 | 52.0 | 49.3 | 0.93 | 63.3 | 38.0 | ---- | 14.3 | ---- |
| 8 | Crop residues | 1.5 | 49.3 | 47.9 | 0.91 | 63.3 | 37.9 | ---- | 16.5 | ---- |
| 9 | Crop residues+limestone | 1.6 | 48.7 | 51.3 | 0.98 | 65.7 | 39.1 | ---- | 13.4 | ---- |
| 10 | Crop residues+limestone+rock phosphate | 1.7 | 48.3 | 52.4 | 0.61 | 66.8 | 41.9 | ---- | 14.3 | ---- |
| 11 | Crop residues+limestone+superphosphate | 1.6 | 53.0 | 59.7 | 0.83 | 67.3 | 42.3 | ---- | 12.5 | ---- |
| 12 | Crop residues+limestone+complete commercial fertilizer | 1.5 | 51.7 | 62.8 | 0.91 | 73.1 | 43.1 | ---- | 16.0 | ---- |
| 13 | Check | 1.5 | 55.7 | 51.4 | 0.70 | 64.9 | 36.6 | ---- | 14.3 | ---- |

(1) Very poor stand of clover.
(2) Very uneven stand of corn.
(3) Crop failure on account of adverse weather conditions.
(4) Poor oats on account of drouth.
(5) Field discontinued, farm changed hands.

TABLE XVIII. FIELD EXPERIMENT, WAUKESHA SILT LOAM, PAGE COUNTY CLARINDA FIELD, SERIES 200

| Plot No. | Treatment | 1916 Corn bu. per A. | 1917 Oats bu. per A. | (1) 1918 Clover tons per A. | 1919 Corn bu. per A. | (2) 1920 Corn bu. per A. | 1921 Oats bu. per A. | (3) 1922 Hubam Clover tons per A. | 1923 Corn bu. per A. | 1924 Corn bu. per A. | 1925 Oats bu. per A. | (4) 1926 Clover tons per A. | (5) 1927 Corn bu. per A. | (6) 1928 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 73.1 | 83.0 | 1.8 | 52.2 | 54.3 | 49.2 | ---- | 70.0 | 31.2 | 35.2 | 1.87 | 40.9 | 62.8 |
| 2 | Manure | 77.1 | 83.0 | 1.4 | 56.0 | 64.4 | 32.6 | ---- | 79.3 | 41.8 | 46.6 | 0.86 | 60.1 | 62.3 |
| 3 | Manure+limestone | 78.2 | 88.0 | 1.2 | 57.3 | 65.0 | 60.8 | ---- | 82.4 | 44.7 | 48.5 | 1.28 | 63.9 | 59.8 |
| 4 | Manure+limestone+rock phosphate | 74.9 | 91.1 | 1.8 | 60.9 | 65.9 | 45.8 | ---- | 87.4 | 39.4 | 47.2 | 1.64 | 60.3 | 67.7 |
| 5 | Manure+limestone+super phosphate | 75.9 | 103.6 | 1.5 | 64.5 | 60.9 | 40.2 | ---- | 86.6 | 40.0 | 48.8 | 1.00 | 62.0 | 61.3 |
| 6 | Manure+limestone+complete commercial fertilizer | 80.2 | 98.0 | 1.7 | 61.5 | 62.2 | 52.0 | ---- | 83.1 | 28.1 | 53.7 | 0.95 | 50.3 | 63.6 |
| 7 | Check | 76.7 | 74.8 | 2.3 | 55.0 | 54.8 | 43.4 | ---- | 79.2 | 24.4 | 37.9 | 1.51 | 42.1 | 56.6 |
| 8 | Crop residues | 78.9 | 73.0 | 2.0 | 54.0 | 58.8 | 45.6 | ---- | 73.8 | 24.1 | 39.7 | 1.55 | 49.7 | 58.1 |
| 9 | Crop residues+limestone | 77.5 | 77.8 | 1.8 | 65.7 | 60.0 | 44.8 | ---- | 69.6 | 31.7 | 39.6 | 1.34 | 61.2 | 61.3 |
| 10 | Crop residues+limestone +rock phosphate | 75.8 | 101.0 | 1.7 | 72.7 | 62.1 | 53.9 | ---- | 70.2 | 26.2 | 40.1 | 1.50 | 62.8 | 64.9 |
| 11 | Crop residues+limestone +superphosphate | 76.6 | 100.3 | 1.7 | 72.8 | 61.1 | 52.4 | ---- | 63.6 | 26.6 | 45.2 | 1.33 | 57.1 | 69.9 |
| 12 | Crop residues+limestone +complete commercial fertilizer | 74.4 | 91.6 | 1.4 | 70.8 | 43.7 | 54.1 | ---- | 69.6 | 25.4 | 46.1 | 1.38 | 37.6 | 57.8 |
| 13 | Check | 74.6 | 68.1 | 1.3 | 58.6 | 44.8 | 48.4 | ---- | 62.8 | 20.6 | 36.3 | 1.12 | 33.1 | 50.2 |

(1) Plots varied in amount of growth due to moisture conditions.
(2) Poor drainage on plots 12 and 13.
(3) Stand failed due to dry weather.
(4) Uneven stand due to large amount of weeds on some plots.
(5) Poor stand on plots 1, 7, 8, 12 and 13 due to poor drainage.
(6) Unable to harvest uniform stand due to the listing of the corn.

yields follow its use. Lime should be applied with the manure if the soil is acid and considerable gains in yields of legume crops will follow its application. When applied with manure and lime, superphosphate seemed somewhat superior to rock phosphate in many seasons, but in most instances the differences were small. Either of these two phosphates will prove of value on this soil type under the livestock system of farming. Under the grain system of farming, their use is quite as desirable as on the livestock farm, and here the use of the superphosphate seems somewhat preferable.

The results secured on the Waukesha silt loam on the Clarinda Field, Series 200, are given in table XVIII. The beneficial effects of manure are again evidenced on this soil type in practically all seasons, and very large increases were secured with the corn in 1920, in 1923 and in 1927. The oats showed a large increase in 1925. In one or two cases no increases were secured with manure, undoubtedly due to some abnormal conditions in connection with the crop growth on the manure treated plots. The addition of lime with the manure gave increases in practically all seasons, especially on the clover in 1926, and on the oats in 1917 and 1921. Small gains were secured on practically all of the corn crops.

Rock phosphate or superphosphate, usually increased the crop yields, particularly of the clover in 1918 and 1926, the oats in 1917, and the corn in 1919, 1923



and 1928. In several instances the superphosphate proved superior to the rock phosphate, especially on the oats in 1917. In other instances the rock phosphate gave slightly larger yields than those brought about by the superphosphate.

The addition of the complete commercial fertilizer brought about crop increases similar to those occasioned by the use of the phosphates. There does not seem to be any pronounced superiority for the commercial fertilizer over the use of a phosphate.

The crop residues increased crop yields to a limited extent in several seasons. The differences, however, were not very large in any case. Limestone applied with the crop residues brought about increases in several cases. The corn in 1919, 1924 and 1927, showed very large increases from the addition of the lime. Oats were increased also in several seasons.

Rock phosphate or superphosphate applied with the crop residues and limestone greatly increased crop yields in most seasons. The largest beneficial effects were shown on the oats in 1917, altho considerable gains were noted for this same crop in 1921 and 1925. The corn showed pronounced benefits in 1919 and in 1928, but in general the increases in this crop were not large. There seems no possible choice between these two phosphates under the grain system of farming as the increases in yields were very similar from the use of the two materials. The addition of a complete commercial fertilizer gave crop yields which in most cases were much the same or slightly lower than those brought about by the superphosphate. Certainly there is no evidence from the data to show any superiority for the complete commercial fertilizer over the phosphates.

The results as a whole confirm definitely those secured on Series 100 on this same field. They indicate the value of applications of farm manure to this soil. They show the desirability of applying lime, especially if legumes are to be grown, and that the addition of a phosphate fertilizer may be profitable, at least in some seasons. Tests of rock phosphate and superphosphate are strongly recommended.

## THE EVERLY FIELD

The results secured on the Lamoure silty clay loam in Clay County, on the Everly Field are given in table XIX. The beneficial effects of farm manure to this soil type are definitely shown in these data. Large increases in crop yields were secured in practically every season. Beneficial effects were very large in the case of the corn in 1924, with the oats in 1922 and 1926, with the clover in 1923 and with the alfalfa in 1927 and 1928. The addition of the superphosphate and the muriate of potash with the manure (the application being made for the first time to this plot in 1921) benefited the crops in practically all cases. Very large increases in crop yields were noted on the clover in 1923, on the oats in 1927 and 1928, and on the corn in 1924. The oats in 1922 and 1926 also responded well.

Rock phosphate or superphosphate with the manure increased the yields in most seasons. Beneficial effects were noted particularly on the clover in 1919 and in 1923, and on the alfalfa in 1927 and 1928. The oats were also materially benefited by the phosphates in 1922 and 1926, and the corn was greatly increased in 1924. In the other seasons when corn was grown no large effects of the phosphates were shown. The superphosphate showed up much better than the

TABLE XIX. FIELD EXPERIMENT, LAMOURE SILTY CLAY LOAM, CLAY COUNTY, EVERLY FIELD—SERIES II

| Plot No. | Treatment | 1919 Clover tons per A. | 1920 Corn bu. per A. | * 1921 Corn bu. per A. | 1922 Oats bu. per A. | 1923 Clover tons per A. | 1924 Corn bu. per A. | 1925 Corn bu. per A. | 1926 Oats bu. per A. | (1) 1927 Alfalfa tons per A. | 1928 Alfalfa tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 1.45 | 74.6 | 65.8 | 35.6 | 0.57 | 31.8 | 57.9 | 47.4 | 1.05 | 2.03 |
| 2 | Manure | 1.45 | 83.2 | 75.3 | 54.1 | 0.71 | 58.2 | 68.6 | 62.9 | 1.43 | 2.94 |
| 3 | Manure+superphosphate +potassium | 1.60 | 83.2 | 75.8 | 70.4 | 1.83 | 69.4 | 58.8 | 76.8 | 2.82 | 4.71 |
| 4 | Manure+rock phosphate | 1.67 | 83.2 | 70.0 | 64.1 | 1.25 | 61.7 | 55.1 | 76.8 | 1.82 | 4.54 |
| 5 | Manure+superphosphate | 2.03 | 80.8 | 68.1 | 70.2 | 1.75 | 67.2 | 55.8 | 83.0 | 3.26 | 5.31 |
| 6 | Manure+complete commercial fertilizer | 1.79 | 80.8 | 63.2 | 68.4 | 1.26 | 60.8 | 54.0 | 71.1 | 3.00 | 4.82 |
| 7 | Check | 1.68 | 66.9 | 54.5 | 58.3 | 0.77 | 43.2 | 44.0 | 54.7 | 1.22 | 2.61 |
| 8 | Crop residues | 1.56 | 70.4 | 54.7 | 52.8 | 0.87 | 39.6 | 43.4 | 53.4 | 1.02 | 2.76 |
| 9 | Crop residues+superphosphate+potassium | 1.56 | 70.4 | 61.9 | 61.1 | 1.47 | 56.5 | 44.2 | 71.6 | 2.26 | 4.22 |
| 10 | Crop residues+rock phosphate | 1.68 | 73.6 | 60.4 | 57.7 | 1.14 | 61.2 | 42.2 | 72.4 | 1.24 | 3.55 |
| 11 | Crop residues+superphosphate | 1.56 | 83.4 | 60.8 | 62.8 | 1.59 | 57.7 | 44.7 | 77.6 | 2.28 | 3.99 |
| 12 | Crop residues+complete commercial fertilizer | 2.03 | 77.8 | 64.7 | 78.4 | 1.73 | 56.4 | 57.7 | 76.5 | 2.72 | 4.37 |
| 13 | Check | 1.62 | 61.2 | 54.0 | 48.5 | 0.83 | 35.7 | 53.5 | 50.4 | 1.00 | 2.04 |

* Superphosphate and potassium added to plots 3 and 9.
(1) Total of 2 cuttings.
(2) Total of 3 cuttings.

rock phosphate on the clover, on the alfalfa and on the oats. The complete commercial fertilizer applied with the manure showed smaller effects than the superphosphate in all seasons. It is certainly not as desirable for use on this soil as the superphosphate. The addition of the muriate of potash with the superphosphate on plot 3, did not show any pronounced benefits over the superphosphates alone on plot 5. In fact, in most cases there was no indication of value from the use of the potash.

The crop residues increased crop yields in several seasons, but the increases were small and not very significant.

The addition of rock phosphate or superphosphate with the crop residues brought about increases in crop yields in most seasons. In some cases the gains were large, as for example on the clover in 1923 and on the alfalfa in 1927 and 1928. Beneficial effects were also noted on the oats and on the corn in several seasons.

Generally the superphosphate showed up much better than the rock phosphate on the various crops grown on this field. The difference is particularly notable on the alfalfa, on the clover in 1923, on the oats in 1922 and 1926, and on the corn in 1920. The superphosphate and muriate of potash applied with the crop residues brought about increases similar to those occasioned by the use of the superphosphate alone. In only one case was there any pronounced difference in yield in favor of the muriate of potash with the superphosphate over the superphosphate alone. This was with the alfalfa in 1928. The complete commercial fertilizer applied with the residues increased the yields in practically all seasons, and in some cases the increases were very large. Large beneficial effects were noted on the clover in 1919 and 1923, and on the alfalfa in 1927 and 1928. On all these crops the complete fertilizer gave larger increases than did the superphosphate. It also proved more effective on the oats in 1922 and on the corn in 1921 and 1925. In the other cases the differences were small but slightly in favor of the phosphate. From these data there is some evidence of superiority for the commercial fertilizer over superphosphate on this soil, at least in some seasons. Owing to the higher cost of the complete fertilizer, it is doubtful whether crop increases would prove as valuable as those brought about by the superphosphate.



It is apparent from the data secured on this field that the Lamoure silty clay loam will respond to small applications of farm manure. Large amounts should not be applied and particularly preceding the growing of a small grain crop as the manure is likely to cause the grain to lodge. The addition of a phosphate fertilizer is very desirable on this soil, and the evidence is strong that superphosphate will bring about larger crop increases than will the rock phosphate on this type. Complete commercial fertilizers are probably not as desirable as a phosphate on this soil. There is no evidence of large value from the use of muriate of potash in addition to superphosphate.

## THE NEEDS OF PLYMOUTH COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The general needs of the soils of this county have been indicated rather definitely by the laboratory, greenhouse and field experiments which have been discussed earlier in this report. Some general recommendations may, therefore, be given which will be applicable to the soils of the county as a whole. While the field experiments described in this report were carried out in other counties, the soil types are the same as those occurring in Plymouth County, hence the results may be considered to indicate fairly accurately the effects which may be expected from the same fertilizing treatments in this county. The recommendations which are given here are based not only upon these experiments but also upon the general experience of many farmers. No suggestions are offered except such as have been shown to be of value by much practical experience. Any of the recommendations made can be put into effect on any farm.

In a number of instances it is urged that tests be carried out on farms to determine the value of certain fertilizing materials. Many farmers are now conducting simple tests on their farms and are securing data of considerable value to themselves and to others located on the same types. Such tests may be readily carried out and they need not be complicated nor expensive to give information of large value. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid any farmers who may be interested in carrying out tests on their own soils.

### Manuring

None of the soils in Plymouth County are strikingly lacking in organic matter but in a few cases there is no large content and in most instances, the soils are not very high in this constituent. In most of the upland types, for example, the content of organic matter is not overly large, and it is evident that some fertilizing material should be used on these soils to supply organic matter in order to keep them in the best condition for crop growth. On the lighter colored types, which are evidently low in organic matter, the addition of some fertilizing material which will supply organic matter is particularly necessary.

The most valuable fertilizing material which can be employed on the farm is farm manure. It brings about large increases in crop yields and aids materially in building up and maintaining the fertility of the soil. Its use is particularly desirable on types not well supplied with organic matter. On the upland soils the addition of farm manure is most necessary, and large beneficial effects of this material have been noted on the Marshall silt loam, the Knox silt loam, the Waukesha silt loam and the Lamoure silty clay loam. On many of the other soil types its use would also undoubtedly prove very desirable. On the heavier textured, dark colored soils, especially those on the bottomlands, small quantities of manure may be very desirable in stimulating the decomposition of organic matter and in increasing the production of available plant food. Manure in large amounts should not be applied to these heavy black soils, nor preceding the growing of a small grain crop, as it may cause the crop to lodge. The usual application of manure amounts to 8 to 10 tons per acre once in a four-year rotation. Larger amounts of manure than this are not ordinarily desirable except on light colored soils which are coarse in texture, or where truck crops are to be grown. On average soils, for general farm crops, the largest increases per ton of manure are secured with 8 ton applications.

Generally the production of farm manure even on the livestock farms is not sufficient to provide manure for the entire farm at the rate of 8 tons per acre once in four years. On the grain farm or general farm, there is little or no production of manure and some other means of supplying organic matter to the land is necessary. The turning under of a leguminous crop as a green manure is very desirable under all types of farming, as a supplement to the use of farm manure or as a substitute for that material. The practice of green manuring is recommended for many of the soils in Plymouth County to increase their fertility and improve crop yields. Legumes should always be used for green manuring purposes inasmuch as they not only supply organic matter to the land but also add nitrogen. Green manuring should not be followed carelessly, however, as undesirable results may occur if the conditions in the soil are not satisfactory for the best decomposition of the green material.

The thoro utilization of all the crop residues produced on the farm is the third means by which the organic matter in the soil may be maintained. If the crop residues are burned or otherwise destroyed, which often happens, there is a considerable loss of valuable fertilizing constituents from the land. On the livestock farms the residues may be used for feed or bedding and returned to the land with the manure. On the grain farms crop residues may be stored and allowed to decompose partially before being applied, or they may be applied directly to the land.



### The Use of Commercial Fertilizers

The analyses of the soils of Plymouth County have indicated that the total content of phosphorus is generally low. Phosphorus fertilizers will be needed on these types in the very near future if crop production is to continue to be satisfactory. The greenhouse and field experiments which have been discussed earlier in this report, and the experiences of a number of farmers, have indicated, however, that considerable increases may often be secured at the present time from the use of a phosphorus carrier.

The two phosphorus fertilizers which may be used to supply phosphorus are rock phosphate and superphosphate. The latter provides the element in a form which is immediately available for plant food. Rock phosphate, however, contains the phosphorus in a form which is made available only rather slowly in the soil. The superphosphate is more expensive but it is applied in smaller amounts, usually at the rate of 150 to 200 pounds per acre annually. The rock phosphate is applied only once in a four-year rotation at the rate of 1,000 to 2,000 pounds per acre. It is not yet possible to make a definite choice between these two phosphorus carriers for general cropping conditions. In some of the field experiments which have been carried out the superphosphate has seemed preferable but in other cases the rock phosphate has shown up quite as well. For quick returns the use of the superphosphate is preferable, as the rock phosphate does not ordinarily show the largest effect until the second or third year after application. It seems very desirable that farmers in this county test both of these phosphorus fertilizers on their own soils and thus determine for their particular conditions which material will be the more profitable. Simple tests may be carried out readily on any farm. Directions for carrying out such tests are given in Circular 97 of the Iowa Agricultural Experiment Station.

Most of the soils are not strikingly low in nitrogen content but in a few cases the supply is not high and in general it is apparent that applications of some fertilizing material supplying nitrogen must be made regularly to all the soils if the content is to be kept up. In a few instances the addition of fertilizing materials containing nitrogen would undoubtedly be of value at the present time. The proper preservation and application of all the manure produced on the farms will return to the land a considerable amount of the nitrogen which has been removed by the crops grown. On the livestock farms the farm manure will play a large part in maintaining the nitrogen supply in the soil. Manure will not, however, increase the nitrogen content. Leguminous crops used as green manures constitute the cheapest and best nitrogenous fertilizer which can be applied. When the legume is inoculated, a large part of the nitrogen is taken from the atmosphere and, hence, if the crop is turned under in the soil as a green manure, the nitrogen content of the soil will be correspondingly increased. For building up the nitrogen supply in the land, therefore, the turning under of well inoculated legumes for green manures is strongly recommended. Green manuring is a very desirable supplement to and a valuable substitute for farm manure in supplying organic matter and nitrogen to the land. The proper utilization of all the crop residues produced on the farm will also aid in keeping up the supply of organic matter and nitrogen. Where all the manure produced and the crop residues are utilized and leguminous crops are used as green manures, it is hardly likely that commercial nitrogenous fertilizers will be needed on these soils. The nitrogen which is required may be more cheaply supplied thru these natural fertilizing materials.

The soils of Plymouth County in general have a large content of total potassium. It is not likely, therefore, that potassium fertilizers need to be applied to these soils at the present time. If there is a sufficiently rapid production of the element in an available form to supply the needs of the crops, there will be no necessity of making an application of a commercial carrier of potash. Potassium fertilizers cannot be recommended at the present time for general use. If it is desired to test them on limited areas, there is no objection to their use but they should always be so tested before any extensive applications are made.

The use of complete commercial fertilizers on the soils of this county may be desirable in individual cases, but in general superphosphate will probably prove more profitable, at least for general farm crops. Complete commercial fertilizers supply nitrogen and potassium as well as phosphorus and as phosphorus is the element most likely to be lacking in the soils, the value of the complete fertilizer lies mainly in the phosphorus content. The addition of the other two elments seems to be of little value from the fertility standpoint. The soils are generally well supplied with potassium, and nitrogen may be more cheaply supplied in the form of a leguminous green manure. The greater cost of the complete fertilizers over the superphosphate in general makes their use less desirable. Complete commercial fertilizers should be tested on small areas in comparison with superphosphate and they should not be extensively used until their value has been determined under the particular soil conditions.

## Liming

Except for the Knox silt loam, the upland soils in Plymouth County are all acid in the surface soil. In the case of the Marshall silt loam and the Clarion silt loam, however, the subsoil seems to be supplied with lime and the acidity is in general limited to the surface and subsurface layers. The terrace types and the Wabash soils on the bottomlands are acid in the surface soils and usually also thru the three-foot soil section. The acidity developed is not great, however, in any of the soil types.

There is no large need for the addition of lime to most of the soil types in Plymouth County. Wherever the surface soil is acid, however, lime is very desirable, especially if legumes are to be grown. For new seedings of alfalfa and sweet clover on such soils lime is particularly desirable. If there is lime in the subsoil, as is the case with a number of the types in this county, the surface soil is not apt to be so strongly acid and later additions of lime will be unnecessary. The use of the lime to start the early growth of the crop is all that is needed. Small applications may have considerable value for legume crops. For other general farm crops such as corn and small grains, the use of lime on these soils would not be necessary. The acidity is not sufficient to cause any injury. On the terrace soils and on the Wabash types on the bottoms, however, the soils should be tested for lime needs and lime should be applied as needed. Farmers may test their own soils for lime requirements but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.



It should be emphasized that the upland types in this county, with the exception of the Knox silt loam, should be tested for lime needs and lime should be applied as necessary when legumes such as sweet clover and alfalfa are to be seeded. On the terrace soils and the Wabash types on the bottoms testing is also desirable and the use of lime is necessary for the most satisfactory crop yields on these types. Further information on the use of lime on soils, losses by leaching, and other points connected with liming are given in Extension Bulletin 105 of the Iowa Agricultural Extension Service. A list of companies prepared to furnish lime for agricultural use is also given in this bulletin.

## Drainage

It has been emphasized earlier in this report that the natural drainage system of most of the land in Plymouth County is quite adequately developed. The various streams with their tributaries and intermittent drainageways extend into practically all parts of the upland in the county. Only in few and very limited areas is the natural drainage of the soils inadequate. On the bottomlands, however, where the topography is level to flat and the subsoil conditions are heavy, there is more need for artificial drainage. On the Wabash and Lamoure types the installation of tile may be very necessary before successful crop growth can be secured.

Soils which are not properly drained will not give satisfactory crop yields. The first treatment needed on such types is proper drainage. The installation of tile may be necessary to provide for adequate crop growth. While tiling is expensive, the results secured warrant the outlay. No fertilizing treatment, and in fact no other treatment of land, will prove of value if drainage is needed. The practical experiences of many farmers indicate the large beneficial effects from tiling land which is too wet. An examination of the map given earlier in this report indicates the adequate natural drainage system of the upland areas in the county and the need for drainage on the more level bottomland areas.

## The Rotation of Crops

It is a matter of common knowledge that the continuous growing of any one crop quickly reduces the fertility of the soil. Even if the crop grown has a large money value, still it is more profitable over a period of years, to rotate crops, including in the rotation crops which may be of actually less money value. This is due to the fact that under continuous cropping, the yields of the crops grown decrease much more rapidly than when a rotation is practiced.

While no experiments have been carried out in Plymouth County in the attempt to select the most desirable rotation to be followed, a number of good rotations in general use thruout the state are given here as suggestive of what a good rotation should contain. Modifications of these rotations may be made to fit almost any conditions. In fact, almost any rotation will prove satisfactory provided it contains a legume and a profitable crop. The following are some of the good rotations being used in Iowa at the present time.

1. SIX-YEAR ROTATION

*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

This rotation may be reduced to a five-year rotation by cutting out either the second or sixth year and to a four-year rotation by omitting the fifth and sixth years.

2. FOUR OR FIVE-YEAR ROTATION

*First year*—Corn
*Second year*—Corn
*Third year*—Wheat or oats (with clover or with clover and timothy)
*Fourth year*—Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy)

3. FOUR-YEAR ROTATION WITH ALFALFA

*First year*—Corn
*Second year*—Oats
*Third year*—Clover
*Fourth year*—Wheat
*Fifth year*—Alfalfa (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year rotation)

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

*First year*—Corn
*Second year*—Oats or wheat (with clover seeded in the grain)
*Third year*—Clover (In grain farming, only the grain and clover seed should be sold; most of the crop residues such as corn stover should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop)

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

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

## The Prevention of Erosion

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground was absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.



The two types of erosion are sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes.

Erosion occurs to some extent in Plymouth County, the effect being particularly evident on the Knox silt loam on the bluffs. There is also some erosion of the Clarion loam and of the Marshall silt loam on the more rolling uplands. There are apparently many cases in the county where some methods of prevention or control of erosion should be adopted.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

### EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

*"Plowing In"*—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas this process may be quite effective. In the more rolling areas, however, it is best to supplement the "plowing in" with a series of "staked in," dams or earth dams.

*"Staking In"*—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists of driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

*Earth Dams*—Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but in many cases they are effective in preventing erosion in "dead furrows."

### SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

*Checking Overfalls*—The formation of small gullies or ditches is practically always the result of overfalls. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush are held in place by cross pieces nailed to the posts.

*"Staking In"*—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies.

*The Straw Dam*—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used.

*The Earth Dam*—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

*The "Christopher" or "Dickey" Dam*—This modification of the earth dam, consists merely in laying a line of tile down the gully and beneath the dam. An elbow or a "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon the earth dam, such as sorghum, or even oats or rye, and later seed it to grass.

*The Adams Dam*—This dam is practically the same as the "Christopher" or "Dickey" dam. In fact the principle of construction is identical. In some sections the name "Adams Dam" has been applied and hence it is mentioned separately.

*The Stone or Rubble Dam*—Where stones abound they are frequently used in constructing dams for the control of erosion.

*The Rubbish Dam*—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method.

*The Woven Wire Dam*—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies.

*Sod Strips*—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve as well. For quick results thickly planted sorghum may be employed.

*The Concrete Dam*—One of the more effective means of controlling erosion is by the concrete dam, provided the "Dickey" system is used in connection with it. This type is, however, rather expensive. Owing to the high cost and the difficulty involved in securing a correct design and construction, concrete dams cannot be considered as adapted to general use on the farm.

*Drainage*—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion.



LARGE GULLIES

The erosion in large gullies or ravines may in general be controlled by the same methods used for small gullies. The "Dickey" dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such lowlying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

*Straightening and Tiling*—The straightening of the larger streams in bottomland areas may be accomplished by a community and while the cost is considerable, large areas of land may thus be reclaimed.

*Trees*—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

*Use of Organic Matter*—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed, if farm manure is not available in sufficient amounts. Crop residues such as straw and cornstalks may also be turned under in soils to increase their organic matter content.

*Growing Crops*—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also desirable for use in such locations.

*Contour Discing*—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa.

*Sod Strips*—The use of narrow strips of sod is very desirable for preventing gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

*Deep Plowing*—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains.

## INDIVIDUAL SOIL TYPES IN PLYMOUTH COUNTY* **

There are 14 individual soil types in the county and these with the shallow phase of the Marshall silt loam make a total of 15 separate soil areas. They

* Plymouth County joins Sioux County on the north and Woodbury County on the south. In places the soil maps of these counties do not agree on the borders as a result of changes in correlation due to a fuller knowledge of the soils of the state. The Sioux loam and Carrington loam of Sioux County are here classed with the O'Neill and Dickinson series, respectively. On account of their small extension into Plymouth County, the Carrington silt loam and the Lamoure clay of Woodbury County have been mapped with the Clarion and Wabash series in this county.

** The description of individual soil types given in the Bureau of Soils report have been closely followed in this section of the report.

are divided into four groups, drift soils, loess soils, terrace soils and swamp and bottomland soils.

### Drift Soils

There are two drift soils in the county classified in the Clarion and the Dickinson series. Together they cover 0.8 percent of the total area.

#### CLARION SILT LOAM (169)

The Clarion silt loam is the larger of the drift soils, covering 0.7 percent of the total area. It occurs in numerous small areas in various parts of the county, being found on the steeper areas adjacent to some of the major streams where the loessial covering has been removed and the underlying drift material is exposed. The type is most extensively developed in the northeastern corner of the county on the bluffs adjacent to Deep Creek and Willow Creek, and in the northwestern part, along Indian Creek. One area of considerable size is located in the north central part, along the Floyd River. Other numerous small areas of the type occur in various parts of the county.

The surface soil of the Clarion silt loam is a very dark grayish-brown mellow silt loam, extending to a depth of 12 inches. Below this point there is a brown or yellowish-brown calcareous heavy loam or silty clay loam, containing some gritty material and a few rocks or pebbles. This layer extends to a depth of 24 inches. The lower part of the subsoil at a depth of 3 feet or more, is a brownish-yellow or yellow silty clay or clay, containing some sand and other gritty material. It is also highly calcareous. Iron stains occur in the lower part of the subsoil.

Where the type joins the shallow phase of the Marshall silt loam and the Knox silt loam, the surface soil is somewhat shallower than where it joins the typical Marshall silt loam. The area occurring in Section 3 and 10 of Portland Township does not have the highly calcareous subsoil but is typically Clarion in other respects. In topography the type is usually gently rolling and natural drainage is ordinarily good.

Because of its position along the lower slopes, much of the type is used for pasture purposes. Where cultivated, general farm crops are grown and crop yields are much the same as those secured on the Marshall silt loam.

The yields of general farm crops on the cultivated sections, however, may be much improved thru proper methods of soil treatment. The liberal application of farm manure to this soil is very desirable to improve fertility. The turning under of leguminous crops as green manures would be of large value. The use of a phosphate fertilizer is desirable on this type and tests of superphosphate are strongly recommended.

#### DICKINSON LOAM (174)

This is a minor type and the second largest drift soil, covering only 0.1 percent of the total area. It is found in two areas of about 300 acres, comprising parts of Sections 3, 4, 9 and 10 of Portland Township and in another area in the northeastern part of Garfield Township.

The surface soil of the Dickinson loam is a dark grayish-brown or very dark grayish-brown loam, extending to a depth of 12 inches. At that point it is underlaid by a brown heavy loam or silt loam containing considerable sand. Below 24 inches the subsoil is a brownish-yellow or yellow loamy sand, becoming more sandy with the lower depths. In topography the Dickinson loam is undulating to gently rolling, and natural drainage is good to excessive.



About three-fourths of this soil type is under cultivation, the remainder being utilized for pasture. General farm crops, including corn, oats, clover and alfalfa, are grown. Yields are usually somewhat less than on the Marshall silt loam, owing probably to less favorable moisture conditions. This type will respond to applications of farm manure, and liberal additions of manure are recommended. The use of a leguminous crop for green manuring purposes is very desirable and will bring about large benefits on crop yields. Both of these treatments will improve the water holding capacity of the soil which is so important in connection with crop growth on it. The use of a phosphate fertilizer is desirable, and tests of superphosphate are strongly recommended. The type is acid in reaction, and the addition of lime is very necessary, especially for the best growth of a legume crop.

### Loess Soils

The two loess types in the county are classified in the Marshall and Knox series and these together with the shallow phase of the Marshall silt loam make up three large areas. Together they cover 85.4 percent of the total area.

#### MARSHALL SILT LOAM (9)

The Marshall silt loam is by far the most extensively developed type and together with the shallow phase which is much less extensively developed, it covers 81.3 percent of the total area. It is found widely distributed over all of the uplands, the largest extensive individual areas occurring in the eastern and northern parts and for some distance north of Potosia in the southwestern part of the county. Numerous sections of the upland are made up entirely of this type of soil except for occasional, ribbon-like areas of bottomland soil along the streams.

The surface soil of the Marshall silt loam is a dark grayish-brown or very dark grayish-brown, smooth, mellow silt loam, extending to a depth of 12 to 14 inches. The upper subsoil to a depth of about 22 inches is a brown silt loam or heavy silt loam, rather compact in nature but not impervious. The lower part of the subsoil to a depth of 3 feet or more consists of a yellowish-brown or yellow heavy silt loam or silty clay loam, lighter in texture and more friable than the upper subsoil. In a few places there is some gray mottling in the lower subsoil and numerous lime concretions also occur, in places, within the three-foot section and even up thru the surface soil.

In some areas the soil is lighter in color and shallower than the typical and this variation from the typical Marshall is found on the eroded hills and ridges. These bodies are small in extent, covering one to two acres, and are too small to be shown on the map. Occasionally at the bases of the slopes and along swales the surface soil may be a little deeper than typical and somewhat darker in color. In topography the type is usually gently rolling, with gradual slopes to the drainageways. The natural drainage of the soil is good. The subsoil is not impervious and the need for artificial drainage on this type is limited to those areas which occur in the bottoms and swales.

At least 90 percent of the Marshall silt loam is under cultivation, and the general farm crops grown include corn, oats, hay, wheat and some barley and potatoes. Alfalfa is widely grown and yields 4 to 7 tons per acre. The average yield of corn is between 40 and 45 bushels per acre, and frequently on the better areas of the Marshall where good systems of management have been practiced yields range from 50 to 65 or 70 bushels per acre. Oats yield 35 to 38 bushels per acre and on the more fertile farms yield 45 to 60 bushels per acre. Sweet clover yields 2 to 3 tons, and clover and timothy 1½ to 3 tons per acre. Spring wheat yields 8 to 12 bushels per acre, and winter varieties 15 to 25 or 30 bushels per acre.

The most desirable treatment for use on the Marshall silt loam is first of all for the addition of liberal amounts of farm manure. Large increases in the yields of general farm crops will follow its use. The experiments referred to earlier in this report indicate the large value of farm manure when applied to this soil. The turning under of a leguminous crop as a green manure will also bring about large beneficial effects on crop yields. The use of a phosphate fertilizer will undoubtedly prove desirable in many cases on this soil and tests of superphosphate and rock phosphate are strongly recommended. While the surface soil of this type is acid in reaction, there is usually an abundance of lime in the lower soil layers. The use of lime is necessary, therefore, only for new seedings of such crops as sweet clover and alfalfa which are very sensitive to acid soil conditions. Small amounts of lime may be desirable for securing a good stand and early growth of these crops. For general farm crops the use of lime is probably not needed now. Other fertilizing materials may be employed on the Marshall silt loam where special crops are grown. For general farm crops, however, it seems that phosphate fertilizers will prove of the largest value, giving much greater economic returns than complete commercial fertilizers.

### MARSHALL SILT LOAM (SHALLOW PHASE) (213)

The shallow phase of the Marshall silt loam is much less extensively developed than the typical soil, covering about 14 percent of the total area. It occurs mostly in the western and southwestern parts of the county, but small areas occur in various other parts. There is an area of considerable size west of West Fork Little Sioux River in the southeastern part of the county and another west of Mud Creek. A more or less continuous area is found west of the Floyd River bottoms from the southern county line north of Merrill and following the west side of West Fork Floyd River to its junction with Mink Creek. It occurs in numerous other small isolated bodies on the hill tops and ridges except in the western part of the county. There it occurs on the lower slopes below the Knox soils.

The surface soil of the shallow Marshall silt loam is a dark grayish-brown or very dark grayish-brown mellow silt loam, containing some very fine sand, and extending to a depth of 7 or 8 inches. The upper part of the subsoil to about 20 inches consists of a brownish-yellow, friable silt loam, containing quite a little very fine sand. The lower part of the subsoil to a depth of 3 feet or more consists of a yellow silt loam containing much very fine sand. The subsoil and in many places the surface soil are highly calcareous, and in some areas there are gray mottlings and iron stains in the lower subsoil.

There are some variations in the characteristics of this soil, due chiefly to



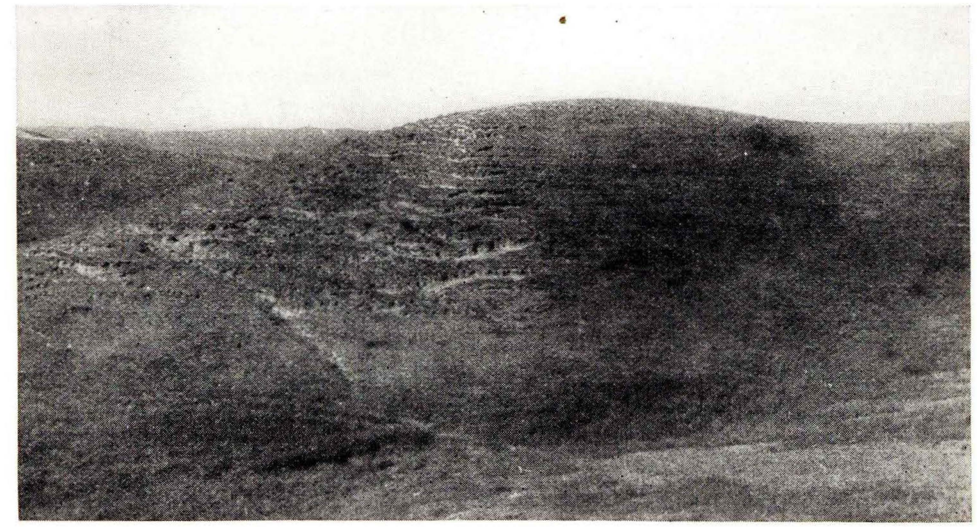


Fig. 5. Effects of erosion in rough area of Knox silt loam in Plymouth County.

differences in the depth of the surface layer. In the western part of the county where the areas occur adjacent to areas of the Knox silt loam, the subsoil has a higher content of very fine sand than in the other areas. In some places it is composed almost entirely of very fine sand but there is generally some silt and clay present. In small areas of this soil in the eastern and northern parts of the county, the subsoil resembles that of the typical Marshall. In all areas the subsoil of the shallow phase Marshall is calcareous and contains lime nodules and these are often found also in the surface soil. In topography the type is usually strongly rolling to rough, altho in the western part of the county, it is more gently rolling.

About three-fourths of this shallow phase are under cultivation, the remainder being in pasture or supporting a forest growth. The chief crops grown on the cultivated areas are corn, oats and hay, including alfalfa, sweet clover, red clover and timothy. Crop yields are usually somewhat less than on the typical Marshall silt loam. Corn yields 50 to 60 bushels per acre under the best farming conditions but ordinarily the yields are somewhat lower than this.

The treatments needed by this soil chiefly center around the methods which will prevent erosion. Care is necessary in preparing the seed bed. Contour plowing is practiced to good advantage on much of this land. The incorporation of organic matter in the soil is very desirable to reduce the washing away of the soil and increase its absorptive power for water. Liberal applications of farm manure are of value and the turning under of leguminous crops as green manures would also help. A phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended. The rougher areas are not suitable for cultivation and are best left in pasture and woodlands.

### KNOX SILT LOAM (11)

The Knox silt loam is the second loess type and the third most extensively developed individual soil. It covers 4.1 percent of the county. It is developed

Practically all of the Waukesha silt loam is under cultivation, general farm crops being grown. Corn, oats and hay give yields which are very similar to those secured on the Marshall silt loam, which type the Waukesha silt loam very closely resembles.

The chief need of this soil to make it more productive is for the addition of organic matter, and liberal applications of farm manure are recommended. The turning under of leguminous crops for green manuring purposes would also be desirable. The use of a phosphate fertilizer may prove extremely desirable on this type, and tests of superphosphate are recommended.

### JUDSON SILT LOAM (131)

The Judson silt loam is the second largest terrace type covering 1.1 percent of the total area. It is found on terraces along the Big Sioux River, the largest development of the type being directly southwest of Akron. Numerous small areas of the type occur along Big Sioux River, Kettle Creek and in other parts of the county along some of the other streams and intermittent drainageways.

The surface soil of the Judson silt loam is a very dark grayish-brown or nearly black silt loam, extending to a depth of 18 inches. Below that point is a medium, dark brown, mellow silt loam to a depth of 30 inches, where a brown silt loam occurs. In places the dark color continues to 3 feet or more with but slight difference in the texture of the soil. This variation is found west and southwest of Akron just east of Big Sioux River.

In topography the Judson silt loam is gently sloping or flat, and drainage is good except in the flatter areas. Some of the type is under cultivation, the smaller bodies being farmed with the adjacent soils. The chief crops grown include corn, hay, oats and other small grain. When the type is well drained the yields are similar to those secured on the Marshall silt loam.

The needs of this type are very similar to those of the Marshall silt loam. The use of farm manure is desirable and liberal applications should be made. The turning under of a leguminous crop as a green manure would also be of value. The use of a phosphate fertilizer may prove distinctly profitable and farmers are urged to test the value of superphosphate and rock phosphate on this soil. The type is acid in reaction and additions of lime are necessary for the best growth of leguminous crops. The first treatment needed on many areas of this soil is adequate drainage.

### O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a very minor type, covering only 0.1 percent of the total area. It occurs in a number of small isolated areas along Big Sioux River and Deep Creek. There are no large areas of the type.

The surface soil of the O'Neill sandy loam is a dark brown or dark grayish-brown sandy loam, extending to a depth of 10 inches. The subsoil is a brown or yellowish-brown sandy loam or loamy sand to a depth of 24 inches, at which point it becomes more sandy, finally grading into a yellowish-brown or yellow sand, in many places having considerable gravel and sand in the lower subsoil.

Drainage is excessive, and only a small acreage is under cultivation. The soil is of little importance agriculturally. If farmed, it would need primarily the addition of organic matter, and liberal applications of farm manure and the turning under of leguminous crops as green manures would be of value.



The use of phosphate fertilizers would also prove profitable for general farm crops grown on this type. It needs first of all, however, the incorporation of organic matter to make it more retentive of moisture before crop yields will be satisfactory.

### O'NEILL LOAM (108)

The O'Neill loam is a minor type, covering only 0.1 percent of the total area. Its occurrence is limited to one body of about 256 acres in Section 4 of Portland Township.

The surface soil of the O'Neill loam is a dark grayish-brown or very dark grayish-brown friable loam, extending to a depth of 15 inches. Below this point the upper subsoil is a sandy loam, which at a depth of 25 inches contains a little more sand and is slightly lighter in color. The lower part of the subsoil below 28 inches is a brown or yellowish loamy sand or sand. The land is flat or sloping in topography and natural drainage is good or excessive, owing to the porous nature of the subsoil.

Some of this type is under cultivation, and yields are fair under favorable conditions. The chief need of the O'Neill loam to make it more productive is for the incorporation of organic matter to increase its water-holding capacity and to reduce the danger of crops suffering in periods of drouth. Liberal applications of farm manure are very desirable on this type and the turning under of leguminous crops as green manures would also be of value. The soil is acid in reaction and the use of lime is necessary for the best growth of legumes. The addition of a phosphate fertilizer would undoubtedly be desirable, and tests of superphosphate are recommended.

## Swamp and Bottomland Soils

The 6 swamp and bottomland soils in the county are classified in the Wabash, Lamoure and Cass series. Together they cover 10.3 percent of the total area.

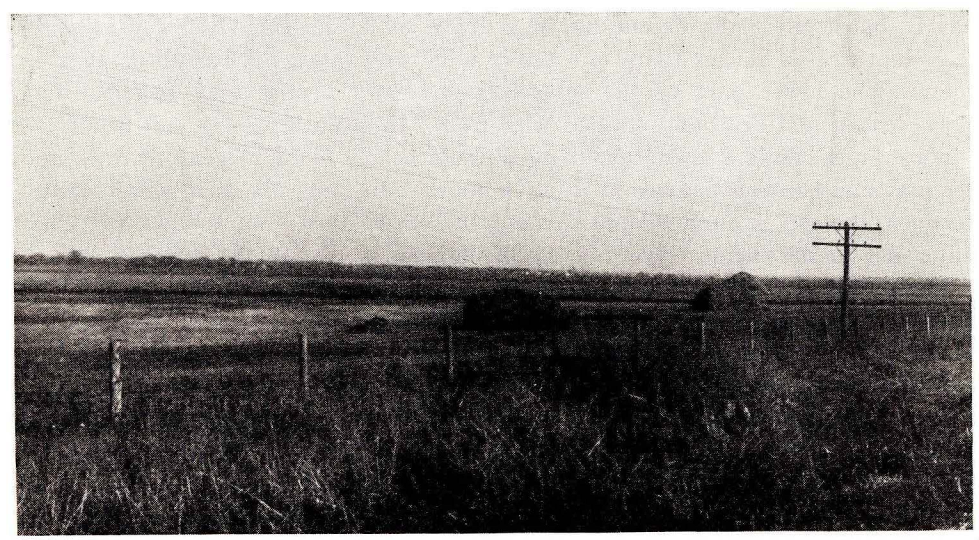


Fig. 7. View across the Big Sioux bottomlands, Plymouth County.

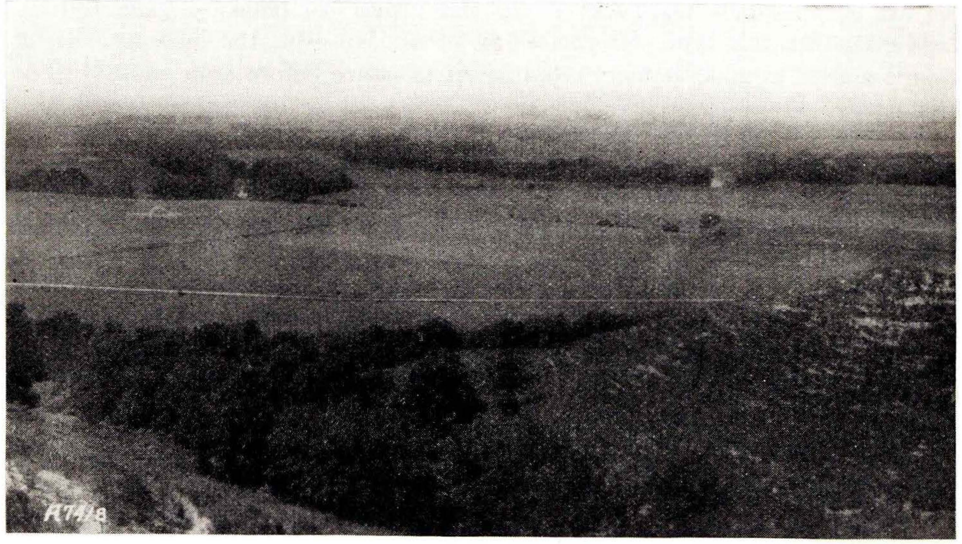


Fig. 8. Another view across the broad bottomlands along the Big Sioux River in Plymouth County.

### WABASH SILT LOAM (26)

The Wabash silt loam is the most extensively developed bottomland soil and the second largest individual soil type. It covers 8.5 percent of the total area. It is widely distributed thru all of the county, forming the bottomlands along most of the small streams and a large proportion of the bottomlands along the larger streams where it ranges in width from one-twelfth of a mile to one mile or more. Along the Big Sioux River, except above Akron, this soil occurs mixed with the other bottomland soils, altho elsewhere, particularly along Floyd River, it is developed in rather continuous bodies.

The surface soil of the Wabash silt loam is a very dark grayish-brown or nearly black silt loam, extending to a depth of 15 inches. Below that point to a depth of 24 inches there is a heavy silty clay loam, dark drab or gray in color. The lower part of the subsoil is generally a silty clay mottled with gray, brown and drab and stained with iron. In some areas the soil below the surface layer shows a gradation in color from nearly black to gray or drab and the material becomes heavier at a lower depth. In some places in small stream bottoms, the soil is dark colored thruout the entire three-foot section, the chief difference in the various layers being an increase in clay at the lower depths.

In topography the Wabash silt loam is flat to gently sloping. Old stream valleys which are more or less filled in, afford the only relief. Drainage is poor and most of the areas of this soil along the smaller streams are flooded in periods of high water or after heavy rains. The surface ranges from 2 to 6 feet above the normal water level of the streams and is practically all subject to occasional overflow. The need for drainage is quite evident on most areas of this soil.

About 30 percent of the Wabash silt loam is under cultivation, the remainder being in native grasses and forest growth. The chief cultivated crops are corn and wheat, altho some of the land is used for clover and alfalfa. Much of the type is used as pasture land, and a scattered tree growth is found on the areas along streams and along old stream channels. On the cultivated areas corn yields 40 to 70 bushels per acre, spring wheat 10 to 15 bushels, fall rye 25 to 35 bushels, clover and timothy 2 to 3 tons and alfalfa 4 to 6 tons.



The chief need of this soil, if it is to be cultivated, is adequate drainage. When drained, much of the land is very productive. The use of small amounts of farm manure would be of value on the type to stimulate the production of available plant food. Large applications should not be made. The turning under of leguminous crops as green manures would also be of value on this soil. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate or rock phosphate are strongly urged. The type is acid in reaction, and if legumes are to be successfully grown lime should be applied.

### WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the second largest bottomland soil, covering 0.8 percent of the total area. This type is developed most extensively along the Big Sioux River. Other large disconnected areas occur in Portland, Westfield and Sioux Townships. There are also considerable areas of the type along the Floyd River, chiefly in Plymouth and Grant Townships. Small areas occur along the streams in other parts of the county.

The surface soil of the Wabash silty clay loam is a very dark brown, dark grayish-brown or nearly black silty clay loam, extending to a depth of 14 inches. The upper subsoil to a depth of 24 inches consists of a dark gray or drab clay loam or silty clay loam with faint iron stains, slightly mottled in places and underlaid by a lighter colored clay which is stained with iron and mottled with gray and drab. In topography the type is flat to depressed, and natural drainage is deficient.

Where the type is drained, general farm crops are grown, and yields are very much the same as on the Wabash silt loam. The needs are also very similar, and the first treatment needed is the proper drainage of the type. Small amounts of farm manure would then be of value in stimulating the production of available plant food. The use of lime is necessary if legumes are to be grown. The addition of a phosphate fertilizer may be of large value on this soil, and tests of superphosphate and rock phosphate are recommended. More care is necessary in the handling of this soil than in the case of the Wabash silt loam because of its physical condition. Fall plowing is very desirable, and the addition of barnyard manure will aid in providing the best physical condition of the soil for crop growth.

### WABASH CLAY (72)

The Wabash clay is a very minor type, covering only 0.1 percent of the total area. It occurs only in the southern part of the county along the Big Sioux River. There are several limited areas of the type in Sioux Township.

The surface soil of the Wabash clay is a very dark gray, grayish-brown, or black clay, extending to a depth of 20 inches. At that point there is a gray and drab mottled clay stained with iron. The upper part of the subsoil is darker in color than the lower part which is a mottled gray, yellow and brown heavy, tenacious clay stained with iron. The type is known locally as "gumbo."

Only a part of the Wabash clay is under cultivation, the remainder being in grass land. The main crops are corn, wheat and hay. The chief need of this soil is for drainage before it can be made productive. When drained, the addition of farm manure in small amounts would be of value in improving the physical condition of the type and in stimulating the production of available plant food. The use of lime is essential if legumes are to be grown, and the addition of a phosphate fertilizer would be very desirable on this soil. Tests of superphosphate and rock phosphate are recommended.

### LAMOURE SILT LOAM (153)

The Lamoure silt loam is a minor type, covering only 0.6 percent of the total area. It occurs in numerous small narrow ribbon-like areas along the head-waters of various drainageways and intermittent drainage lines and in small areas in the bottomlands along some of the larger streams.

The surface soil of the Lamoure silt loam is a very dark brown or black silt loam, extending to a depth of 14 inches. At that point it is underlaid to a depth of 24 inches by a black, gray, or drab, clay loam or silty clay. The lower part of the subsoil is a gray or drab mottled silty clay or clay and is highly calcareous.

The Lamoure silt loam is very similar to the Wabash silt loam, except for the calcareous nature of the soil and subsoil. This type is farmed similarly and general farm crops yield very similarly to those on the Wabash silt loam. The chief need is adequate drainage and when this is accomplished, small amounts of farm manure would aid in stimulating available plant food production. The use of a phosphate fertilizer would undoubtedly be desirable, and tests of superphosphate and rock phosphate are recommended.

### LAMOURE SILTY CLAY LOAM (111)

This is a minor type, covering 0.2 percent of the total area. It is developed in only a few areas along the Big Sioux River in the southwestern townships and along the Floyd River in Plymouth Township.

The surface soil of the Lamoure silty clay loam is a very dark brown to nearly black silty clay loam, extending to a depth of 15 inches. The subsoil at 24 inches is a dark gray or drab heavy silty clay loam or silty clay, stained with iron and highly calcareous.

This type is very similar to the Wabash silty clay loam. It needs first of all drainage, then to be made more productive a small amount of farm manure would help and the use of a phosphate fertilizer would undoubtedly be of value.

### CASS FINE SANDY LOAM (130)

This is a very minor type, covering only 0.1 percent of the total area. It occurs in one body in Section 17 of Portland Township.

The surface soil of the Cass fine sandy loam consists of a dark grayish-brown fine sandy loam, extending to a depth of 15 inches. The upper part of the subsoil is a brown loamy sand or light sandy loam to a depth of 28 inches, the amount of sand increasing with the lower depth. The lower part of the subsoil is a brown loamy sand, grading into a pure sand at depths of about 30 inches.

The type as developed in Plymouth County is not cultivated and is of little value except for pasture.

It is found along the river bank, has an irregular surface, and supports a very scant tree growth, and a rather poor stand of pasture grasses.

# APPENDIX

## THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are

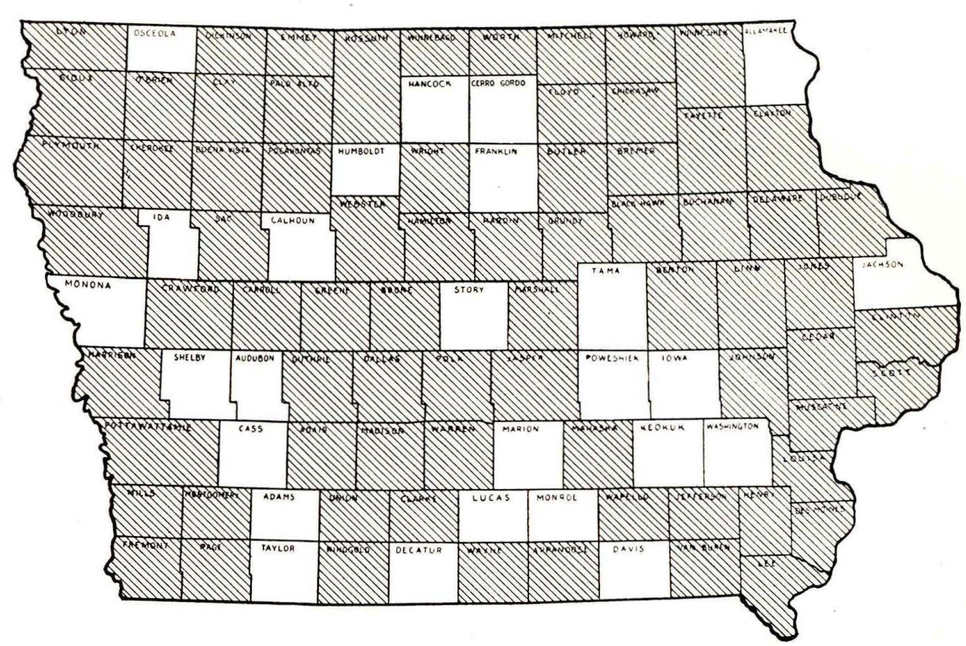



Fig. 9. Map of Iowa showing the counties surveyed.

emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested.

## *PLANT FOOD IN SOILS*

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

### THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

### AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth.

### REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in superphosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly



TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$) ), Phosphorus (P) at 12c (Superphosphate), and Potassium (K) at 6c (Potassium Chloride (KCl) ).

| Crop | Yield | Plant Food, Lbs. | | | Value of Plant Food | | | Total Value of Plant Food |
|---|---|---|---|---|---|---|---|---|
| | | Nitrogen | Phosphorus | Potassium | Nitrogen | Phosphorus | Potassium | |
| Corn, grain | 75 bu. | 75 | 12.75 | 14 | $12.00 | $1.52 | $0.84 | $14.37 |
| Corn, stover | 2.25 T. | 36 | 4.5 | 39 | 5.76 | 0.54 | 2.34 | 8.64 |
| Corn, crop | ------- | 111 | 17.25 | 53 | 17.76 | 2.07 | 3.18 | 23.01 |
| Wheat, grain | 30 bu. | 42.6 | 7.2 | 7.8 | 6.81 | 0.86 | 0.46 | 8.13 |
| Wheat, straw | 1.5 T. | 15 | 2.4 | 27 | 2.40 | 0.28 | 1.62 | 4.30 |
| Wheat, crop | ------- | 57.6 | 9.6 | 34.8 | 9.21 | 1.14 | 2.08 | 12.43 |
| Oats, grain | 50 bu. | 33 | 5.5 | 8 | 5.28 | 0.66 | 0.48 | 6.42 |
| Oats, straw | 1.25 T. | 15.5 | 2.5 | 26 | 2.48 | 0.30 | 1.56 | 8.28 |
| Oats, crop | ------- | 48.5 | 8 | 34 | 7.76 | 0.96 | 2.04 | 14.70 |
| Barley, grain | 30 bu. | 23 | 5 | 5.5 | 3.68 | 0.60 | 0.33 | 4.61 |
| Barley, straw | 0.75 T. | 9.5 | 1 | 13 | 1.52 | 0.12 | 0.78 | 2.42 |
| Barley, crop | ------- | 32.5 | 6 | 18.5 | 5.20 | 0.72 | 1.11 | 7.03 |
| Rye, grain | 30 bu. | 29.4 | 6 | 7.8 | 4.70 | 0.72 | 0.46 | 5.88 |
| Rye, straw | 1.5 T. | 12 | 3 | 21 | 1.92 | 0.36 | 1.26 | 3.54 |
| Rye, crop | ------- | 41.4 | 9 | 28.8 | 6.62 | 1.08 | 1.72 | 9.42 |
| Potatoes | 300 bu. | 63 | 12.7 | 90 | 10.08 | 1.25 | 5.40 | 17.00 |
| Alfalfa, hay | 6 T. | 300 | 27 | 144 | 48.00 | 3.24 | 8.64 | 59.88 |
| Timothy, hay | 3 T. | 72 | 9 | 67.5 | 11.52 | 1.08 | 3.95 | 16.55 |
| Clover, hay | 3 T. | 120 | 15 | 90 | 19.20 | 1.80 | 5.40 | 16.40 |

reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food losses.

### REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

## *PERMANENT FERTILITY IN IOWA SOILS*

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper system of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

### CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for crop production, largely because they help control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for lack of water necessary to bring them their food and also for lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

### THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

There are a number of explanations of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In proper rotations the time between two different crops of the same plant is long enough to allow the "toxic" substances to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reasons for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

### MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.



Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of the soils need be resorted to.

### THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and superphosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

### LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil.

## *SOIL AREAS IN IOWA*

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various areas. The various areas are shown in the map, fig. 10.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of the fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

## THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

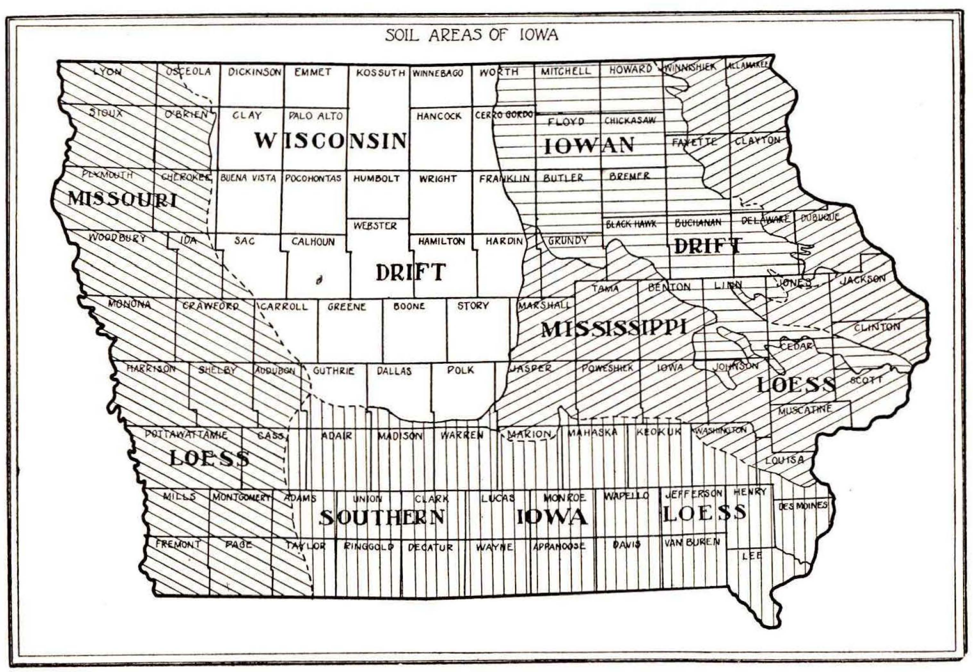



Fig. 10. Map showing the principal soil areas in Iowa.



## GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a graduation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

| | |
|---|---|
| Organic matter | All partially destroyed or decomposed vegetable and animal material. |
| Inorganic matter | Stones—over 32 mm.*<br>Gravel—32—2.0 mm.<br>Very coarse sand—2.0—1.0 mm.<br>Coarse sand—1.0—0.5 mm.<br>Medium sand—0.5—0.25 mm.<br>Fine sand—0.25—0.10 mm.<br>Very fine sand—0.10—0.05 mm.<br>Silt—0.05—0.00 mm. |

## SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

*Peats*—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

*Peaty Loams*—15 to 35 per cent organic matter mixed with much sand and silt and a little clay.

*Mucks*—25 to 35 per cent of partly decomposed organic matter mixed with much clay and some silt.

*Clays*—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.

*Silty Clay Loams*—20 to 30 per cent clay and more than 50 per cent silt.

*Clay Loams*—20 to 30 per cent clay and less than 50 per cent silt and some sand.

*Silt Loams*—20 per cent clay and more than 50 per cent silt mixed with some sand.

*Loams*—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

*Sandy Clays*—20 per cent silt and small amounts of clay up to 30 per cent.

*Fine Sandy Loams*—More than 50 per cent fine sand and very fine sand mixed with less than 25 per cent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 per cent.

*Sandy Loams*—More than 25 per cent very coarse, coarse and medium sand; silt and clay 20 to 50 per cent.

*Very fine Sand*—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

*Fine Sand*—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

*Sand*—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent fine sand, less than 20 per cent silt and clay.

*Coarse Sand*—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent of other grades, less than 20 per cent silt and clay.

*Gravelly Loams*—25 to 50 per cent very coarse sand and much sand and some silt.

* 25mm equals 1 in. † Bureau of Soils Handbook.

*Gravels*—More than 50 per cent very coarse sand.

*Stony Loams*—A large number of stones over one inch in diameter.

## METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact map of the county.

# IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

(Those followed by a * are out of print, but are often available in public libraries.)

## BULLETINS

No.
78 Drainage Conditions in Iowa.*
82 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
98 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.*
124 A Centrifugal Method for the Determination of Humus.*
150 The Fertility in Iowa Soils.*
150 The Fertility in Iowa Soils (Popular Edition).
151 Soil Acidity and the Liming of Iowa Soils.*
151 Soil Acidity and the Liming of Iowa Soils (Abridged).*
157 Improving Iowa's Peat and Alkali Soils.*
161 Maintaining Fertility in the Wisconsin Drift Soil Areas of Iowa.*
167 Rotation and Manure Experiments on the Wisconsin Drift Soil Areas.
177 The Alkali Soils of Iowa.
183 Soil Erosion in Iowa.*
191 Reclaiming Iowa's Push Soils.
213 Iowa System of Soil Management.*
221 Crop Yields on Soil Experiment Fields in Iowa.
232 Field Experiments with Gypsum.
236 The Economic Value of Farm Manure as a Fertilizer on Iowa Soils.
241 Crop Returns Under Various Rotations in the Wisconsin Drift Soil Area.

## CIRCULARS

2 Liming Iowa Soils.*
7 Bacteria and Soil Fertility.*
8 The Inoculation of Legumes.*
9 Farm Manures.*
10 Green Manuring and Soil Fertility.*
15 Testing Soils in Laboratory and Field.*
24 Fertilizing Lawn and Garden Soils.
43 Soil Inoculation.
51 Soil Surveys, Field Experiments and Soil Management in Iowa.*
58 Use of Lime on Iowa Soils.*
82 Iowa Soil Survey and Field Experiments.*
89 The Pasture Problem in Iowa.
97 The Use of Fertilizers on Iowa Soils.
102 Inoculation of Legumes.

## RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
3 Influences of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
8 Bacteria at Different Depths in Some Typical Iowa Soils.*
9 Amino Acid and Acid Amides as Source of Ammonia in Soils.*
11 Methods for the Bacteriological Examination of Soils.*
13 Bacteriological Studies of Field Soils, III.*
17 The Determination of Ammonia in Soils.
18 Sulfofication of Soils.
24 Determination of Amino Acids and Nitrates in Soils.
25 Bacterial Activities and Crop Production.
34 Studies of Sulfofication.
35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of Some Common Humus-Forming Materials of Narrow and Wide Nitrogen-Carbon Ratio on Bacterial Activities.
39 Carbon Dioxide Production in Soils and Carbon and Nitrogen Changes in Soils Variously Treated.
43 The Effect of Sulfur and Manure on the Availability of Rock Phosphate in Soil.*
44 The Effect of Certain Alkali Salts on Ammonification.
45 Soil Inoculation with Azotobacter.
56 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.
58 Nitrification in Acid Soils.
75 The Color of Soils in Relation to Organic Matter Content.
76 The Relationships between Hydrogen Ion, Hydroxyl Ion and Salt Concentrations and the Growth of Seven Soil Molds.
87 A Study of the Secondary Effects of Hill Fertilization.
104 Some Effects on Methods of Applications of Fertilizers on Corn and Soils.*
109 The Numbers of Microorganisms in Carrington Loam as Influenced by Different Soil Treatments.
110 Studies on Nitrification and Its Relation to Crop Production on Carrington Loam Under Different Treatments.
113 Physiological Studies on the Nitrogen Fixing Bacteria of the Genus Rhizobium.
114 Soybean Inoculation Studies.