# SOIL SURVEY OF IOWA

## WORTH COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 49
June, 1927
Ames, Iowa

# IOWA AGRICULTURAL EXPERIMENT STATION

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# SOIL SURVEY OF IOWA

## Report No. 49—WORTH COUNTY SOILS

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

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

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# WORTH COUNTY SOILS

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

Worth County is located in north central Iowa in the fifth tier of counties west of the Mississippi River and bordering the state of Minnesota on the north. It is partly in the Iowan drift soil area and partly in the Wisconsin drift soil area. Hence, the soils of the county are all of glacial origin, being derived in major part from the Iowan drift and to a smaller extent from the Wisconsin drift. The total area of the county is 399 square miles or 255,360 acres. Of this area 244,808 acres or 96.2 percent is in farm land. The total number of farms is 1450 and the average size of the farms is 169. The farms are operated by 687 owners, 238 relative renters, 433 renters, 90 both owning and renting, and 2 unclassified.

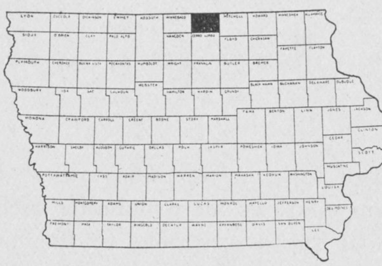

Fig. 1. A map showing the location of Worth County.

The following figures from the Iowa Yearbook of Agriculture for 1925 show the utilization of the farm land in the county.

| | |
|---|---|
| Acreage in general farm crops | 169,328 |
| Acreage in farm buildings, public highways and feed lots | 13,291 |
| Acreage in pasture | 58,581 |
| Acreage in waste land not utilized for any purpose | 1,435 |
| Acreage in farm wood lots used for timber only | 881 |
| Acreage in crop land laying idle | 684 |
| Acreage in crops not otherwise listed | 711 |

## THE AGRICULTURE OF WORTH COUNTY

The dominant type of agriculture in Worth County at present consists of a system of general farming including the raising of various field crops and the breeding and feeding of beef cattle, dairy cattle, and hogs. There is some grain farming, but the great majority of farmers are combining grain production with livestock raising and many farms at the present time are being operated on a livestock basis. The system of general farming or of livestock farming permits more ready maintenance of the productiveness of the soil. Since this fact has been recognized, there has been a general trend toward these systems of farming.

The income of the county comes from the sale of the surplus corn, oats, and other minor crops and from the sale of beef cattle, hogs, and dairy products. Almost half of the corn grown in the county is sold on the markets. A small part of the oats crop is similarly disposed of, and on some farms the income is increased from the sale of certain of the other crops grown on limited areas. The sale of beef cattle, of hogs, and of dairy products provides the entire source of income on some farms and makes up a large part of the income on all others.

The acreage in waste land in the county is considerable, and some methods of

*See Soil Survey of Worth County, Iowa, by D. S. Gray of the Iowa Agricultural Experiment Station and A. L. Gray of the U. S. Department of Agriculture. Field Operations of the Bureau of Soils 1922.

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

| Crop | Acreage | Percent of total farm land of the county | Bushels or tons per acre | Total bushels or tons | Average price | Total value of crop |
|---|---|---|---|---|---|---|
| Corn | 67,196 | 27.4 | 42.8 | 2,875,989 | $ 0.56 | $1,610,553 |
| Oats | 66,391 | 27.1 | 44.0 | 2,904,608 | 0.32 | 929,474 |
| Winter wheat | 87 | 0.03 | 20.0 | 1,740 | 1.36 | 2,366 |
| Spring wheat | 383 | 0.1 | 15.0 | 5,745 | 1.30 | 7,468 |
| Barley | 2,087 | 0.9 | 28.0 | 58,436 | 0.57 | 33,308 |
| Rye | 880 | 0.3 | 22.0 | 19,360 | 0.80 | 15,488 |
| Tame hay | 20,866 | 8.5 | 1.4 | 29,212 | 13.50 | 394,362 |
| Wild hay | 8,241 | 3.3 | 0.9 | 7,417 | 10.50 | 77,878 |
| Alfalfa | 189 | 0.07 | 3.0 | 567 | 17.50 | 9,922 |
| Potatoes | 393 | 0.1 | 77.0 | 30,261 | 2.35 | 71,113 |
| Flax | 1,643 | 0.7 | 13.0 | 21,359 | 2.20 | 46,989 |
| Pasture | 58,581 | 23.9 | ... | ...... | .... | ...... |

*Iowa Yearbook of Agriculture, 1925.

treatment should be adopted for the reclamation of these areas. The causes of infertility are variable and, hence, general recommendations for reclaiming such land cannot be given. Later in this report under the descriptions of the individual soil types, special treatments will be suggested for use under individual soil conditions to make the land more productive. In special cases for more or less abnormal conditions, advice regarding treatment may be secured upon request from the Soils Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Worth County in order of their importance are corn, oats, hay, potatoes, flax, barley, rye, alfalfa, and wheat. 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 1925, it was grown on 27.4 percent of the total farm land with an average yield of 42.8 bushels per acre. The leading varieties are Murdock and Silver King. Other varieties, including Golden Giant, Kossuth County Reliance, and Minnesota No. 13 are grown to a lesser extent. Much of the corn crop is fed to the livestock on the farms. From 40 to 50 percent, however, is sold out of the county and serves as a cash crop.

The second crop in acreage and value is oats. In 1925 this crop was grown on 27.1 percent of the total farm land. Average yields in that year amounted to 44 bushels per acre. The chief varieties are Medium Early Yellow, Iowa No. 103, Iowa No. 105, and some Iowar. These latter varieties are being more commonly used because they are better adapted to the heavier soils on which the longer strawed varieties tend to lodge. The major portion of the oat crop is used for feed on the farms. A portion, however, serves as a cash crop.

The third crop in acreage and value is hay. Tame hay was produced in 1925 on 8.5 percent of the total farm land with average yields of 1.4 tons per acre. The chief tame hay crop consists of timothy and clover mixed. Some timothy is grown alone and in some cases clover is also grown alone. Occasionally these crops are both grown for seed. Clover may yield as much as 1 bushel of seed per acre, while timothy sometimes gives as high as two bushels per acre. Some wild hay is grown in the county, average yields amounting to 0.9 ton per acre.

In 1925, it was estimated that 3.3 percent of the total farm land of the county was in wild hay. All the hay produced in the county is used for feeding purposes on the farms.

Potatoes are grown to a considerable extent and average yields amount to 77 bushels per acre. The chief varieties are Rural New Yorker, Irish Cobbler, and Early Ohio. A large part of the potato crop is sold locally, but there is some sale outside of the county, particularly on the markets at Mason City.

Flax is grown to a limited extent. Average yields of 13 bushels per acre were reported in 1925. This crop is seeded chiefly on poorly drained areas which have been brought under cultivation for the first time, or on areas of muck or peat. It serves as a cash crop.

There is some barley grown with average yields of 28 bushels per acre. A small total acreage in rye yields 22 bushels per acre.

Alfalfa is grown on a small acreage and average yields of this crop amount to three tons per acre. It is a valuable crop and might be grown much more extensively. With proper precautions in seeding, very satisfactory yields of alfalfa may be secured.

Sweet clover is being grown to some extent at the present time. It is looked upon with considerable favor as a valuable pasture crop. It may be grown successfully on so-called ''alkali'' areas, and when plowed under to provide a green manuring material it is sometimes of considerable value on these areas.

At the present time wheat is grown to only a limited extent. More spring varieties are grown than winter varieties. Average yields of spring wheat amount to 16 bushels per acre, while the yields of winter wheat amount to 20 bushels per acre. The wheat serves as a cash crop.

In the eastern part of the county there is some truck farming on the Carrington silt loam. Some onions are grown and potatoes constitute quite an important truck crop. Sweet corn is grown near Bristol in the western part of the county. Other crops of minor importance which are grown on a small scale, include beans, sugar beets, and sorghum.

## THE LIVESTOCK INDUSTRY IN WORTH COUNTY

The livestock industry of the county is extensively developed. The following figures taken from the Iowa Monthly Crop Report for July 1st, 1926, based on the January 1st, 1926 estimates of the Division of Crop and Livestock Estimates of the U. S. Department of Agriculture show its extent.

| | |
|---|---|
| Horses | 8,200 |
| Mules | 200 |
| All cattle | 35,600 |
| Hogs | 61,900 |
| Sheep | 2,400 |

The beef cattle industry is very important and much of the income of the farms is derived from the breeding and feeding of beef cattle. The Shorthorn and Hereford are the most popular breeds. There are, however, some pure bred Aberdeen Angus. A good many steers are fed each year.

The dairy industry is developed considerably and the dairy products produced are quite valuable. The majority of the dairy cattle are grades. The

Holstein and Guernsey are the most popular breeds. Most of the cream is disposed of at the local creameries. A few creameries located just outside of the county also draw upon the milk produced.

Some hogs are raised on every farm. The most popular breeds are the Poland China and Duroc Jersey. Some Chester Whites, Hampshires and spotted Poland Chinas are also raised. The total number in the county on January 1, 1926 was 61,900. The income on most of the farms of the county is derived in part from the sale of hogs.

Sheep feeding and breeding are practiced to a very limited extent. A few farmers ship in feeders each year. A few horses are raised in the county largely to provide work stock on the farms.

Some poultry is maintained on practically every farm. The value of the poultry and eggs produced in the county is considerable. Farmers are appreciating the fact that more attention may well be paid to this industry with the view of increasing the income on their farms.

## THE FERTILITY SITUATION IN WORTH COUNTY

The yields of general farm crops secured in Worth County are usually quite satisfactory, but there are many cases where better bethods of soil treatment would bring about profitable increases in crops.

The drainage conditions are quite unsatisfactory in some of the soils and in many areas the first treatment needed to secure satisfactory crop growth is the installation of tile. The Clyde silt loam, the Webster silt loam, the Floyd silt loam, the Webster loam, the Webster clay loam on the drift uplands are all in need of better drainage. There are also some areas in the Carrington silt loam where drainage would be of value. The Bremer soils on the terraces, the Wabash and the Lamoure types on the bottoms, the Sogn silt loam, a residual soil and the areas of muck and peat are all in need of better drainage.

Most of the soil types are acid in reaction, and on these the addition of lime is very necessary for the best growth of general farm crops, particularly of legumes. Only in the Webster silt loam, and the clay loam on the drift uplands, the Benoit silt loam on the terraces, the Lamoure soils on the bottoms and the Sogn silt loam, a residual soil, is there any occurrence of carbonates in the surface soil. On these types, therefore, the application of lime would not be necessary. In the case of some of the other soil types, notably the Clarion loam on the uplands, lime occurs in the lower soil layers. However, even in these cases if the surface soil is acid, the application of lime would certainly be desirable for the best growth of leguminous crops. It is apparent, therefore, that the soils of the county, except for the Webster, Benoit, Lamoure, and Sogn types, should be tested for acidity or lime requirement. The amount of lime shown to be necessary according to the test should be applied before legumes are grown.

Some of the soil types are not very well supplied with organic matter and applications of farm manure or the turning under of leguminous crops as green manures would be of considerable value. In a number of the upland types and some of the terrace and bottomland soils there is a very large content of organic matter and additional applications do not seem necessary. It is found, however, by various experiments and by much farm experience that the application of farm manure is valuable even on those soils which are apparently better supplied with organic matter and dark in color. On the light colored sandy soils, the use of farm manure and green manures is particularly necessary to make the soils properly productive.

The nitrogen supply is not strikingly low and in many cases the soils seem to be very well supplied with this constituent. On all the soils of the county, however, the use of nitrogenous fertilizers will be needed at regular intervals in the future if the supply of this constituent is to be kept up. The best means of supplying nitrogen to these soils is by the proper use of farm manure, and the turning under of leguminous crops as green manures. Thus the use of commercial nitrogenous fertilizers will not be needed on these soils.

None of the soils show any large content of phosphorus and in most cases the supply of this constituent seems to be rather low. Apparently the need of phosphorus fertilization will be evident in the very near future even if it is not acute at the present time. The experimental work which has been carried out with phosphate fertilizers on some of the soils has indicated the value of applications of rock phosphate or acid phosphate. It is plain, therefore, that the use of phosphorus fertilizers on most of the soils will be of distinct value at the present time. Definite recommendations regarding the use of phosphorus fertilizers cannot yet be made inasmuch as the data secured show some variations. It is urged, therefore, that farmers test the need of phosphorus on their own soils and by using both acid phosphate and rock phosphate in comparative tests, they may determine not only whether their soil will respond to phosphorus fertilizers, but also which phosphorus carrier will prove the more profitable for use under their particular conditions.

Complete commercial fertilizers have been tested on some of the soil types in comparison with acid phosphate and rock phosphate. It does not seem from these results that the complete commercial fertilizers would be as desirable for general use as a phosphate fertilizer.

Erosion occurs in some areas in the rolling phase of the Carrington loam, the rolling phase of the Clarion loam, and other upland types. Considerable washing away of the soil sometimes occurs and gullying frequently takes place. It is very desirable wherever erosion occurs that some precautionary measures be taken to prevent the extensive washing away of the surface soils and to stop the formation of gullies.

## THE GEOLOGY OF WORTH COUNTY

It is unnecessary to consider the early geological history of Worth County as it has no significance from the standpoint of present day soil conditions. The original bed rock material has been buried so deeply in most cases by the glacial deposits that there is little or no effect of this material upon the soil characteristics. Only in two of the soil types is there any influence of the bedrock on the soil. The Sogn silt loam is classified as a residual soil being derived mainly from the native limestone rock. The Dodgeville soils are influenced only to a limited extent by this limestone rock. The surface soils of this type are of drift origin. The lime rock occurs at short distances from the surface and affects the character of the soil only slightly.

With the exception of the small area of the Sogn silt loam, the upland soils of the county have been derived from the glacial deposits made by two great ice sheets which in previous geological ages swept over the county, and upon their retreat left behind large deposits of glacial drift or till.

The earlier glacier known as the Iowan swept over the entire surface burying the native bedrock in most areas to considerable depths. The earlier topographic features were mainly obliterated by this glacier. The deposit left by the Iowan glacier is known as the Iowan drift and in depth it usually extends from 10 to 20 feet. In an unweathered condition, the Iowan drift is a bluish-gray or drab clay, but where it has been weathered and exposed to oxidation, the color has been changed to a brown or yellowish-brown. The texture ranges from a heavy clay to a gravelly or sandy clay. Pockets of sand and gravel occur and glacial boulders of varying size and description abound over the surface and scattered thruout the soil section. During the period which has elapsed since the deposition of this glacial drift the calcareous material has been largely removed by leaching and in most of the soils no lime remains. The soils of the Carrington, Clyde, Webster, Floyd, Dickinson, Lindley and Dodgeville series on the uplands are derived in whole or in part from this Iowan drift material. In addition many of the types on the terraces and bottomlands have originated from the Iowan drift.

At a later date a second glacier covered the western part of the county leaving behind a layer of drift material known as the Wisconsin drift. The depth of this deposit is variable, averaging usually somewhat less than 10 feet. This drift material is a dull yellow in color. In the lower part where weathering has not occurred, it consists of a blue boulder clay. Boulders are common thruout the drift deposit. In most cases the Wisconsin drift is high in calcareous material and the soils developed from this glacial deposit will generally effervesce with acid in the subsoil and often even up thru the surface soils. The soils of the Webster, Clarion, and Pierce types are developed from this Wisconsin glaciation. The Pierce soils are considered formed in part from the deposits in what is known as the terminal moraine. Sand and gravel and numerous boulders occur in this terminal moraine which represents the edge of the deposition of the Wisconsin drift material.

The terrace and bottomland soils as developed in the county have been derived entirely from the glacial upland soils, which have been reworked and laid down along the streams. In the eastern part these bottomland soils are derived from the upland till of Iowan drift origin. In the western part where the uplands are derived from the Wisconsin till, the bottomland soils are formed from these same soil materials and in many cases the differences in the bottomland soils reflect the differences in the upland soil conditions. Thus in the western part of the county, the bottomland soils show a lime content, in many instances. In the eastern part, however, very rarely does any lime occur in the bottomland soils.

## PHYSIOGRAPHY AND DRAINAGE

In topography, the county may be divided into two parts. The eastern portion is characterized by a topography ranging from flat to gently undulating. In

# SOIL MAP OF WORTH COUNTY, IOWA

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. C. F. Marbut, in charge Soil Survey

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 Acriculture.

IOWA AGRICULTURAL EXPERIMENT STATION
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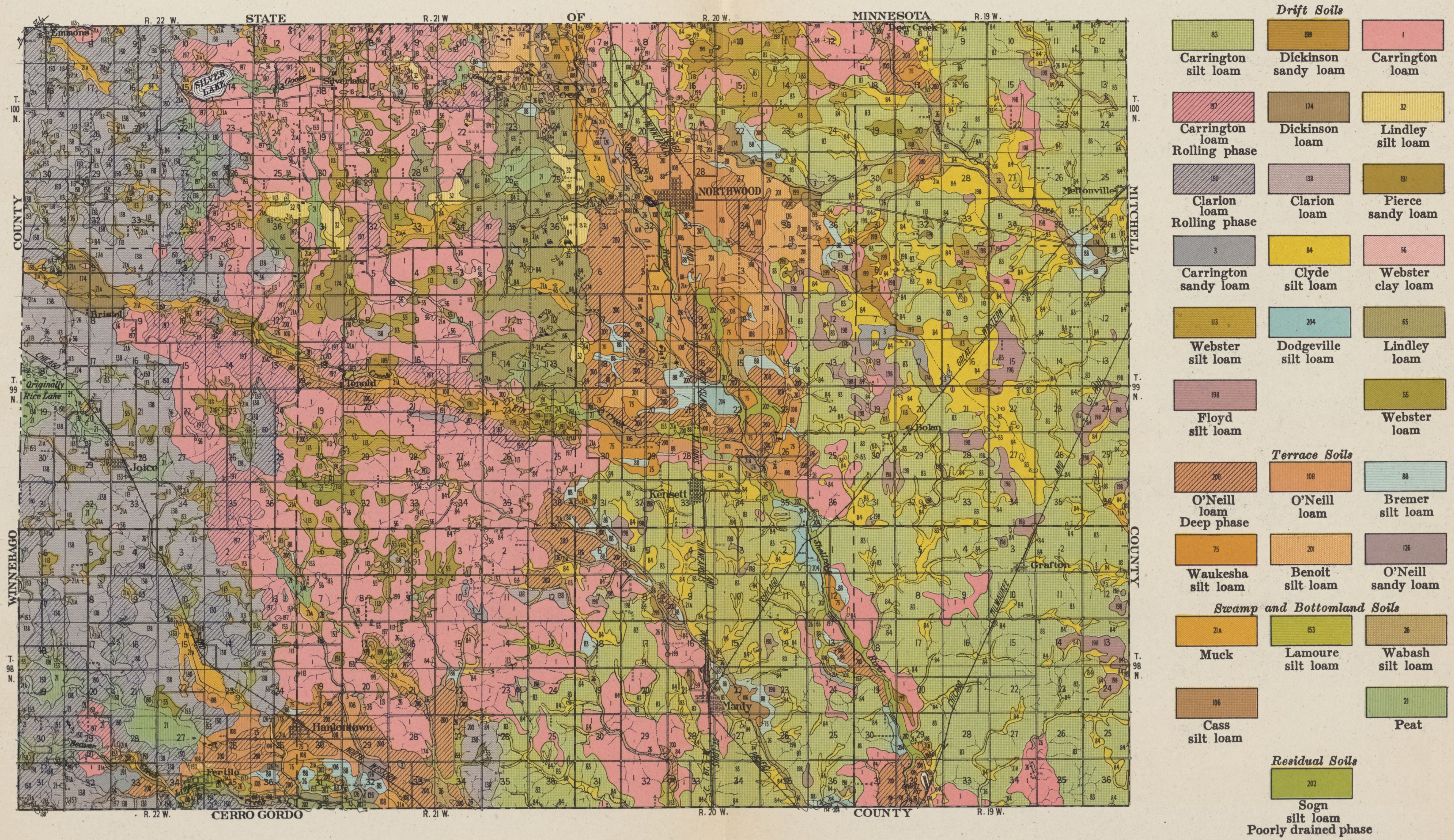
P. E. Brown, Associate in Charge




SCALE: 1 INCH TO 2½ MILES

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

the western part there is a rougher topography, in general ranging from a flat or gently undulating to strongly rolling or sloping. The prevailing topography is gently rolling.

There are broad relatively flat areas of second bottoms or terraces along the Shellrock River and Lime Creek. There is an extensive area of terraces on both sides of the Shellrock River extending from just north of Northwood to below the entrance of Elk Creek into the Shellrock River above Kensett. It is 4 to 5 miles in width and 5 to 7 miles in length. Another extensive terrace area is found in the vicinity of Fertile and Hanlontown.

In general thruout the eastern part the topographic features are not very well developed and there is no striking relief. In the western part, however, there are rather striking topographic differences, and the land ranges from rough to broken on one hand to level, flat to depressed, on the other. As will be noted later, there is a rather definite relationship between the topographic conditions in the county and the occurrence of the various soil types. Very often the topographic boundaries will indicate the boundaries of the soil types.

Deer Creek, the Shellrock River, and Lime Creek and their tributary streams drain the county. Deer Creek with its tributaries drains the northeastern part of the county. The Shellrock River which flows thru the central part of the area with its tributaries drains the central portion. The extreme southwestern part is drained by Lime Creek and its tributaries.

The natural drainage system is not very well developed in certain sections, and there are many areas where artificial drainage is necessary. The accompanying

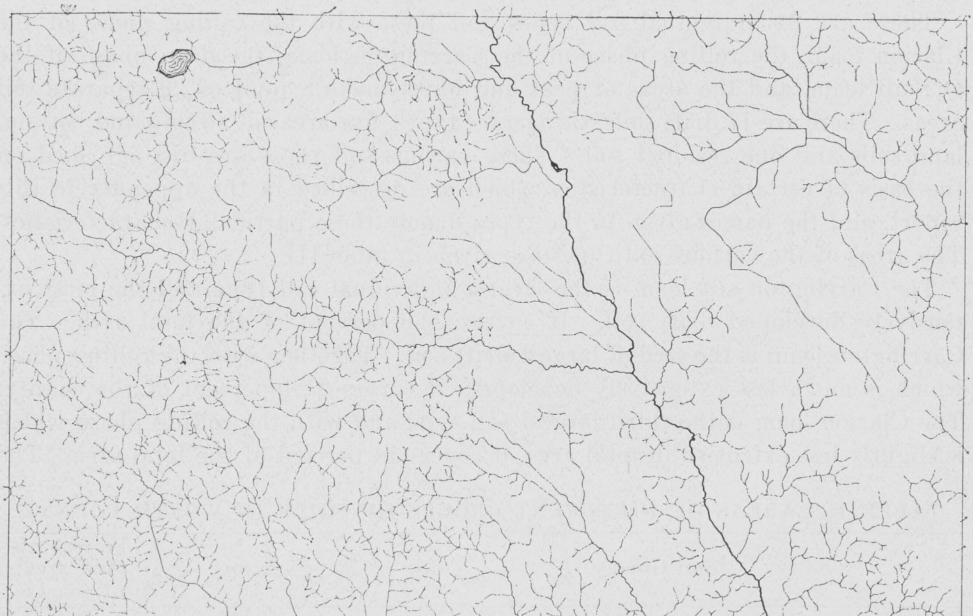


Fig. 2. Natural drainage system of Worth County.

drainage map indicates the extent of the natural drainage system, and it shows the rather considerable areas between the various streams and their tributaries where the drainage conditions are not well developed. There are extensive areas of the Webster soils, the Clyde soils, the Bremer types, the Floyd soils, some of the bottomland types and many areas of muck and peat which are poorly drained. In all these cases, the laying of tile or the installation of drainage ditches is necessary for the adequate drainage of the areas.

## THE SOILS OF WORTH COUNTY

There are four groups of soils in Worth County, drift soils, terrace soils, swamp and bottomland soils, and residual soils. Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams. They are subject to more or less frequent overflow. Residual soils are those formed in place from the underlying rock material. The extent and occurrence of these soils are shown in table II.

Over three-fourths of the total area, 78.3 percent, is covered by drift soils. Terrace soils are rather extensively developed, covering 11.9 percent. There is a somewhat smaller area of swamp and bottomland soils, covering 9.1 percent. There is one area of residual soil, covering 0.7 percent of the total area.

There are 24 individual soil types and these with the rolling phase of the Clarion loam, the rolling phase of the Carrington loam, the deep phase of the O'Neill loam, and the areas of peat and muck make a total of 29 separate soil areas. There are 17 drift soils, six terrace types, five areas of swamp and bottomland soils and one residual soil. These various soil types are distinguished on the basis of certain characteristics which are described in the appendix to this report, and the names given to the types denote these particular characteristics. The areas of the various soil types are given in table III.

The Carrington silt loam is the largest individual soil type and the most extensively developed drift soil. It covers 22.8 percent of the total area. The Carrington loam is the second largest drift soil. Together with the rolling phase which is much less extensively developed, it covers 21.4 percent of the county. The Clarion loam is the third largest soil type and with the rolling phase which is slightly less extensive in total area, it covers 14 percent of the total area. The

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

| Soil Group | Acres | Percent of total area of county |
|---|---|---|
| Drift soils | 199,808 | 78.3 |
| Terrace soils | 30,336 | 11.9 |
| Swamp and bottomland soils | 23,424 | 9.1 |
| Residual soils | 1,792 | 0.7 |
| Total | 255,360 | ... |

Clyde silt loam is the fourth largest soil type, covering 7.6 percent of the county. The Webster silt loam covers a much smaller area, 3 percent of the county, the Lindley loam 2.8 percent, the Floyd silt loam, 1.9 percent and the Webster loam, 1.3 percent of the total area respectively. The remaining drift soils, the Dickinson sandy loam, the Dickinson loam, the Lindley silt loam, the Pierce sandy loam, the Carrington sandy loam, the Webster clay loam and the Dodgeville silt loam, all cover less than one percent of the area.

The O'Neill loam together with the deep phase which is more extensively developed than the typical soil covers 7.5 percent, and it is the largest terrace soil and the fifth most extensively developed type. The Benoit silt loam covers 1.5 percent of the county, the Bremer silt loam 1.4 percent, the Waukesha silt loam 1.1 percent and the O'Neill sandy loam 0.4 percent.

The areas of swamp and bottomland soils are all minor in extent. Muck is the most extensively developed covering 2.8 percent of the area. The Wabash silt loam covers 2.2 percent of the county, peat 2.2. percent, the Lamoure silt loam 1.6 percent and the Cass silt loam 0.3 percent. There is one residual type, the Sogn silt loam, poorly drained phase which covers 0.7 percent of the county.

There is a rather definite relationship between the occurrence of the individual

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WORTH COUNTY

| Soil No. | Soil Type | Acres | Percent of total area of county |
|---|---|---|---|
| | DRIFT SOILS | | |
| 83 | Carrington silt loam | 58,112 | 22.8 |
| 1 | Carrington loam | 45,888 | 21.4 |
| 197 | Carrington loam (rolling phase) | 8,768 | |
| 138 | Clarion loam | 20,480 | 14.0 |
| 150 | Clarion loam (rolling phase) | 15,296 | |
| 84 | Clyde silt loam | 19,328 | 7.6 |
| 113 | Webster silt loam | 7,744 | 3.0 |
| 65 | Lindley loam | 7,232 | 2.8 |
| 198 | Floyd silt loam | 4,992 | 1.9 |
| 55 | Webster loam | 3,392 | 1.3 |
| 199 | Dickinson sandy loam | 2,304 | 0.9 |
| 174 | Dickinson loam | 1,728 | 0.7 |
| 32 | Lindley silt loam | 1,216 | 0.5 |
| 191 | Pierce sandy loam | 960 | 0.4 |
| 3 | Carrington sandy loam | 896 | 0.4 |
| 56 | Webster clay loam | 832 | 0.3 |
| 204 | Dodgeville silt loam | 640 | 0.3 |
| | TERRACE SOILS | | |
| 108 | O'Neill loam | 7,616 | 7.5 |
| 200 | O'Neill loam (deep phase) | 11,456 | |
| 201 | Benoit silt loam | 3,968 | 1.5 |
| 88 | Bremer silt loam | 3,584 | 1.4 |
| 75 | Waukesha silt loam | 2,816 | 1.1 |
| 126 | O'Neill sandy loam | 896 | 0.4 |
| | SWAMP AND BOTTOMLAND SOILS | | |
| 21a | Muck | 7,168 | 2.8 |
| 26 | Wabash silt loam | 5,760 | 2.2 |
| 21 | Peat | 5,696 | 2.2 |
| 153 | Lamoure silt loam | 4,096 | 1.6 |
| 106 | Cass silt loam | 704 | 0.3 |
| | RESIDUAL SOILS | | |
| 202 | Sogn silt loam (poorly drained phase) | 1,792 | 0.7 |

soil types and the topographic condition. On the drift upland, the rolling condition is indicated by the names "rolling phase Carrington loam" and "rolling phase Clarion loam." The typical soils of these types are gently undulating in topography. The Clyde silt loam occurs in depressions and is level to flat or depressed in topography. The Webster soils and the Floyd silt loam occur on level areas. The Dickinson, Lindley and Pierce soils are found in more rolling to rough topographic positions. In the case of the Pierce the rough topography is especially pronounced, as this soil occurs on knobs or knolls in the upland. The terrace soils are more or less level in topography and there are no topographic features of significance in the bottomland types.

## THE FERTILITY IN WORTH COUNTY SOILS

Samples were taken for analyses from each of the soil types except the Lindley loam on the uplands and the areas of peat and muck on the bottoms. The more extensive types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest care that the samples should be thoroly representative of the particular soil type, and that any variations, due to local conditions or previous treatments might be eliminated. The samples were secured at three depths, 0–6 2/3″, 6 2/3″–20″ and 20″–40″, representing the surface soil, the subsurface soil and the subsoil respectively.

Analyses were made on all these samples for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirements. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Truog qualitative test was used for determining the limestone requirements of the soils. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type.

### THE SURFACE SOILS

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

There is considerable variation in the phosphorus content of the various soils, the amount present ranging from 889 pounds per acre in the O'Neill sandy loam up to 2,688 pounds per acre in the Lamoure silt loam. No definite relationships are indicated between the phosphorus content of the soils and the various groups of soils. The swamp and bottomland types will average a little higher than the upland soils and the terrace soils. This might be expected owing to the fact that there has been less crop growth on the bottomland types, and hence, a smaller removal of plant food constitutents. In general there are much wider variations in the phosphorus content of the soils within the groups than between the various groups of soils.

Certain relationships are evident, however, between the phosphorus supply in the soils and the particular soil series. Thus on the drift upland, the Webster soils are the richest in phosphorus of any of the series represented. The Carrington and Clarion soils are very much the same in phosphorus content, the Clarion being a little higher on the average. The Clyde soils are a little better supplied than the Carrington and Clarion types. The soils in the Dickinson, Lindley, and Pierce series are much more poorly supplied than are the Webster, Carrington, Clarion and Clyde soils. The Floyd and Dodgeville types have very much the same phosphorus content as the Carrington soils. On the terraces the Benoit, Waukesha, and Bremer soils are better supplied than the O'Neill types. On the bottoms the Lamoure is better supplied than the other bottomland soils. It is higher in phosphorus than the Wabash which may be due, however, to a peculiarity of the particular sample analysed.

Apparently, there is a rather definite relationship evidenced here between the phosphorus content of the soil and those characteristics which serve to differentiate the soil series. The topography is of significance. Those soils like the Webster on the uplands and the Bremer on the terraces which are more nearly level to flat in topography are higher in phosphorus. The gently rolling to undulating topographic condition which is characteristic of the typical Carrington and Clarion soils is correlated with a somewhat higher phosphorus content than that found in the more steeply rolling to rough Dickinson, Lindley, and Pierce soils. The Clyde silt loam is somewhat higher in phosphorus than the Carrington and Clarion soils and the topography is more nearly level. The color of the soil

TABLE IV. PLANT FOOD IN WORTH 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 | | | | | |
| 83 | Carrington silt loam | 1,254 | 5,053 | 63,350 | ...... | 3,333 |
| 1 | Carrington loam | 1,266 | 5,300 | 61,088 | ...... | 2,000 |
| 197 | Carrington loam (rolling phase) | 1,077 | 3,920 | 45,818 | ...... | 4,000 |
| 138 | Clarion loam | 1,171 | 3,780 | 45,024 | ...... | 1,000 |
| 150 | Clarion loam (rolling phase) | 1,427 | 4,860 | 59,160 | ...... | 3,000 |
| 84 | Clyde silt loam | 1,306 | 4,320 | 49,892 | ...... | 6,000 |
| 113 | Webster silt loam | 2,080 | 8,440 | 92,637 | 26,298 | .... |
| 198 | Floyd silt loam | 1,293 | 6,560 | 82,798 | ...... | 4,000 |
| 55 | Webster loam | 1,306 | 6,740 | 69,418 | 2,143 | .... |
| 199 | Dickinson sandy loam | 902 | 1,940 | 26,620 | ...... | 4,000 |
| 174 | Dickinson loam | 1,360 | 4,200 | 27,268 | ...... | 3,500 |
| 32 | Lindley silt loam | 996 | 2,780 | 30,133 | ...... | 3,000 |
| 191 | Pierce sandy loam | 942 | 3,360 | 35,393 | ...... | 1,000 |
| 3 | Carrington sandy loam | 1,171 | 2,840 | 39,256 | ...... | 1,000 |
| 56 | Webster clay loam | 1,670 | 6,720 | 80,844 | 974 | .... |
| 204 | Dodgeville silt loam | 1,279 | 5,440 | 66,810 | ...... | 4,000 |
| | TERRACE SOILS | | | | | |
| 108 | O'Neill loam | 929 | 3,240 | 41,432 | ...... | 7,000 |
| 200 | O'Neill loam (deep phase) | 1,104 | 3,680 | 37,352 | ...... | 5,000 |
| 201 | Benoit silt loam | 1,575 | 8,160 | 14,466 | 80,433 | .... |
| 88 | Bremer silt loam | 1,212 | 7,580 | 88,805 | ...... | 1,000 |
| 75 | Waukesha silt loam | 1,481 | 3,680 | 42,901 | ...... | 3,000 |
| 126 | O'Neill sandy loam | 889 | 2,240 | 26,765 | ...... | 5,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam | 889 | 2,600 | 105,800 | ...... | .... |
| 153 | Lamoure silt loam | 2,688 | 2,940 | 164,691 | 6,745 | .... |
| 106 | Cass silt loam | 2,396 | 2,100 | 131,440 | ...... | 1,000 |
| | RESIDUAL SOILS | | | | | |
| 202 | Sogn silt loam (poorly drained phase) | 2,067 | 10,380 | 85,237 | 1,096 | .... |

apparently also plays some part in indicating the phosphorus supply. Soils like the Webster and Clyde, which are black in color, are richer in phosphorus than the lighter colored soils. The subsoil condition is likewise of significance. On those types where the subsoil is heavy the supply of phosphorus is better. This is true of the Webster and Floyd soils on the drift uplands and of the Bremer, Waukesha and Benoit types on the terraces.

There is a further relationship evident from these data between the texture of the soils and the supply of phosphorus. The Carrington silt loam and the Carrington loam contain about the same content of phosphorus, but the rolling phase of the Carrington loam and the Carrington sandy loam are much lower in this constituent. The Webster silt loam is higher than the Webster loam and it is also somewhat higher than the Webster clay loam. This is contrary to the usual results as the clay loam is frequently better supplied with the plant food than the silt loam. The Dickinson loam is higher in phosphorus than the Dickinson sandy loam. On the terraces the deep phase of the O'Neill loam is richer in phosphorus than the typical loam which in turn is better supplied than the sandy loam. These are the only comparisons which can be made of the soils of different textures classed in the same series, and while there are some variations as have been pointed out, in general, the results bear out the conclusion reached from former analyses that the texture of the soil plays a very important part in determining the content of plant food. Soils which are coarse textured or sandy are more poorly supplied with plant food than are the fine textured types. Thus silt loams are ordinarily better supplied than loams. Loams are richer than sandy loams or sands, and clay loams and silty clay loams are ordinarily higher than silt loams and loams.

The supply of phosphorus in the soils of Worth County is not high and it seems quite evident from these analyses that phosphorus fertilizers will be needed on the soils of this county in the very near future if they are not of value at the present time. The results of experiments which have been carried out on some of these soils, which will be referred to later in the report, indicate that applications of a phosphorus fertilizer might be made on these types with profitable results at the present time.

There is a wide variation in the nitrogen content of the soils in the county, the amount present ranging from 1,100 pounds in the Cass silt loam on the bottoms up to 10,380 pounds in the Sogn silt loam poorly drained phase. Many of the soil types in the county are rather poorly supplied with nitrogen while on the other hand there are a number of soils which are rich in this constituent.

There is no relationship evident between the nitrogen content of the soils and various soil groups. There is some evidence, however, of a relationship between the soil series and the content of nitrogen. Thus on the drift uplands, the Webster soils are the richest in nitrogen. The Floyd and Dodgeville soils are somewhat lower in this constituent. These are followed by the Carrington, Clarion, and Clyde types, while the Dickinson, Lindley and Pierce soils are the most poorly supplied of all the upland types. There is evidently a relationship here between the characteristics which serve to determine the soil series and the content of nitrogen. Those soils like the Webster, Floyd, and Clyde, which are more level in topography, blacker in color, with heavier textured subsoils, are ordinarily better supplied with nitrogen than are the types which are more rolling in topography, lighter colored in the surface soil, and with lighter textured subsoils. On the terraces the Benoit, the Bremer and the Waukesha soils are better supplied than the O'Neill types and on the bottoms the Wabash and Lamoure soils are richer than the Cass. In all these cases the color of the soil, the topographic conditions and the character of the subsoil serve in large part to indicate the nitrogen content.

A relationship is evident here also between the texture of the soil and nitrogen content. Thus on the drift uplands the Webster silt loam is higher than the loam. The Webster clay loam is not as well supplied as the silt loam of the same series, which is contrary to the usual results due probably to some abnormal condition in the particular sample. The Carrington silt loam and Carrington loam are very similar in nitrogen content, the loam being a little higher than the silt loam. Ordinarily the silt loam would show a little larger content of nitrogen. The rolling phase of the Carrington loam is much lower in nitrogen than the typical loam and the Carrington sandy loam is the lowest of all the types in this series. The Dickinson sandy loam is much lower in nitrogen than the Dickinson loam. On the terraces the O'Neill is much better supplied than the sandy loam of the same series, the deep phase of the O'Neill being richer than the typical loam. These comparisons indicate the relationship between the soil texture and the nitrogen content which is ordinarily observed. While there are some variations, in general it seems to be true that those soils which are coarser-textured are more poorly supplied with nitrogen. Silty clay loams and clay loams are ordinarily richer than silt loams, silt loams are better supplied than loams, and loams show a higher content of plant food than do sandy loams or sands.

While many of the soils in this county are fairly well supplied with nitrogen, there are one or two cases where the nitrogen content is rather low. In such cases applications of nitrogenous fertilizing materials are very necessary and on all the soils of the county the use of nitrogen-containing fertilizers at regular intervals will be necessary if the supply of this constituent is to be kept up.

The proper preservation and application to the soil of all the manure produced on the farms will aid considerably in keeping up the supply of nitrogen in the soil. Crop residues also will return to the land much of the nitrogen which has been removed by the crops grown. The use of leguminous crops as green manures is very desirable in many cases to supplement the use of farm manure. When soils are low in nitrogen content, it is particularly necessary that leguminous crops be used as green manures in order to increase the nitrogen content of the soil.

The total organic carbon content of the soils of the county varies quite as widely as the nitrogen content, the amount present ranging from 14,466 pounds in the Benoit silt loam up to 164,691 pounds in the Lamoure silt loam on the bottoms. Many of the soils in the county are apparently very well supplied with organic matter or organic carbon while in others the supply is not so adequate and in a number of cases the content is rather low.

The relationships between the various soils in the county in regard to organic carbon are very much the same as those noted in the case of the nitrogen. Thus on the drift uplands, the Webster soils are richer in organic matter than are the other types. The Floyd and Dodgeville soils are second, then come the Carrington, the Clarion, and the Clyde soils. The Dickinson, Lindley, and Pierce types are the most poorly supplied with organic matter. On the terraces the Bremer and Waukesha soils are the richest in organic matter, while the O'Neill soils are low. Again the relationship between the soil series and the content of organic matter is definitely evidenced in these results. Those soils which are characterized by a level to flat topography, by a black color, and by a heavy subsoil condition are richer in organic matter as well as in nitrogen.

There is also a relationship between the texture of the soils and their content of organic matter. The Webster silt loam is higher in organic matter than the Webster loam. The Carrington silt loam is a little higher than the Carrington loam which is in turn better supplied than the rolling phase of the Carrington loam and all are much richer than the Carrington sandy loam. The Webster clay loam is not as high in organic matter as the Webster silt loam which may be due to some abnormality in the particular sample. It is, however, richer than the Webster loam. The Dickinson loam is richer in organic matter than the Dickinson sandy loam. On the terraces the O'Neill loam is higher in organic matter than the sandy loam of the same series. It appears, therefore, that the texture of the soil plays a large part in determining the organic matter supply.

While many of the individual soil types in Worth County are apparently very well supplied with organic matter and black in color, some are not rich in this constituent and in one or two cases the supply is rather low. In such cases the use of fertilizers supplying organic matter is very necessary and on all the types in the county some fertilizing material supplying organic matter must be used regularly if the supply is to be kept up. The application of farm manure is by far the best means of supplying organic matter to the soil and liberal use of this material on the coarse textured or sandy types in this county is particularly desirable. The turning under of all crop residues will aid in maintaining the supply of organic matter. The use of leguminous crops as green manures is often profitable as a means of improving soil conditions for crop growth.

The Webster soils on the drift uplands, the Benoit silt loam on the terraces, the Lamoure silt loam on the bottomlands and the poorly drained phase of the Sogn silt loam, a residual soil, show some inorganic carbon in the surface soil. These soils are, therefore, supplied with basic materials such as lime and are not acid in reaction. All the other soil types, however, show a lack of inorganic carbon and hence an acidity or limestone requirement which in some cases is quite high. The occurrence of inorganic carbon or lime in these soils is related to the characteristics which serve to determine the soil series. Thus it is characteristic of the Webster, the Benoit, the Lamoure, and the Sogn soils to show a lime content. Very rarely are these soils deficient in lime or acid in reaction.

It is apparent, therefore, that on the soil types in Worth County, except those of the Webster, the Benoit, the Lamoure, and Sogn series, the application of lime is very necessary for the best growth of leguminous crops and also for the production of general farm crops. The soils of the county, with the exception of the types just mentioned, should all be tested for acidity or limestone requirement at regular intervals. The amount of lime shown to be necessary by the tests should be applied. The figures given in the table indicate roughly the lime requirements of these various acid soils, but they should not be taken to show definitely the needs of all soils of these types. The soil from every individual field should be tested for lime requirement in order that the proper application may be made.

## THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on a basis of four million pounds of subsurface soil and six million pounds of subsoil per acre.

In general the needs of the soils as indicated by the analyses of the surface soils are quite accurate and are little modified by a consideration of the plant food present in the lower soil layers. The analyses of the subsurface soils and subsoils in Worth County show that there is no large content of any individual plant food constituent nor is there any striking deficiency in any of the elements. It is apparently unnecessary, therefore, to consider these results in detail. It may merely be noted that the needs of the individual soils in the county as indicated by the analyses of the surface soils are largely confirmed by the results obtained from the analyses of the lower soil layers.

The phosphorus content of the soils of the county is not high in any case and in most of the soils the supply is rather low, so low that it is evident that phosphorus

TABLE V. PLANT FOOD IN WORTH 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 | | | | | |
| 83 | Carrington silt loam........ | 1,592 | 4,173 | 43,976 | ...... | 4,333 |
| 1 | Carrington loam ............ | 2,182 | 6,680 | 76,336 | ...... | 1,000 |
| 197 | Carrington loam (rolling phase) .................. | 1,830 | 4,520 | 56,684 | ...... | 2,000 |
| 138 | Clarion loam ............. | 1,791 | 3,880 | 41,420 | ...... | 1,000 |
| 150 | Clarion loam (rolling phase) | 2,316 | 6,720 | 73,610 | 8,166 | .... |
| 84 | Clyde silt loam............ | 1,293 | 2,960 | 26,542 | ...... | .... |
| 113 | Webster silt loam........... | 2,733 | 5,200 | 65,860 | 45,388 | .... |
| 198 | Floyd silt loam............. | 1,562 | 4,240 | 50,136 | ...... | 3,000 |
| 55 | Webster loam .............. | 2,612 | 7,280 | 51,078 | 29,610 | .... |
| 199 | Dickinson sandy loam....... | 1,670 | 3,080 | 35,944 | ...... | 3,000 |
| 174 | Dickinson loam ............ | 2,316 | 5,880 | 67,080 | ...... | 4,000 |
| 32 | Lindley silt loam........... | 1,499 | 3,173 | 38,210 | ...... | 3,333 |
| 191 | Pierce sandy loam (no sample) | | | | | |
| 3 | Carrington sandy loam...... | 1,724 | 3,280 | 38,176 | ...... | 2,000 |
| 56 | Webster clay loam......... | 2,208 | 3,600 | 33,900 | 86,100 | .... |
| 204 | Dodgeville silt loam........ | 1,778 | 5,360 | 32,720 | ...... | 5,000 |
| | TERRACE SOILS | | | | | |
| 108 | O'Neill loam ............ | 1,804 | 4,600 | 57,772 | ...... | 6,000 |
| 200 | O'Neill loam (deep phase) .. | 1,724 | 4,600 | 22,235 | ...... | 4,000 |
| 201 | Benoit silt loam........... | 1,885 | 3,720 | 45,713 | 85,586 | .... |
| 88 | Bremer silt loam........... | 834 | 3,720 | 25,864 | ...... | .... |
| 75 | Waukesha silt loam......... | 2,195 | 5,480 | 63,264 | ...... | 4,000 |
| 126 | O'Neill sandy loam......... | 1,616 | 2,280 | 22,972 | ...... | 6,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam........... | 2,074 | 4,400 | 57,006 | ...... | .... |
| 153 | Lamoure silt loam.......... | 2,396 | 4,240 | 25,674 | 40,310 | .... |
| 106 | Cass silt loam............. | 1,750 | 2,920 | 32,680 | ...... | 1,000 |
| | RESIDUAL SOILS | | | | | |
| 202 | Sogn silt loam (poorly drained phase) ........... | 2,612 | 6,720 | 86,246 | 1,022 | .... |

TABLE VI. PLANT FOOD IN WORTH 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 | | | | | |
| 83 | Carrington silt loam........ | 1,932 | 2,520 | 27,798 | ..... | 4,000 |
| 1 | Carrington loam ........... | 2,019 | 3,360 | 45,756 | ..... | .... |
| 197 | Carrington loam (rolling phase) ........... | 2,019 | 2,880 | 20,432 | ...... | 1,000 |
| 138 | Clarion loam ............. | 2,391 | 3,240 | 11,146 | 71,616 | .... |
| 150 | Clarion loam (rolling phase) | 2,988 | 7,080 | 71,818 | 13,208 | .... |
| 84 | Clyde silt loam........... | 1,857 | 2,280 | 20,432 | ...... | .... |
| 113 | Webster silt loam.......... | 3,594 | 2,400 | 41,316 | 14,316 | .... |
| 198 | Floyd silt loam........... | 2,262 | 1,680 | 19,958 | ...... | 2,000 |
| 55 | Webster loam ............ | 2,988 | 2,520 | 38,056 | 109,190 | .... |
| 199 | Dickinson sandy loam....... | 2,019 | 3,240 | 39,228 | ...... | 2,000 |
| 174 | Dickinson loam ........... | 3,474 | 2,640 | 28,655 | ...... | 2,000 |
| 32 | Lindley silt loam.......... | 2,665 | 2,280 | 27,026 | ...... | 5,000 |
| 191 | Pierce sandy loam (no sample) | | | | | |
| 3 | Carrington sandy loam...... | 2,262 | 2,040 | 16,362 | ...... | 1,000 |
| 56 | Webster clay loam......... | 3,069 | 4,200 | 2,120 | 186,040 | .... |
| 204 | Dodgeville silt loam........ | 2,220 | 3,360 | 40,860 | ...... | 6,000 |
| | TERRACE SOILS | | | | | |
| 108 | O'Neill loam ............. | 1,818 | 4,080 | 49,020 | ...... | 3,000 |
| 200 | O'Neill loam (deep phase).. | 1,857 | 1,920 | 23,190 | ...... | 2,000 |
| 201 | Benoit silt loam........... | 2,343 | 3,600 | 36,248 | 63,482 | .... |
| 88 | Bremer silt loam........... | 2,019 | 2,760 | 32,972 | ...... | 1,000 |
| 75 | Waukesha silt loam........ | 2,787 | 3,960 | 39,816 | ...... | 6,000 |
| 126 | O'Neill sandy loam........ | 1,737 | 1,340 | 19,817 | ...... | 1,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam.......... | 2,505 | 2,400 | 50,297 | ...... | .... |
| 153 | Lamoure silt loam......... | 3,030 | 2,640 | 28,783 | 54,007 | .... |
| 106 | Cass silt loam............ | 1,899 | 9,600 | 6,634 | 6,456 | .... |
| | RESIDUAL SOILS | | | | | |
| 202 | Sogn silt loam (poorly drained phase) .......... | 4,080 | 3,480 | 46,778 | 31,762 | .... |

fertilizers will be needed on these soils in the very near future even if they are not of value at the present time. The indications are from certain experiments, however, that phosphorus fertilizers may be used with profit on many of these soils now.

The supply of organic matter and nitrogen in the soils of this county must be maintained if the land is to remain fertile. In some of the types there is need for an increase in the supply of these constituents at the present time. The proper preservation and application of all the farm manure produced on the farm is very desirable in order to build up and maintain the supply of organic matter and nitrogen in these soils. The thoro utilization of crop residues is desirable, and the turning under of leguminous crops as green manures is necessary in order to keep up the supply of nitrogen.

The soils which showed a lime content in the surface soil are all well supplied with lime in the lower soil layers. The rolling phase of the Clarion loam has a lime content in the subsurface soil and in the subsoil and the typical Clarion loam shows a lime content in the subsoil. The Cass silt loam on the bottoms also has a lime content in the subsoil. In general, however, the conclusions drawn from the analyses of the surface soils are borne out by these data. Except for the Webster, Benoit, Lamoure, and Sogn types the soils of this county should be tested for acidity or lime requirement, and lime should be applied as needed. Even on those types which contain lime in the subsoil such as the Clarion loam and the Cass silt loam if the surface soil is acid the use of lime is necessary especially if legumes are to be grown.

## GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Worth County in the attempt to learn something of the needs of the soils and to secure indications of the value of the applications of certain fertilizing materials. These experiments were carried out on the Carrington silt loam and the Clyde silt loam, two of the more important types in the county. In addition to these experiments, the results secured in the greenhouse experiments on the Carrington silt loam from Mitchell County, on the Clarion loam from Winnebago County, on the Webster clay loam from Winnebago County, on the Carrington loam from Hardin County and on the Webster loam from Hamilton County are all included inasmuch as the soil types are the same as those occurring in Worth County and the results secured indicate quite accurately what may be expected of the same soils in this county.

The plan of all of these experiments was the same and the treatments used included manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These materials were applied in the same amounts in which they are used in the field, and, hence, the results of the greenhouse experiments may be considered definitely indicative of what may be expected in the field.

Manure was supplied at the rate of 8 tons per acre; lime was added in sufficient amounts to neutralize the acidity of the soil; rock phosphate was applied at the rate of 2,000 pounds per acre; acid phosphate at the rate of 200 pounds per acre; and the standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments, the clover being seeded after the wheat had been up about a month. In some of the tests the yields of clover were not secured.

### RESULTS ON CARRINGTON SILT LOAM FROM WORTH COUNTY

The results secured in the greenhouse experiment on the Carrington silt loam from Worth County are given in table VII. Only the yields of wheat were secured in this test. The application of manure increased the yield of this crop as is indicated in the table. Lime with the manure brought about a further increase in the yield of wheat. This is unexpected as lime usually does not bring about as large increases in the yields of grain crops as with legume crops. The application of rock phosphate with the manure and lime increased the yield of wheat to a considerable extent. The acid phosphate with the manure and lime brought about a much larger increase in the wheat yields. The complete commercial fertilizer increased the yields more than did the rock phosphate but showed a smaller effect than the acid phosphate.

These results indicate that the Carrington silt loam will respond to applications of manure, lime and a phosphate fertilizer. The application of manure seems to be particularly valuable. The use of lime with the manure is necessary


Fig. 3. Wheat and clover on Carrington silt loam from Worth County.

as the soil is acid in reaction. The use of a phosphate fertilizer is certainly very desirable on this soil. The acid phosphate showed somewhat better results in this test than did the rock phosphate. The difference, however, was not great.

## RESULTS ON CLYDE SILT LOAM FROM WORTH COUNTY

The results secured in the greenhouse experiment on the Clyde silt loam from Worth County are given in table VIII. The application of manure brought about a slight increase in the yield of wheat and gave a pronounced gain in the yield of clover. The application of lime with the manure increased both crops, the effects of the lime showing up quite as definitely on the wheat as on the clover. The acid phosphate with the manure and lime increased the yield of wheat more than did the rock phosphate but showed about the same effect on the clover. The complete commercial fertilizer had a larger effect on the wheat than did the rock phosphate but showed a smaller effect than did the acid phosphate. It gave a somewhat larger influence on the clover but the influence was not great.

It is apparent from these results that even tho this soil is well supplied with organic matter and dark in color, the application of manure is of value in in-

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, WORTH COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams |
|---|---|---|
| 1 | Check | 5.4 |
| 2 | Manure | 5.7 |
| 3 | Manure+lime | 6.8 |
| 4 | Manure+lime+rock phosphate | 7.7 |
| 5 | Manure+lime+acid phosphate | 8.4 |
| 6 | Manure+lime+complete commercial fertilizer | 8.0 |

TABLE VIII. GREENHOUSE EXPERIMENT, CLYDE SILT LOAM, WORTH COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 6.1 | 18.0 |
| 2 | Manure | 6.2 | 20.3 |
| 3 | Manure+lime | 7.1 | 21.7 |
| 4 | Manure+lime+rock phosphate | 7.8 | 23.5 |
| 5 | Manure+lime+acid phosphate | 8.5 | 23.4 |
| 6 | Manure+lime+complete commercial fertilizer | 8.1 | 23.8 |

creasing the yields of general farm crops. The soil is acid in reaction and the application of lime will bring about increases in crop yields which are distinctly profitable. The application of acid phosphate with manure and lime seemed to be more effective on the wheat than did the rock phosphate. The difference was negligible, however, in the case of the clover crop. The use of the complete commercial fertilizer would probably not be as profitable as the application of acid phosphate, owing to the greater cost of the complete commercial fertilizer and the fact that it does not bring about any larger effects on the crop yields.

## RESULTS ON CARRINGTON SILT LOAM FROM MITCHELL COUNTY

The results secured in the greenhouse experiment on the Carrington silt loam from Mitchell County are given in table IX. The manure brought about a distinct increase in both the wheat and clover crops, the effect being particularly evident on the clover. Lime increased the wheat yield slightly but with the clover crop, the yield was more than doubled. The rock phosphate, the acid phosphate, and the complete commercial fertilizer showed no effect on the clover, but brought about distinct increases in the yields of wheat.

These results confirm those previously secured on this soil type indicating that manure will bring about large increases in crop yields. The soil is acid in reaction and the use of lime is very desirable. The use of a phosphate fertilizer seems to be desirable on this soil and increased yields of crops will follow the application of rock phosphate or acid phosphate. The use of a complete commercial fertilizer cannot be recommended on this soil because it does not seem to bring about any larger increases in crop yields than does acid phosphate.

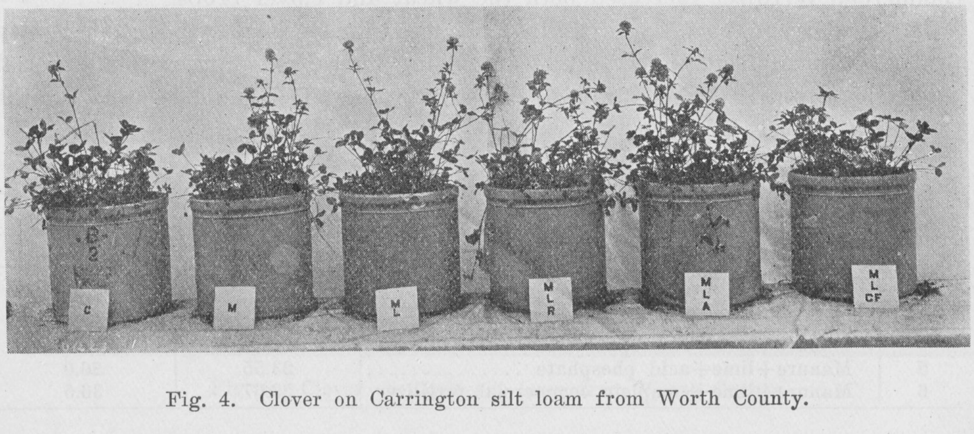



Fig. 4. Clover on Carrington silt loam from Worth County.


Fig. 5. Wheat and clover on Clyde silt loam from Worth County.

## RESULTS ON CLARION LOAM FROM WINNEBAGO COUNTY

The results secured on the greenhouse experiment on the Clarion loam from Winnebago County are given in table X. Manure brought about very distinct increases in the wheat grown on this soil and the clover crop was also increased materially. The addition of lime along with manure had a slight effect on the wheat but showed no influence on the clover. This is contrary to the usual results as the beneficial effects of lime are ordinarily apparent on the legume crop of the rotation rather than on the grain crop. In general farm experience has shown definitely the beneficial effects of applications of lime on clover and it is recommended that the lime needs be determined before clover is grown and that proper application of lime be made when it is found to be necessary. The application of rock phosphate and acid phosphate had no influence on the wheat but the rock phosphate brought about an increase in the clover. The complete commercial fertilizer increased both the wheat and clover crops.

It would seem from these results that the Clarion loam will respond very profitably to applications of farm manure and liberal amounts of this material should be applied. The soil is acid in reaction and lime should be used for the

TABLE IX. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, MITCHELL COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 16.93 | 10.5 |
| 2 | Manure | 19.56 | 16.0 |
| 3 | Manure+lime | 20.93 | 36.5 |
| 4 | Manure+lime+rock phosphate | 22.39 | 27.0 |
| 5 | Manure+lime+acid phosphate | 23.55 | 26.0 |
| 6 | Manure+lime+complete commercial fertilizer | 23.67 | 36.5 |

TABLE X. GREENHOUSE EXPERIMENT, CLARION LOAM, WINNEBAGO COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 11.75 | 52.16 |
| 2 | Manure | 17.25 | 58.96 |
| 3 | Manure+lime | 20.00 | 58.96 |
| 4 | Manure+lime+rock phosphate | 20.00 | 68.04 |
| 5 | Manure+lime+acid phosphate | 20.00 | 58.96 |
| 6 | Manure+lime+complete commercial fertilizer | 23.25 | 68.04 |

best growth of general farm crops. The application of a phosphate fertilizer would probably be of value on this soil. The use of a complete commercial fertilizer may be desirable in some cases on this soil but it seems probable that acid phosphate will generally be more profitable for use.

### RESULTS ON WEBSTER CLAY LOAM FROM WINNEBAGO COUNTY

The results secured in the greenhouse experiment on the Webster clay loam from Winnebago County are given in table XI. The effect of manure is definitely evidenced on this soil, the yields of both the wheat and the clover crops being increased considerably by the application. In spite of the fact that this soil is well supplied with organic matter, the addition of farm manure seems to have much value. The particular sample of soil used in this experiment was slightly acid in reaction and lime was applied. The amount of acidity was small, however, and the application of lime showed no influence. In general this soil type is not acid in reaction, and applications of lime should not be made. After the soil has been under cultivation for a longer period of time and drainage conditions are well established, the loss of lime will increase and the need of testing the soil and making applications of lime will be apparent in later years. The rock phosphate, the acid phosphate, and the complete commercial fertilizer gave increases in the yields of both the wheat and the clover. Unfortunately, the clover crop on the acid phosphate pots was evidently abnormal and the results are not included here. The rock phosphate showed up somewhat better than the acid phosphate on the wheat crop and the complete fertilizer likewise gave a larger effect than the acid phosphate but smaller than the rock. On the clover the complete fertilizer proved slightly more effective than the rock phosphate.

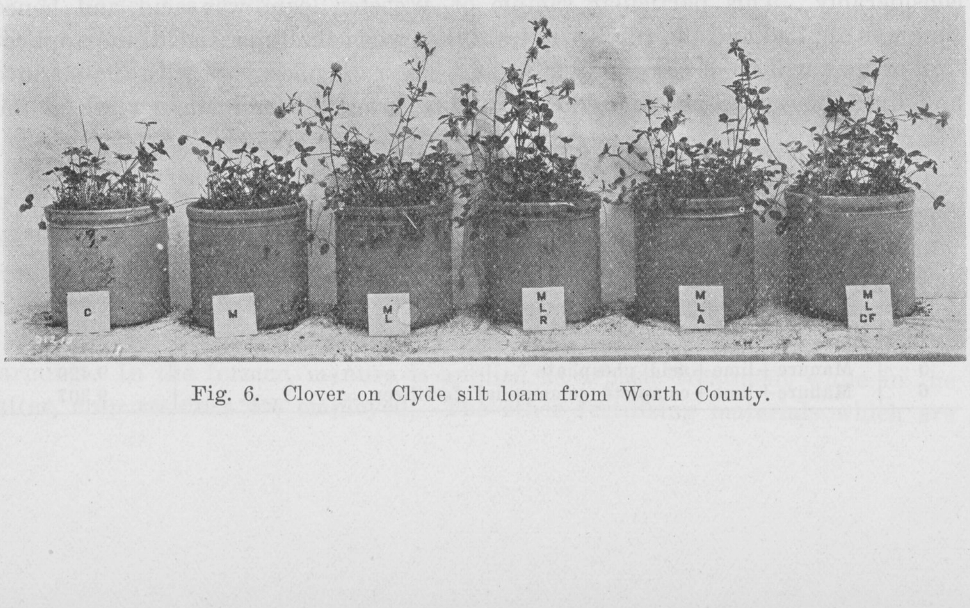



Fig. 6. Clover on Clyde silt loam from Worth County.

TABLE XI. GREENHOUSE EXPERIMENT, WEBSTER CLAY LOAM, WINNEBAGO COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 18.00 | 70.25 |
| 2 | Manure | 22.00 | 74.84 |
| 3 | Manure+lime | 22.75 | 74.84 |
| 4 | Manure+lime+rock phosphate | 26.00 | 77.11 |
| 5 | Manure+lime+acid phosphate | 23.00 | .... |
| 6 | Manure+lime+complete commercial fertilizer | 25.00 | 79.38 |

In general it appears that applications of manure are very desirable on this soil type. When the soil is acid in reaction, lime should be applied and there are strong indications of value from the use of a phosphate fertilizer.

## RESULTS ON CARRINGTON LOAM FROM HARDIN COUNTY

The results secured in the greenhouse experiment on the Carrington loam from Hardin County are given in table XII. Only the yield of wheat was secured in this experiment. The application of manure brought about a distinct increase in the wheat crop. Lime with the manure showed some additional effect. The phosphates and the complete commercial fertilizer brought about still greater gains. The rock phosphate had a much smaller effect than did the acid phosphate. The latter material gave a very pronounced increase. The complete commercial fertilizer had a very slightly smaller effect than the acid phosphate.

Apparently this soil will respond to applications of manure, lime and a phosphate. The addition of manure seems to be of particularly large value. Lime showed an effect on the wheat grown on this soil and would certainly have a much larger effect on a legume crop. The acid phosphate seemed to be somewhat superior to rock phosphate in this test but definite conclusions should not be drawn from one experiment. It seems evident, however, that some phosphate fertilizer should be employed on this soil.

## RESULTS ON WEBSTER LOAM FROM HAMILTON COUNTY

The results secured in the greenhouse experiment on the Webster loam from Hamilton County, are given in table XIII. The addition of manure brought about an increase in the wheat crop. The yield of clover on the manure treated pots was not secured. Lime in addition to the manure increased the wheat yields considerably. This particular sample of Webster loam was acid and hence lime was applied and the results indicate that when the type is acid, the application of lime will be of considerable value. The rock phosphate with the manure and lime showed no effect on the wheat but brought about an increase in the

TABLE XII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, HARDIN COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams |
|---|---|---|
| 1 | Check | 5.223 |
| 2 | Manure | 8.295 |
| 3 | Manure+lime | 8.712 |
| 4 | Manure+lime+rock phosphate | 8.840 |
| 5 | Manure+lime+acid phosphate | 9.420 |
| 6 | Manure+lime+complete commercial fertilizer | 9.307 |

TABLE XIII. GREENHOUSE EXPERIMENT, WEBSTER LOAM, HAMILTON COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 13.15 | 59.5 |
| 2 | Manure | 13.77 | ... |
| 3 | Manure+lime | 17.61 | 70.0 |
| 4 | Manure+lime+rock phosphate | 13.94 | 74.5 |
| 5 | Manure+lime+acid phosphate | 18.01 | 80.0 |
| 6 | Manure+lime+complete commercial fertilizer | 20.31 | 82.0 |

yield of clover. The acid phosphate increased the yield of wheat and showed a pronounced increase in the yield of clover. The complete commercial fertilizer showed a slightly greater effect than the acid phosphate on both the wheat and clover crops.

It is apparent from these results that manure may prove of value on this type. Lime should be used when the surface soil is acid in order to secure the best crop growth. The application of a phosphate fertilizer may be of considerable value on the soil. Acid phosphate seems to be preferable in this test but definite conclusions regarding the relative value of the two phosphates should not be drawn until comparative tests have been carried out under individual farm conditions. The use of a complete commercial fertilizer may be desirable on this soil but tests on the farm in comparison with acid phosphate should be carried out before any extensive utilization of a complete fertilizer is made.

## FIELD EXPERIMENTS

A field experiment has been started in Worth County but the results have not been secured over a long enough period of time as yet for the data to be of significance. Experiments have been under way, however, in counties adjacent to Worth County, on the same soil types which occur extensively in this county. The results secured in these experiments will be given here as they indicate quite definitely the fertilizer effects which may be expected on these same soil types in Worth County. Tests on the Carrington silt loam on the Osage Field in Mitchell County, on the Carrington silt loam on the Springville Field, Series I, and Series II, in Linn County, on the Carrington loam on the Waverly Field, No. II, Series I, and Series II, in Bremer County, on the Carrington loam on the Eldora Field, Series 100, in Hardin County, on the Carrington loam on the Truesdale Field, Series I and Series II, in Buena Vista County, and on the O'Neill loam on the Everly Field, Series I, in Clay County, are given here.

These field experiments are carried out in order to determine the value of certain soil treatments, and they are all laid out on land which is representative of the particular soil types. The fields include 13 plots 155′ 7″ by 28′ or one-tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops, to insure the securing of accurate results.

The experiments are carried out under the livestock and grain systems of farming. In the former, manure is applied as a basic treatment while in the latter, crop residues are employed. The other fertilizing materials which are tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residues treatment consists in plowing under the corn stalks which have been cut with a disk or stalk cutter and plowing under 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 correct the acidity of the soil. Rock phosphate is added at the rate of 2,000 pounds per acre once in four years. Since 1925, rock phosphate has been employed at the rate of 1,000 pounds per acre once in four years. Acid phosphate is added at the rate of 150 pounds per acre annually. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, applications being made at the rate of 300 pounds per acre annually. Since that time the new standard 2-12-2 brand has been employed, applications being made at the rate of 202 pounds per acre annually, thus applying the same amount of phosphorus as that contained in the 150 pounds of acid phosphate.

### THE OSAGE FIELD

The results secured on the Carrington silt loam on the Osage Field, Series I, in Mitchell County, are given in table XIV. The application of manure brought about a very beneficial effect on the crops grown on this field in all but one season. In some cases very large effects were noted as, for example, on the oats in 1920, on the clover in 1921, on the corn in 1922, on the corn in 1923, on the clover and timothy in 1925, and on the corn in 1926. Lime with the manure increased the crop yields to an appreciable extent in most seasons and in several instances very considerable increases were noted as, for example, on the corn in 1923 and on the clover in 1921 and 1925. The increases in the yields in other seasons were in general quite definite.

The use of rock phosphate with the manure and lime increased crop yields in practically every season. In some cases the gains were quite definite but in several instances very small increases were secured. The acid phosphate with the manure and lime showed a larger effect than the rock phosphate in several seasons as, for example, on the oats in 1924 and on the clover and timothy in 1925. In one or two other seasons the rock phosphate seemed to give slightly larger effects but in these cases the differences were not very great. The complete commercial fertilizer with manure and lime had a larger effect on the crop yields in several seasons, but in general the differences were not large and in one or two instances the effects were less definite than those brought about by the phosphates.

The crop residues had little effect on the yields of the various crops grown on this field. Lime with the crop residues increased the crop yields, and in general the increases were very pronounced as, for example, on the corn in 1923, on the oats in 1924, on the clover and timothy in 1925 and on the corn in 1926.

The rock phosphate with the crop residues and lime increased the yields in practically every season. In some cases very considerable gains were noted as on the oats in 1920 and on the clover and timothy in 1925. In most of the other seasons the gains were less definite and in one or two cases no increases at all

TABLE XIV. FIELD EXPERIMENT, CARRINGTON SILT LOAM, MITCHELL COUNTY
OSAGE FIELD, SERIES I

| Plot No. | Treatment | (1) 1918 Corn bu. per A. | 1919 Corn bu. per A. | (2) 1920 Oats bu. per A. | (3) 1921 Clover tons per A. | (4) 1922 Corn bu. per A. | (5) 1923 Corn bu. per A. | (6) 1924 Oats bu. per A. | (7) 1925 Clover and Timothy Tons per A. | 1926 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 46.5 | 55.8 | 34.6 | 1.09 | 58.8 | 42.3 | 72.4 | 0.97 | 37.3 |
| 2 | Manure | 52.8 | 60.0 | 60.3 | 1.55 | 68.0 | 50.8 | 71.0 | 1.25 | 51.4 |
| 3 | Manure+lime | 52.8 | 70.0 | 56.3 | 1.98 | 68.0 | 64.1 | 82.8 | 1.64 | 56.0 |
| 4 | Manure+lime+rock phosphate | 54.8 | 72.0 | 61.2 | 1.94 | 74.3 | 70.7 | 86.5 | 1.68 | 57.0 |
| 5 | Manure+lime+acid phosphate | 56.4 | 77.0 | 61.2 | 1.82 | 76.0 | 70.7 | 98.0 | 1.90 | 55.7 |
| 6 | Manure+lime+complete commercial fertilizer | 44.5 | 79.0 | 67.3 | 1.63 | 72.3 | 70.2 | 102.9 | 1.92 | 60.8 |
| 7 | Check | 38.8 | 67.0 | 59.8 | 1.48 | 50.0 | 53.7 | 74.3 | 1.12 | 46.6 |
| 8 | Crop residues | 37.7 | 65.0 | 55.0 | 1.55 | 51.4 | 52.0 | 71.8 | 1.14 | 41.3 |
| 9 | Crop residues+lime | 39.4 | 74.0 | 50.3 | 1.55 | 58.3 | 65.2 | 81.6 | 1.63 | 52.0 |
| 10 | Crop residues+lime+rock phosphate | 47.4 | 75.0 | 61.8 | 1.55 | 57.7 | 64.4 | 90.3 | 1.94 | 52.5 |
| 11 | Crop residues+lime+acid phosphate | 44.2 | 73.0 | 59.8 | 1.44 | 62.3 | 64.9 | 78.4 | 2.07 | 51.2 |
| 12 | Crop residues+lime+complete commercial fertilizer | 48.8 | 78.0 | 67.3 | 1.79 | 65.5 | 69.9 | 87.1 | 1.55 | 50.9 |
| 13 | Check | 39.7 | 67.0 | 53.1 | 1.59 | 52.3 | 53.2 | 75.6 | 0.88 | 44.0 |

1. Four tons lime applied.
2. Plot 1, low yield, oats down badly; four tons lime applied in September.
3. Clover pastured heavily in spring.
4. Corn down badly on checks and crop residue plots.
5. Dry weather reduced yields.
6. Poor stand on plot 11 due to pocket gophers.
7. Clover mostly killed out in spring due to ice sheet, good stand of timothy.

were noted. The acid phosphate with the crop residues and lime showed a larger effect than the rock phosphate in one or two cases, but in several instances had a less beneficial influence. The differences were not large and it would seem that the two phosphates had very much the same effect on the various crops grown. The complete commercial fertilizer with the crop residues and lime showed a larger effect than the phosphates in several seasons. The differences were quite definite in one or two cases. In a few instances, however, there were less beneficial effects from the complete fertilizer than from the phosphates.

The results secured on this field show the large increases in the yields of general farm crops following the application of manure. Lime with the manure brings about beneficial effects not only on the legume crops of the rotation but also on the general farm crops which are grown. The use of a phosphate fertilizer is especially desirable on this soil. Whether rock phosphate or acid phosphate should be employed cannot be definitely stated as both phosphates seem to give very similar effects in most cases. It would not seem that a complete commercial fertilizer should be recommended for use on this soil as acid phosphate or rock phosphate will probably bring about quite as large crop increases.

## THE SPRINGVILLE FIELD

The results secured on the Carrington silt loam on the Springville Field, Series I, in Linn County, are given in table XV. The application of manure to this soil type is apparently very valuable. Considerable increases in crop yields

TABLE XV. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY SPRINGVILLE FIELD, SERIES I

| Plot No. | Treatment | (1) 1918 Clover tons per A. | (2) 1919 Corn bu. per A. | (3) 1920 Corn bu. per A. | 1921 Oats bu. per A. | (4) 1922 Clover tons per A. | (5) 1923 Corn bu. per A. | (6) 1924 Corn bu. per A. | (7) 1925 Oats bu. per A. | (8) 1926 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 2.25 | 58.6 | 46.5 | 44.8 | 1.37 | 40.2 | .... | 53.9 | 41.6 |
| 2 | Manure+lime | 2.47 | 64.8 | 63.3 | 36.4 | 1.47 | 51.2 | .... | 72.4 | 49.3 |
| 3 | Manure | 2.40 | 63.7 | 51.1 | 46.9 | 1.35 | 55.9 | .... | 57.4 | 46.4 |
| 4 | Manure+lime+rock phosphate | 2.70 | 60.8 | 66.1 | 42.8 | 2.02 | 60.2 | .... | 71.6 | 50.4 |
| 5 | Manure+lime+acid phosphate | 2.70 | 67.1 | 60.8 | 46.3 | 2.14 | 59.7 | .... | 68.6 | 47.4 |
| 6 | Manure+lime+complete commercial fertilizer | 2.70 | 64.5 | 61.0 | 49.2 | 1.99 | 60.7 | .... | 74.1 | 47.4 |
| 7 | Check | 1.65 | 60.0 | 51.9 | 36.9 | 1.35 | 40.0 | .... | 43.6 | 34.4 |
| 8 | Crop residues | 2.05 | 62.5 | 55.0 | 42.8 | 1.40 | 46.2 | .... | 47.4 | 37.8 |
| 9 | Crop residues+lime | 2.02 | 49.4 | 59.6 | 38.9 | 1.56 | 44.2 | .... | 62.1 | 38.6 |
| 10 | Crop residues+lime+rock phosphate | 2.16 | 55.7 | 58.5 | 43.6 | 1.98 | 54.4 | .... | 64.8 | 36.8 |
| 11 | Crop residues+lime+acid phosphate | 2.47 | 55.4 | 58.5 | 48.4 | 2.10 | 43.5 | .... | 62.2 | 37.0 |
| 12 | Crop residues+lime+complete commercial fertilizer | 2.10 | 33.1 | 57.3 | 37.8 | 2.04 | 44.7 | .... | 72.4 | 38.6 |
| 13 | Check | 1.80 | 45.7 | 41.1 | 36.0 | 1.51 | 36.1 | .... | 45.3 | 30.9 |

1. Three and one-half tons lime, fall 1917.
2. Plots 10, 11, 12 and 13 on low ground, poor stand.
3. Plot 2 small ditch, abnormal yield.
4. Clover down badly on 5 and 6, and 11 and 12, only 85% could be cut.
5. Season dry.
6. Field was replanted and corn did not mature.
7. Plot 2 is high in fertility and poorly drained which resulted in high yield due to dry season.
8. Hot winds and dry weather damaged corn.

were secured in all but one season. In some cases the increases were very large as in the corn in 1920 and 1925 and in the oats in 1925. The application of lime with the manure increased the crop yields in one or two seasons but no large effects were noted from the use of this material. In several cases no increases at all were secured. The application of rock phosphate with the manure and lime brought about very large crop increases in some seasons as, for example, on the clover in 1918, on the corn in 1920, on the clover in 1922, and on the oats in 1925. Increases were secured from the use of this material in all but two seasons. The acid phosphate with the manure and lime had a larger effect than the rock phosphate in several cases but in general showed very much the same influence. The corn in 1919, the oats in 1921 and the clover in 1922 showed larger effects from the acid phosphate than from the rock phosphate, but in several other seasons the latter seemed more beneficial. The complete commercial fertilizer had a slightly greater effect than the acid phosphate in one or two seasons but in general the influence was very much the same as that brought about by the two phosphates.

Crop residues showed little effect on the various crops grown. In one or two seasons small increases were noted, but in general the yields were influenced very little. The application of lime with the crop residues showed a beneficial effect on the crops grown in several seasons, the largest influence was evidenced on the clover in 1922, and on the oats in 1925. In several other cases slight increases in crop yields were secured. In one or two seasons no gains at all were noted.

The application of rock phosphate with the crop residues and lime increased the crop yields in practically every season. In some cases very large increases were secured as, for example, on the clover in 1922, and on the corn in 1923. The acid phosphate with the crop residues and lime had a larger effect than the rock phosphate in most seasons. In general, however, the differences between the effects of these two phosphates were not very pronounced. The complete commercial fertilizer with the crop residues and lime showed less effect than the acid phosphate in many cases. Only in one season was there any large difference in the yield and this was in the case of the oats in 1925. In several other seasons the complete fertilizer gave slightly larger effects but the differences were not definite.

The results secured in the field test on the same soil type in Series II, of the same field, are given in table XVI. Here again the beneficial effect of the application of manure is evidenced by the increased crop yields secured in every season. In some cases the increases were not very large but in general quite definite gains were noted. The clover in 1921, the corn in 1922, and the corn in 1923 showed the most pronounced effects from the application of manure. The addition of lime with the manure increased the crop yields in practically every season. The clover in 1921 and 1925 were particularly benefited by the lime. The corn in 1923 was increased to a pronounced extent by the use of lime.

The rock phosphate with the manure and lime increased the crop yields in every season. In some cases the gains were small but in general they were quite definite. Beneficial effects were noted particularly on the clover in 1921 and in 1925. The acid phosphate with the manure and lime showed a larger effect than the rock phosphate in one or two seasons but in several other cases there were slightly smaller effects. In general the difference between the influence of these

TABLE XVI. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY SPRINGVILLE FIELD, SERIES II

| Plot No. | Treatment | (1) 1919 Corn bu. per A. | (2) 1920 Oats bu. per A. | 1921 Clover tons per A. | 1922 Corn bu. per A. | (3) 1923 Corn bu. per A. | (4) 1924 Oats bu. per A. | (5) 1925 Clover tons per A. | (6) 1926 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 61.1 | 41.1 | 1.16 | 62.6 | 32.0 | .... | 0.87 | 40.0 |
| 2 | Manure | 66.0 | 46.8 | 1.42 | 76.0 | 40.0 | .... | 0.90 | 41.0 |
| 3 | Manure+lime | 66.2 | 48.8 | 1.86 | 82.8 | 46.6 | .... | 1.30 | 40.0 |
| 4 | Manure+lime+rock phosphate | 66.5 | 49.6 | 2.29 | 84.3 | 46.8 | .... | 1.48 | 48.0 |
| 5 | Manure+lime+acid phosphate | 59.7 | 50.8 | 2.56 | 78.0 | 44.4 | .... | 1.30 | 40.5 |
| 6 | Manure+lime+complete commercial fertilizer | 64.2 | 43.4 | 2.50 | 79.1 | 47.4 | .... | 1.39 | 41.0 |
| 7 | Check | 57.1 | 47.6 | 1.51 | 62.9 | 33.5 | .... | 0.95 | 36.8 |
| 8 | Crop residues | 56.9 | 47.6 | 1.17 | 61.7 | 36.2 | .... | 0.78 | 37.8 |
| 9 | Crop residues+lime | 53.1 | 58.9 | 1.27 | 63.4 | 35.6 | .... | 1.13 | 50.6 |
| 10 | Crop residues+lime+rock phosphate | 61.4 | 63.7 | 2.31 | 60.6 | 34.9 | .... | 1.15 | 44.8 |
| 11 | Crop residues+lime+acid phosphate | 62.9 | 70.6 | 2.34 | 59.1 | 38.1 | .... | 1.41 | 44.2 |
| 12 | Crop residues+lime+complete commercial fertilizer | 60.0 | 50.2 | 2.25 | 74.7 | 44.9 | .... | 1.35 | 44.2 |
| 13 | Check | ... | 55.6 | 1.35 | 64.8 | 40.0 | .... | 0.43 | 41.0 |

1. Plot 13 cut by mistake.
2. Wet spring reduced crop on manured plots, 4 tons lime, September.
3. Poor drainage made series weedy in spots.
4. No results taken.
5. No fertilizer applications made since spring of 1923, carried as a residual series.
6. Hot winds and dry weather damaged corn.

two phosphates was not very great. The complete commercial fertilizer with the manure and lime showed slightly larger effects than the acid phosphate in most seasons. The differences, however, were not great, and in general it may be considered that the two materials gave very similar increases in the yields of general farm crops.

The crop residues had little effect on the yields of the various crops grown in this test. Lime with the residues brought about increases in most seasons. In some cases very large gains were noted as, for example, on the clover in 1925 and on the corn in 1926. The rock phosphate with the crop residues and lime increased the yields to a considerable extent in several seasons. Beneficial effects were particularly evidenced on the clover in 1921. In several cases no gains were noted from the use of the rock phosphate. The acid phosphate with the crop residues and lime showed a larger effect than the rock phosphate in most seasons. In general, however, the differences were not very pronounced and the two phosphates seemed to have quite similar effects. The complete commercial fertilizer had a larger effect than the acid phosphate in one or two seasons, but in several other cases it showed smaller effects.

The results secured in this experiment confirm those previously discussed in showing that the Carrington silt loam will respond in a very profitable way to applications of manure, lime and a phosphate fertilizer.

## THE WAVERLY FIELD

The data secured from the field experiment on the Carrington loam on the Waverly Field, No. II, Series I, in Bremer County are given in table XVII. Beneficial effects of manure on this soil were evidenced by the increased crop yields secured in practically every season. In some cases very large gains were noted as, for example, on the clover in 1919. Lime with the manure brought about increased crop yields in practically all cases. The effect was particularly noticeable on the oats in 1921 and in 1925. The yield on plot 3 in 1919 was evidently abnormal.

The rock phosphate with the manure and lime increased crop yields to a very pronounced extent in some seasons. In one or two years it showed no beneficial effects. The clover in 1919 was increased to the largest extent but there was a considerable influence also on the oats in 1925. The acid phosphate with the manure and lime showed a greater effect than the rock phosphate in most seasons. The differences, however, were generally not very large. In one case the acid phosphate showed less effect than the rock phosphate. The complete commercial fertilizer had a greater influence than the acid phosphate in one or two cases but in general showed a very similar effect to that brought about by the acid phosphate. A very large increase was noted, however, in 1925, from the complete fertilizer.

The crop residues showed very little effect on the various crops grown. Lime with the residues increased the crop yields in all seasons. In some cases very large gains were noted, particularly on the clover in 1919 and 1922. Large effects were also shown on the oats in 1921 and 1925.

The rock phosphate with the crop residues and lime increased the crop yields to a considerable extent in practically every season. The largest influence was

TABLE XVII. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY
WAVERLY FIELD, NO. II, SERIES I

| Plot No. | Treatment | (1) 1918 Corn bu. per A. | 1919 Clover tons per A. | (2) 1920 Corn bu. per A. | (3) 1921 Oats bu. per A. | (4) 1922 Clover tons per A. | (5) 1923 Corn bu. per A. | (6) 1924 Corn bu. per A. | (7) 1925 Oats bu. per A. | (8) 1926 clover tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check .................. | 42.8 | 1.50 | 47.8 | 25.7 | 2.22 | .... | 11.0 | .... | .... |
| 2 | Manure ............... | 61.0 | 1.75 | 56.5 | 34.3 | 2.20 | .... | 24.7 | 63.9 | .... |
| 3 | Manure+lime ......... | 64.9 | 1.10 | 57.5 | 50.6 | 2.32 | .... | 30.4 | 77.7 | .... |
| 4 | Manure+lime+rock phosphate ............ | 65.5 | 2.60 | 58.0 | 40.3 | 2.10 | .... | 34.3 | 87.8 | .... |
| 5 | Manure+lime+complete commercial fertilizer .. | 72.1 | 2.35 | 44.0 | 35.7 | 2.78 | .... | 42.1 | 103.3 | .... |
| 6 | Manure+lime+acid phosphate ............ | 67.2 | 2.85 | 47.0 | 42.0 | 2.90 | .... | 38.2 | 89.3 | .... |
| 7 | Check .................. | 55.1 | 1.55 | 36.6 | 30.6 | 1.76 | .... | 19.2 | 59.9 | .... |
| 8 | Crop residues ........... | 49.6 | 1.05 | 39.6 | 20.3 | 1.24 | .... | 18.8 | 51.7 | .... |
| 9 | Crop residues+lime ..... | 66.2 | 1.50 | 40.8 | 30.4 | 1.84 | .... | 20.3 | 62.1 | .... |
| 10 | Crop residues+lime+rock phosphate ........... | 70.0 | 1.75 | 41.6 | 40.6 | 2.16 | .... | 20.5 | 85.3 | .... |
| 11 | Crop residues+lime+acid phosphate ........... | 88.2 | 2.55 | 43.3 | 38.4 | 2.70 | .... | 23.1 | 86.9 | .... |
| 12 | Crop residues+lime+ complete commercial fertilizer ............ | 88.6 | 2.10 | 45.8 | 46.0 | 2.70 | .... | 22.4 | 86.5 | .... |
| 13 | Check .................. | 79.7 | 1.55 | 35.1 | 26.7 | 1.48 | .... | 16.3 | 53.4 | .... |

1. Six tons lime, fall 1917.
2. Soybeans planted in corn, both crops poor. Wet spring injured plots in center series. Plots 5 and 6 and crop residue plots weedy.
3. Plot 3 too high, many morning glory vines on plot.
4. Stand uneven on 2 and 4.
5. No crop yields secured owing to drought.
6. Crop damaged by frost—phosphate plots showed more maturity.
7. Barley seeded by mistake on plot 1. Unable to account for high yield on plot 5.
8. Field pastured—no results taken.

noted on the clover crop and on the oats in 1925. The acid phosphate with the crop residues and lime had a larger effect than the rock phosphate in practically every season. In some cases the gains were very pronounced, as on the clover in 1919 and 1922. In other seasons the differences were not large. The complete commercial fertilizer with the crop residues and lime exerted very much the same effect as did the acid phosphate, showing a slightly greater influence in some cases and a somewhat smaller effect in other instances.

The results secured on the Carrington loam on the Waverly Field, No. II, Series II, in Bremer County, are given in table XVIII. Here again the beneficial influence of manure on this soil is evidenced by the great increases in crop yields secured in practically every season. The clover in 1920 and 1921 and the corn in 1922 and 1923 showed the largest influence from the use of manure. The application of lime with the manure brought about distinct gains in the crop yields in practically every season. In some cases the increases were very large as on the clover in 1920, 1921 and 1925, on the corn in 1923, on the oats in 1924 and on alfalfa in 1926.

The rock phosphate with the manure and lime showed a beneficial effect on the crop yields in most seasons. The differences, however, were not very distinct and in some cases no gains were noted. The acid phosphate with the manure and lime increased the yields to a considerable extent in most seasons. The largest effects were noted on the clover and alfalfa crops altho there was a large effect also on the oats in 1924. The complete commercial fertilizer

TABLE XVIII. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY
WAVERLY FIELD, NO. 2, SERIES II

| Plot No. | Treatment | (1) 1918 Corn bu. per A | 1919 Oats bu. per A. | (2) 1920 Clover tons per A. | 1921 Clover and timothy tons per A. | (3) 1922 Corn bu. per A. | (4) 1923 Corn bu. per A. | 1924 Oats bu. per A. | (5) 1925 Sweet clover tons per A. | (6) 1926 Alfalfa tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check ................ | 38.5 | 39.8 | 0.47 | 1.03 | 39.4 | 25.0 | 42.8 | 0.39 | ... |
| 2 | Manure ................ | 54.0 | 49.3 | 0.67 | 1.30 | 55.7 | 40.2 | 49.7 | 0.45 | 0.76 |
| 3 | Manure+lime ......... | 56.8 | 61.9 | 1.36 | 1.87 | 62.3 | 57.0 | 66.4 | 2.66 | 1.28 |
| 4 | Manure+lime+rock phosphate .......... | 57.2 | 46.4 | 1.66 | 1.98 | 63.1 | 62.0 | 64.9 | 2.72 | 1.61 |
| 5 | Manure+lime+acid phosphate .......... | 60.5 | 57.8 | 2.05 | 2.19 | 64.0 | 60.7 | 75.8 | 3.03 | 1.65 |
| 6 | Manure+lime+complete commercial fertilizer | 61.3 | 61.9 | 1.99 | 2.47 | 62.9 | 63.0 | 65.3 | 3.03 | 1.35 |
| 7 | Check ................ | 48.7 | 35.4 | 0.84 | 1.17 | 45.7 | 34.2 | 42.5 | 0.62 | 0.67 |
| 8 | Crop residues ......... | 46.4 | 39.4 | 0.67 | 1.09 | 41.4 | 34.0 | 48.3 | 0.62 | 0.69 |
| 9 | Crop residues+lime ... | 50.0 | 48.3 | 0.87 | 1.26 | 50.6 | 45.2 | 55.5 | 2.93 | 1.10 |
| 10 | Crop residues+lime+ rock phosphate ...... | 56.7 | 40.8 | 1.14 | 1.44 | 52.0 | 46.5 | 74.7 | 3.02 | 1.11 |
| 11 | Crop residues+lime+ acid phosphate ..... | 48.7 | 47.3 | 1.11 | 1.63 | 51.4 | 47.5 | 70.9 | 3.02 | 1.36 |
| 12 | Crop residues+lime+ complete commercial fertilizer .......... | 42.7 | 53.5 | 1.32 | 2.10 | 60.8 | 50.7 | 51.2 | 2.96 | 1.31 |
| 13 | Check ................ | 33.4 | 32.9 | 0.33 | 0.87 | 34.8 | 43.2 | 37.8 | 0.45 | 0.69 |

1. Six tons lime, fall 1917. Heavy rains washed 11, 12 and 13 badly.
2. Plots 1 and 2 poorer in fertility than other plots.
3. Dry season.
4. Plot 13 high probably due to manure application made thru error.
5. Biennial white sweet clover.
6. Grasshoppers injured plot 1 and the west side of all plots.

showed a somewhat greater effect than the acid phosphate in some cases, but in several instances did not bring about as large increases.

The crop residues showed little effect on the crop yields, small increases being noted only in one or two cases. Lime with the residues increased the crop yields in a very pronounced way, in some cases bringing about enormous increases, as for example on the clover in 1925. The rock phosphate with the crop residues and lime increased the yields in most seasons, the differences being considerable in some cases, as on the clover crops and on the oats in 1924. The acid phosphate with the crop residues and lime showed a larger effect than the rock phosphate in one or two cases, but the differences were not large and in general the two phosphates seemed to give about the same returns. The complete commercial fertilizer showed a larger effect than the acid phosphate in some cases, particularly on the clover and timothy in 1921, but in other instances there was a smaller influence from the complete fertilizer.

These results as a whole indicate that the Carrington loam will respond profitably to applications of manure, lime and a phosphate fertilizer. Liberal additions of manure to this type are recommended and large crop increases will follow the application. The type is acid in reaction and the application of lime is very necessary for the best growth of general farm crops and particularly if the most desirable yields of legumes are to be secured. The use of a phosphate fertilizer seems to be particularly profitable on this type. Acid phosphate and rock phosphate both bring about large increases in the yields of general farm crops.

## THE ELDORA FIELD

The results secured on the Carrington loam on the Eldora Field, Series 100 in Hardin County, are given in table XIX. This experiment was begun in 1915 and the results have been secured over a period of 12 years. The beneficial effects of manure when applied to this soil are shown by the increased crop yields which were secured in practically all cases. Lime with the manure brought about increases in crops in some instances. Gains were not noted in all cases, however, and in some seasons the differences in yields were small. In general, however, it is definitely shown that lime will generally bring about beneficial effects on crops grown on this soil.

The use of rock phosphate and acid phosphate on this soil proved to be very valuable in increasing crop yields. The increases were particularly noticeable in the case of the clover crop, altho very large effects were noted in some cases on the corn and oats crops. Acid phosphate generally brought about somewhat larger effects than the rock phosphate. In some cases the differences were considerable as, for example, on the corn in 1918. In other instances, however, there seems to be very little choice between the two phosphates. The complete commercial fertilizer occasionally showed larger effects than the acid phosphate but in several cases it had less influence.

TABLE XIX. FIELD EXPERIMENT, CARRINGTON LOAM, HARDIN COUNTY
ELDORA FIELD, SERIES 100

| Plot No. | Treatment | (1) 1919 Corn bu. per A. | 1916 Oats bu. per A. | 1917 Clover tons per A. | 1918 Corn bu. per A. | (2) 1919 Corn bu. per A. | (3) 1920 Oats bu. per A | (4) 1921 Clover tons per A. | 1922 Corn bu. per A. | (5) 1923 Corn bu. per A. | 1924 Oats bu. per A. | (6) 1925 Clover tons per A. | 1926 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check ........ | 47.5 | 40.0 | 1.19 | 46.4 | 33.9 | 42.8 | 1.75 | 64.3 | 41.5 | 59.6 | 0.89 | 59.8 |
| 2 | Manure ...... | 38.5 | 50.0 | 1.36 | 55.8 | 52.5 | 49.6 | 1.65 | 67.2 | 40.0 | 69.1 | 1.05 | 69.4 |
| 3 | Manure+lime | 40.8 | 40.0 | 1.53 | 52.2 | 50.6 | 56.9 | 1.50 | 69.9 | 38.2 | 70.4 | 1.14 | 63.1 |
| 4 | Manure+lime+ rock phosphate | 53.3 | 46.0 | 1.78 | 48.9 | 58.8 | 57.7 | 2.30 | 66.4 | 41.8 | 71.5 | 1.18 | 52.2 |
| 5 | Manure+lime+ acid phosphate | 53.9 | 53.0 | 1.87 | 68.8 | 61.1 | 60.3 | 2.55 | 73.6 | 44.8 | 79.4 | 1.32 | 58.8 |
| 6 | Manure+lime+ complete commercial fertilizer ... | 52.2 | 53.6 | 2.04 | 60.7 | 57.9 | 59.8 | 2.65 | 70.7 | 50.4 | 78.0 | 1.46 | 60.1 |
| 7 | Check ........ | 35.3 | 33.8 | 1.44 | 56.8 | 35.4 | 43.1 | 1.40 | 61.7 | 34.9 | 52.6 | 0.75 | 53.5 |
| 8 | Crop residues.. | 37.2 | 33.9 | 1.36 | 53.3 | 39.6 | 38.7 | 1.40 | 62.2 | 33.0 | 55.9 | 0.63 | 50.2 |
| 9 | Crop residues +lime ..... | 37.3 | 30.0 | 1.28 | 60.3 | 39.2 | 50.2 | 1.55 | 64.3 | 41.5 | 71.6 | 1.18 | 52.9 |
| 10 | Crop residues +lime+ rock phosphate | 38.7 | 33.3 | 1.70 | 62.2 | 44.0 | 52.2 | 2.40 | 73.6 | 45.6 | 79.5 | 1.32 | 63.1 |
| 11 | Crop residues +lime+ acid phosphate | 46.8 | 46.6 | 1.87 | 65.3 | 46.0 | 55.7 | 3.00 | 82.2 | 43.9 | 83.4 | 1.25 | 63.8 |
| 12 | Crop residues +lime+ complete commercial fertilizer .... | 35.0 | 50.0 | 1.70 | 63.7 | 41.6 | 67.2 | 2.85 | 70.0 | 45.9 | 74.2 | 1.25 | 61.8 |
| 13 | Check ........ | 28.8 | 33.8 | 1.23 | 58.3 | 35.0 | 39.4 | 2.00 | 65.0 | 38.2 | 58.0 | 0.82 | 57.8 |

1. Lime 3 tons per acre, fall of 1914.
2. Dry season, yields low.
3. Plots limed in spring.
4. Much sweet clover on plot 13.
5. Corn down badly, dry season.
6. Extremely dry spring, low yield.

The crop residues had little effect on this soil as would be expected. The use of lime with the crop residues brought about slight increases in crop yields in most seasons. In one or two cases the use of lime proved very valuable. The effect was noted particularly on the oats in 1920, on the clover in 1921 and on the corn, oats and clover in 1923, 1924 and 1925.

The use of rock phosphate and acid phosphate was of considerable value on this soil, the acid phosphate showing up to particular advantage when applied with lime and crop residues. Larger increases were secured in many cases than those brought about by the rock phosphate when used with lime and residues. The greater beneficial effect of the acid phosphate was noted particularly on the oats in 1916, on the clover in 1917, on the clover in 1921 and on the corn in 1922. In several other cases the rock phosphate was quite as beneficial in effect, sometimes giving a slightly larger influence on the crop yields. The complete commercial fertilizer frequently had less beneficial effect than the acid phosphate. In one or two instances it gave a larger influence but the differences were not great.

These results confirm those previously discussed in indicating that the Carrington loam will respond in a very large way to applications of manure, lime, and a phosphate fertilizer.

## THE TRUESDALE FIELD

The results secured on the Carrington loam on the Truesdale Field, Series I, in Buena Vista County, are given in table XX. The results secured in this field are applicable to Clarion loam as mapped in Worth County While the soil type was called Carrington loam in Buena Vista County, it has all the characteristics of the Clarion loam, the latter soil type being differentiated from the Carrington loam after the completion of the survey of Buena Vista County.

Manure brought about an increase in the yields of all the crops except the clover in 1921. The largest increase was evidenced on the corn in 1922. Lime increased the yields in all cases, showing the largest effect on the clover as would be expected. The rock phosphate with the manure and lime gave increases in most years, the largest effects being shown on the clover. The influence on the oats and corn was smaller, and in the case of the corn in 1922 and the oats in 1923, no increases at all were secured. The acid phosphate with the manure and lime gave very similar increases to the rock phosphate in some seasons. With the clover in 1921, however, there was a very much larger effect from the acid phosphate, while on the same crop in 1926 there was a smaller effect. The oats in 1925 were increased to a much larger extent by the acid phosphate than by the rock phosphate. In most of the other seasons, the variations between the effects of the two phosphates were insignificant. The complete comercial fertilizer showed gains which were very similar to those brought about by the phosphates, giving slightly smaller effects than the acid phosphate in some instances and slightly larger effects than this material in other cases.

The crop residues showed little influence on the yields of the succeeding crops except in one or two cases. Lime with the residues brought about increases in the yields in most seasons, the effects being most evidenced on the clover in 1926 and on some of the oats crops. The rock phosphate with the lime and crop residues

TABLE XX. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY TRUESDALE FIELD, SERIES I

| Plot No. | Treatment | (1) 1918 Corn bu. per A. | (2) 1919 Corn bu. per A. | (3) 1920 Oats bu. per A. | 1921 Clover tons per A. | (4) 1922 Corn bu. per A. | (5) 1923 Oats bu. per A. | (6) 1924 Corn bu. per A. | 1925 Oats bu. per A. | 1926 Clover tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 38.9 | 56.5 | 57.2 | 1.40 | 48.6 | 44.2 | 13.0 | 48.3 | 1.12 |
| 2 | Manure | 44.3 | 57.1 | 57.9 | 1.20 | 61.6 | 57.7 | 24.2 | 57.0 | 1.45 |
| 3 | Manure+lime | 46.4 | 58.1 | 59.2 | 1.60 | 64.0 | 61.2 | 32.7 | 63.2 | 1.64 |
| 4 | Manure+lime+rock phosphate | 54.4 | 58.7 | 64.7 | 2.45 | 63.2 | 60.0 | 34.1 | 64.6 | 1.77 |
| 5 | Manure+lime+acid phosphate | 49.6 | 58.7 | 64.9 | 3.30 | 61.6 | 61.2 | 32.8 | 73.1 | 1.60 |
| 6 | Manure+lime+complete commercial fertilizer | 49.6 | 58.7 | 64.7 | 3.10 | 63.7 | 68.0 | 37.5 | 71.0 | 1.79 |
| 7 | Check | 38.4 | 58.1 | 56.4 | 2.20 | 51.0 | 54.8 | 30.2 | 50.4 | 1.13 |
| 8 | Crop residues | 49.1 | 61.9 | 67.7 | 2.20 | 49.7 | 55.5 | 27.1 | 44.3 | 1.52 |
| 9 | Crop residues+lime | 51.2 | 66.6 | 66.0 | 2.20 | 50.6 | 54.5 | 31.0 | 51.7 | 1.68 |
| 10 | Crop residues+lime+rock phosphate | 58.9 | 68.8 | 68.1 | 3.10 | 61.6 | 60.0 | 31.4 | 57.6 | 1.50 |
| 11 | Crop residues+lime+acid phosphate | 57.6 | 67.2 | 76.8 | 2.90 | 64.1 | 64.5 | 24.5 | 71.0 | 1.44 |
| 12 | Crop residues+lime+complete commercial fertilizer | 62.9 | 66.1 | 77.6 | 3.00 | 60.4 | 77.0 | 34.4 | 71.6 | 1.29 |
| 13 | Check | 47.5 | 64.0 | 56.5 | 2.10 | 49.0 | 48.7 | 29.6 | 54.4 | 0.92 |

1. Three tons lime, fall 1917.
2. Plots 8, 13 more moisture, slopes into heavier soil.
3. Three tons lime in October.
4. Dry season cut yields.
5. Phosphate plots down at harvest.
6. Plots 1 and 2 injured by squirrels. Corn green when husked due to a killing frost.

increased the yields in practically all cases. Only with the clover in 1926 was no increase noted. In some seasons the increases were quite large while in other seasons they were small. The clover in 1921 showed a large increase. The oats in 1923 was increased considerably and likewise in 1925. The acid phosphate showed larger effects than the rock phosphate in some instances, particularly on the oats in 1920 and on the same crop in 1925, a very large difference being evidenced in the latter year. In several other cases, however, the rock phosphate seemed to give quite as good results as the acid phosphate and in the case of the clover crop, it had a slightly larger influence. The complete commercial fertilizer had about the same effect as the acid phosphate in most cases. In a few instances it gave better results and in one or two cases had a smaller influence. The differences, however, were not large enough in most cases to be significant. Only on the oats in 1923 and on the corn in 1924 were the differences of very large import.

The results secured on Series II of the Truesdale Field in Buena Vista County on the same soil type are given in table XXI. Here again the application of manure was found to increase the yields of the various crops grown, showing very large effects in practically all cases. The corn and oats crops were benefited greatly by the use of manure and there was a large influence also on the clover crop, shown by the increased yield in 1923. Lime brought about further increases in the crop yields in most cases. In one or two instances the application of the lime did not prove significant. In general, however, when this soil is acid, it is very desirable to apply lime in order to secure the best growth of leguminous crops.

TABLE XXI. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY
TRUESDALE FIELD, SERIES II

| Plot No. | Treatment | (1) 1918 Oats bu. per A. | (2) 1919 Clover tons per A. | 1920 Corn bu. per A. | (3) 1921 Corn bu. per A. | (4) 1922 Oats bu. per A. | 1923 Clover tons per A. | (5) 1924 Corn bu. per A. | 1925 Corn bu. per A. | (6) 1926 Oats bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 69.9 | ... | 47.5 | 32.8 | 18.5 | 1.72 | 38.0 | 40.0 | 29.9 |
| 2 | Manure | 94.2 | ... | 57.0 | 39.7 | 24.6 | 1.90 | 52.7 | 50.4 | 38.1 |
| 3 | Manure+lime | 91.2 | ... | 59.0 | 41.8 | 27.2 | 1.86 | 46.9 | 51.8 | 37.0 |
| 4 | Manure+lime+rock phosphate | 88.2 | ... | 61.2 | 38.1 | 32.4 | 2.26 | 44.4 | 51.7 | 37.3 |
| 5 | Manure+lime+acid phosphate | 91.2 | 1.89 | 62.1 | 40.2 | 31.0 | 2.24 | 24.4 | 54.8 | 43.3 |
| 6 | Manure+lime+complete commercial fertilizer | 88.2 | 2.00 | 64.0 | 44.5 | 31.9 | 2.42 | 45.0 | 58.6 | 43.6 |
| 7 | Check | 85.1 | 1.59 | 57.1 | 36.3 | 23.6 | 1.93 | 42.9 | 51.6 | 34.3 |
| 8 | Crop residues | 89.7 | 1.98 | 38.5 | 32.9 | 31.2 | 1.98 | 40.7 | 59.2 | 35.4 |
| 9 | Crop residues+lime | 97.3 | 2.07 | 59.2 | 40.1 | 29.8 | 2.03 | 41.8 | 52.2 | 32.7 |
| 10 | Crop residues+lime+ rock phosphate | 91.2 | 2.19 | 60.0 | 35.6 | 34.4 | 2.39 | 46.0 | 51.1 | 38.7 |
| 11 | Crop residues+lime+ acid phosphate | 92.7 | 2.22 | 60.4 | 33.6 | 36.8 | 2.11 | 40.7 | 60.4 | 47.4 |
| 12 | Crop residues+lime+ complete commercial fertilizer | 95.8 | 2.37 | 61.9 | 35.5 | 37.3 | 2.39 | 39.3 | 55.2 | 40.3 |
| 13 | Check | 85.1 | 1.91 | 60.9 | 34.9 | 28.4 | 2.03 | 39.5 | 49.8 | 29.9 |

1. 2½ tons lime in March.
2. Plots 1, 2, 3 and 4 disced and seeded to oats. Clover winter-killed.
3. Poor stand of corn.
4. Two tons lime in April.
5. Plot 5 injured by squirrels.
6. Dry season, low yields.

The rock phosphate, the acid phosphate, and the complete commercial fertilizer increased yields in practically all cases when applied with the manure and lime. In one or two seasons the rock phosphate did not appear to be of value, but the acid phosphate and complete commercial fertilizer always brought about increases in yields, the effects being particularly noted on the clover in 1923.

The crop residues exerted slight effects on the crop yields in several instances. The application of lime with the crop residues brought about increases in yields in most seasons. The effects were not very large except in one or two cases, however, and in 1925 and 1926, no value from the application of lime was evidenced on the corn and oats.

The rock phosphate, the acid phosphate and the complete commercial fertilizer increased the crop yields in practically all seasons. The acid phosphate seemed to be slightly superior to the rock phosphate in some cases while in other instances the rock phosphate gave somewhat better results. The greater influence from the latter material is shown on the clover in 1923 and on the corn in 1924. The acid phosphate, however, gave much larger effects on the corn in 1925 and on the oats in 1926. The complete commercial fertilizer had very much the same effect as the acid phosphate in most seasons, showing less influence, however, than the latter material in 1925 and 1926 and slightly larger effects in some other seasons.

These results very largely confirm those secured in Series I on the same soil type and indicate the large value of manure on this soil. The use of lime is desirable with manure in the livestock system of farming, or with crop residues in the grain system. The application of a phosphate fertilizer will certainly prove valuable on this type and either rock phosphate or acid phosphate should be employed. The use of a complete commercial fertilizer has not been shown to be of large enough value to make the application profitable.

### THE EVERLY FIELD

The results secured in the field experiment on the O'Neill loam in Clay County on the Everly Field Series I are given in table XXII. The application of manure to this soil type was apparently very valuable. Increases in crop yields were secured in practically every season. In some cases very large gains were noted as, for example, on the clover in 1921, on the corn in 1922, and on the oats in 1924. Lime with the manure was of value on this soil and increases in crop yields quite generally followed its application. Large increases were secured in many cases on the oats and corn as well as on the legumes.

The rock phosphate with the manure and lime increased the crop yields in several seasons. In general, no large effects were noted, however, except on the clover in 1921. The acid phosphate with the manure and lime showed a larger effect on the crop yields in several seasons. The beneficial influence of the acid phosphate was noted particularly on the clover in 1921 and 1925 and on the oats in 1924. In the other seasons, the differences between the effects of the two phosphates were not very pronounced. The complete commercial fertilizer with the manure and lime had about the same influence on the crop yields as did the phosphates. In one or two cases slightly greater increases were secured while in other instances the yields were somewhat smaller. In no case, however, was there any large difference.

TABLE XXII. FIELD EXPERIMENT, O'NEILL LOAM, CLAY COUNTY
EVERLY FIELD, SERIES I

| Plot No. | Treatment | (1) 1918 Corn bu. per A. | 1919 Corn bu. per A. | (2) 1920 Oats bu. per A. | (3) 1921 Clover tons per A. | (4) 1922 Corn bu. per A. | (5) 1923 Corn bu. per A. | 1924 Oats bu. per A. | (6) 1925 Clover tons per A. | 1926 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 47.7 | 37.1 | 23.3 | 1.80 | 41.2 | 37.2 | 47.9 | 0.40 | 51.5 |
| 2 | Manure | 56.2 | 34.1 | 27.5 | 2.35 | 51.5 | 37.0 | 58.8 | 0.48 | 59.3 |
| 3 | Manure+lime | 56.4 | 38.0 | 28.9 | 2.60 | 53.1 | 42.3 | 66.7 | 0.47 | 65.4 |
| 4 | Manure+lime+rock phosphate | 56.0 | 40.3 | 33.6 | 2.94 | 53.3 | 41.7 | 66.1 | 0.57 | 62.7 |
| 5 | Manure+lime+acid phosphate | 59.2 | 39.0 | 32.6 | 3.28 | 54.7 | 39.2 | 71.5 | 0.65 | 62.4 |
| 6 | Manure+lime+complete commercial fertilizer | 55.4 | 40.9 | 30.9 | 2.97 | 55.4 | 38.3 | 69.3 | 0.64 | 62.7 |
| 7 | Check | 46.6 | 37.1 | 24.1 | 1.80 | 44.6 | 35.8 | 44.6 | 0.40 | 54.9 |
| 8 | Crop residues | 51.4 | 36.4 | 24.9 | 2.00 | 45.6 | 36.4 | 49.7 | 0.43 | 52.8 |
| 9 | Crop residues+lime | 54.1 | 37.0 | 24.4 | 2.22 | 44.5 | 38.7 | 64.8 | 0.36 | 56.3 |
| 10 | Crop residues+lime+rock phosphate | 57.0 | 37.3 | 28.2 | 3.20 | 51.5 | 38.8 | 56.2 | 0.41 | 57.7 |
| 11 | Crop residues+lime+acid phosphate | 56.2 | 35.1 | 30.6 | 3.13 | 51.9 | 41.3 | 62.1 | 0.56 | 62.7 |
| 12 | Crop residues+lime+complete commercial fertilizer | 57.6 | 37.9 | 26.8 | 3.00 | 51.7 | 37.3 | 54.1 | 0.41 | 60.8 |
| 13 | Check | 47.2 | 32.1 | 23.1 | 1.87 | 40.9 | 33.3 | 37.8 | 0.41 | 50.3 |

1. Three tons lime, fall 1917.
2. Poor stand.
3. First cutting only.
4. Dry summer reduced yield.
5. Dry summer reduced yield.
6. Very small crop due to dry weather.

The crop residues showed little effect on the crops grown in most seasons. Lime with the residues brought about increases in the yields in practically all cases. In some seasons very large effects were noted as on the clover in 1921 and on the oats in 1924. The rock phosphate with the residues and lime increased the crop yields in practically all cases. In several seasons the increases were not very large but in one or two cases considerable gains were noted, as on the clover in 1921. The acid phosphate with the residues and lime showed about the same effect on the crop yields as did the rock phosphate in most seasons. In one or two cases larger increases were secured from the acid phosphate, but in general the differences were not very pronouncd. The complete commercial fertilizer with the crop residues and lime showed no greater effects on the crop yields than did the acid phosphate. In fact in most instances slightly smaller crop yields were secured from the complete fertilizer.

The liberal application of manure is particularly recommended on this soil type as it is characterized by a sandy to gravelly subsoil condition and hence it has a tendency to be droughty. The soil is acid in reaction and will respond to the addition of lime. The application of a phosphate fertilizer is of considerable value on this soil and either rock phosphate or acid phosphate should be employed.

## PEAT SOILS

Peat is partially rotted vegetable matter, which consists either of swamp grasses, sedges, rushes and flags, or of a sphagnum moss, the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits only very incomplete decomposition. It is mainly in the level Wisconsin drift soil area that peat occurs in Iowa. Worth County is located in this soil area and has several peat areas, aggregating 5,696 acres or 2.2 percent of the area. There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out.* They are composed of fibrous, fairly dry vegetable matter, extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer, therefore, only to the shallow peats and are not at all applicable to deep peats.

The peat in Worth County is generally from 6 to 20 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Hence, practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

### FIELD EXPERIMENTS ON PEAT SOILS

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story

*Iowa Geological Survey 19: 168, 1908.

counties, respectively. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination in the amounts in which such materials are generally applied to soils. In no case was there any profitable increase in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and untreated soils were only such as might well occur between duplicate plots.

Recent tests, however, have shown profitable increases from the use of muriate of potash or acid phosphate on shallow peats. Sometimes the phosphate is the most effective. At other times the potash gives the best results. Tests of these two fertilizers on the peat soils in Worth County are recommended. Applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria and increase the speed of decomposition. In general, manure should not be used on peat soils, but should be utilized on land in greater need of organic matter and nitrogen.

### DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Worth County need mainly to make them productive is physical improvement thru drainage, cultivation and the growing of proper crops.

Drainage is the most important step. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential. The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case, the compacting of the peat would bring the tile too close to the surface and re-laying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is quite impervious. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will allow the ready passage of water into the drains.

Fall plowing is desirable in order to expose the peat soil to the action of the frost, rain and snow during the winter and hasten decay. Fall-plowed peats may be worked earlier in the spring, hence, the seed bed may be more thoroly prepared. Deep plowing is also valuable, especially when the peat is very shallow and some of the underlying, heavy clay, rich in phosphorus and potassium, may be mixed with the peat.

Iowa peat soils which are not over sixteen inches in depth should not be rolled, as such an operation may compact them too much and check decomposition. Where the peat is deeper than this, careful rolling may be valuable in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening decay of the organic matter.

Corn and small grain crops, as a rule, do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore, it is not advisable to seed these crops on peat soils until several years after their reclamation when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat and thus aids in its decomposition.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit the successful growth of corn and small grain crops. Frequently the application of acid phosphate or muriate of potash or both may be advisable, especially where truck crops are grown. Tests of these fertilizers are very desirable.

## "ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of "alkali" soils in Worth County and while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots while other crops are less affected.

These spots occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in detail in another publication.*

### TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained, but this does not mean that the drainage produces the "alkali" condition. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of "alkali" salts from the soil. In draining a slough or pond, lines of tile should be laid around the low area as well as thru the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be more rapid. The lines of tile may be brought together again below the slough and, if the area is rather wide, a third line of tile thru the center of the slough may be advisable.

If tile is properly laid when a pond or slough is drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully

*Bulletin 177, Iowa Agricultural Experiment Station—The Alkali Soils of Iowa.

developed, as is frequently the case in Worth County, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available in sufficient amounts. In other cases, green manures or straw may serve for the purpose, but where such materials are used a small application of manure should be made along with them, in order to hasten the decomposition processes, which in turn hasten the removal of the excess of salts.

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

The laboratory, greenhouse, and field experiments, which have been discussed in previous pages, give sufficient information so that certain general recommendations regarding the treatment needed by the soils of this county may be made. While the field tests reported have been carried out in other counties, they are located on the same soil types as those found extensively developed in Worth County and the results may be considered to indicate quite definitely, therefore, the effects which may be expected from the same fertilizer treatment in this county. The recommendations are also made upon the general experience of many farmers, and only those suggestions are offered which have been found to be of value by considerable practical experience. It should be emphasized that the recommendations made are such as can be put into effect under any particular farm condition.

In several instances it is urged that tests be carried out on the farm. Such tests as are referred to are simple and may be carried out quite generally. Fertilizer tests are now being carried out on many farms and the results which the farmers are securing are proving of considerable value to them and also to others who are located on the same soils. The Soils Section of the Iowa Agricultural Experiment Station will aid farmers who wish to carry out tests on their own soils. It is very desirable that the value of rock phosphate and acid phosphate be determined by tests on small areas before applications are made extensively. Similarly in the case of the complete commercial fertilizers, tests should be carried out on small areas in comparison with acid phosphate before applications are made to large areas. This is true also in the case of potassium fertilizers. Tests should be carried out along with acid phosphate using the potassium fertilizer in addition to acid phosphate in order to determine whether or not profitable crop increases will be secured.

### LIMING

Most of the surface soils in Worth County are acid in reaction. The exceptions include the Webster soils on the upland, the Benoit silt loam on the terraces, the Lamoure silt loam on the bottomland, and the Sogn silt loam on the residual upland areas. These soils show a lime content in the surface soil and, hence, they are not acid in reaction and not in need of lime. With the exception of these types, however, the soils of the county are acid and applications of lime should be made to remedy this condition if the best growth of general farm crops, particularly of legumes, is to be secured. In one or two cases lime is found in the lower soil layers, but the presence of lime in the subsoil will have little effect upon the lime requirement of the surface soil. Lime rarely moves upward in the soil and the presence of any carbonate in the subsoil will have little influence on the securing of a good stand of legumes if the surface soil is acid.

The amount of lime which is needed by the various soils which show acidity is extremely variable. The figures given earlier in this report merely indicate the needs of the particular samples, and should not be used as a basis upon which to make applications to these soil types. There is such a wide variation in lime requirement even in soils of the same type in different fields that lime should be applied to an area only after soil from that area has been tested and the actual lime requirement determined. Farmers may test their own soils for acidity and need of lime, but it will generally be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

The experiments which have been discussed earlier in this report have indicated the increases in crop yields which are secured from the application of lime to acid soils. All the types, therefore, except the Webster, Benoit, Lamoure and Sogn should be tested for lime needs and the amount shown to be necessary should be applied for the best growth of general farm crops, particularly of legumes.

It is suggested further that the soils should be tested for lime needs at least once in a four-year rotation and application should be made just preceding the legume crop of the rotation. Lime disappears rapidly from soils under continuous cultivation and it is important that the supply be replenished regularly if the soils are to remain most satisfactorily productive. Further information regarding the losses of lime from the soil, the requirements of certain crops, and other points connected with liming are given in the Extension Bulletin No. 105 of the Iowa Agricultural Extension Service.

## MANURING

The soils in Worth County are in general well supplied with organic matter. Some of the types, however, particularly those which are coarse or sandy in texture need applications of fertilizing materials supplying organic matter at the present time. On all the soils fertilizing materials must be used regularly if the supply of organic matter is to be kept up.

The application of farm manure has been found to be valuable on many of the soil types in this county. It is frequently the most profitable fertilizer which can be employed. The experiments which have been discussed earlier in this report have indicated the large crop increases which follow the application of farm manure. While the beneficial influence is evidenced particularly on the lighter colored sandy types, manure is of value also on those soils which are darker in color and apparently richer in organic matter. Even on those soils which are very high in organic matter, the use of small amounts of manure may be very desirable in order to stimulate the production of available plant food.

On such soils as the Webster types, the Clyde soils, the Floyd soils and the Bremer and Lamoure types, manure should not be applied preceding the small grain crop as it may cause the crop to lodge. Small amounts used on these soils at other points in the rotation, however, bring about very beneficial effects.

The value of manure has been shown particularly in the field and greenhouse experiments discussed earlier on the Carrington silt loam, the Carrington loam, the Clarion loam, some of the Webster soils and the O'Neill loam. The other types of the county would undoubtedly respond quite as well to applications of manure.

On many livestock farms there is an insufficient production of manure to supply all the soils on the farm. On the grain farms some other fertilizing material must be employed in place of farm manure. In both cases green manuring with leguminous crops is strongly recommended. When legumes are well inoculated they have the ability of utilizing the nitrogen of the atmosphere and hence when turned under as green manures in the soil, they will add considerable amounts of nitrogen. They serve therefore, a dual purpose in the soil supplying not only organic matter which is so necessary to fertility, but also increasing the supply of nitrogen. There are many cases where green manuring would undoubtedly be of value in Worth County.

The thoro utilization of all crop residues is of importance as an aid in maintaining the supply of organic matter in the soil. These materials should never be burned or otherwise destroyed as there is considerable loss of valuable constituents. On the livestock farm, they may be utilized for feed or bedding and returned to the land with the manure. On the grain farm they are often stored and allowed to decompose partially before application.

## THE USE OF COMMERCIAL FERTILIZERS

The supply of phosphorus in the soils of Worth County is not large and applications of phosphorus fertilizers will certainly be needed in the very near future. There is evidence, however, from the field and greenhouse experiments which have been carried out on some of the important types in the county that applications of a phosphate fertilizer might be of considerable value at the present time. The results secured in the tests on the Carrington silt loam, the Carrington loam, the Webster loam, the Webster clay loam, the Clarion loam, the O'Neill loam, and the Clyde silt loam, show very definitely that rock phosphate or acid phosphate may bring about very profitable returns when applied to these soils.

It is not yet possible to make definite recommendations regarding the relative value of rock phosphate and acid phosphate on these soils. In some of the experiments, the rock phosphate has given quite as satisfactory returns as the acid phosphate, but in other instances the acid phosphate has seemed preferable. Rock phosphate supplies the element phosphorus in an unavailable form and the fertilizer must be applied in rather large amounts. Acid phosphate is more expensive but supplies the phosphorus in an available form. Smaller applications of the acid phosphate are required. Farmers are urged to test the relative effects of these two phosphates on small areas on their own farms in order to determine which may be used with the greater profit. Comparisons should be made to determine the relative value of the crop increases secured from the applications with the cost of the fertilizer. That phosphate which proves the more economically profitable should be used. Simple field tests may be carried out on any farm using these two phosphates. Directions for such tests are given in circular 97 of the Iowa Agricultural Experiment Station.

The soils of this county do not show any striking deficiency in nitrogen and in most of the types there seems to be a rather considerable supply of this element. In a few cases the content of nitrogen is high. There is a constant removal of nitrogen from soils, however, thru continuous cultivation and any system of permanent fertility must provide for the regular return of nitrogen to the soils in order that the supply may be kept up. On those particular types where the content of nitrogen is not high at the present time it is particularly desirable that applications of some fertilizing material supplying nitrogen be made now.

Farm manure and leguminous green manures provide the cheapest and best means of supplying nitrogen to the land. When the manure produced on the livestock farm is carefully stored and applied to the soil, there is a considerable return of the nitrogen removed by the crops grown. When leguminous crops are well inoculated as they should be, they take a considerable amount of nitrogen from the atmosphere and, hence, when turned under in the soil as green manures, they increase the content of nitrogen in those soils. The proper application of farm manure and the turning under of leguminous crops as green manures will serve to build up and maintain the supply of nitrogen in the soils of this county. The proper utilization of crop residues will also aid in maintaining the nitrogen content of the soil.

The use of commercial nitrogenous fertilizers on the soils of this county will not be economically profitable at the present time inasmuch as nitrogen may be more cheaply supplied thru the proper use of farm manure and leguminous green manure crops. Small applications of commercial nitrogenous materials may, however, be made with profit as top dressings to stimulate the early growth of crops. Such fertilizers should not be applied extensively, however, until tests are made on a small scale on the farm in order to determine the profit from the application.

Many analyses of the soils occurring in the state have shown a high content of potassium and it does not seem probable that the use of potassium fertilizers is necessary on these soils at the present time. If there is an early and sufficiently rapid production of the element potassium in an available form, there is no need of a commercial potassium fertilizer. By keeping the soil in the best condition for crop growth, potassium should be made available rapidly enough to supply the needs of crops. Applications of muriate or sulphate of potash may prove profitable on some of the soils in this county, but before applications are made to any extensive areas, farmers should test the effects of the particular potassium fertilizer on a small area. If the results secured show a profitable effect from the application then the material can be applied to a larger area with the assurance of profit.

The complete commercial fertilizer tested in the field experiments, which have been discussed, did not seem to bring about any greater crop increases than the acid phosphate. The complete fertilizers are more expensive than acid phosphate and consequently their application does not seem as desirable unless they bring about very much larger crop increases. Other brands of complete fertilizers might of course, yield different results than those which have been discussed. It should be emphasized that tests should be carried out in comparison with acid phosphate in order to secure a definite idea of the actual profit from the application of a complete fertilizer.

## DRAINAGE

The drainage conditions in Worth County are in general satisfactory. There are areas, however, where artificial drainage is desirable and in some cases even necessary for the best crop growth. The map given earlier in this report shows the extent of the natural drainage system in the county and it will be noted that in many areas there is no evidence of natural drainage. On the level areas of the Clyde silt loam, the Webster soils and the Floyd silt loam on the uplands drainage is needed in order to provide for the most satisfactory crop yields. Most of the other upland types are fairly well drained. There are small areas, however, in some of these soils where tiling would be of value. Some of the terrace types are in need of draining, particularly the Bremer soils. Some of the bottomland types such as the soils of the Wabash and Lamoure series are poorly drained and for general farm crops the installation of tile would be of much value.

Wherever the soil is too wet, crop production is decreased considerably. Even if the expense involved in the installation of tile is considerable, the returns secured more than warrant the outlay. No other treatment will prove valuable on a soil which is too wet. The addition of fertilizers should not be made to a soil until it is well drained.

## THE ROTATION OF CROPS

One of the essentials for the permanent fertility of any soil is the proper rotation of crops. If one crop is grown continuously on land, the soil is rapidly depleted in fertility constituents and it becomes increasingly difficult to build it up again. Even if the crop grown continuously is a money crop, the value of all the crops produced on the area over a period of years will be greater when a rotation is practiced. The experiments which have been carried out comparing rotations with continuous cropping have indicated definitely the greater profit under the rotation system. Too much emphasis cannot be placed on the importance of adopting a proper rotation on every farm, and farmers should appreciate the fact that the growing of one crop continuously will make their land very rapidly decline in fertility and it will become more and more difficult to bring the soil into a high state of productivity.

No particular rotation experiments have been carried out in Worth County but there are many satisfactory rotations which can be used under various conditions. Some of these which have proven very satisfactory in the state are suggested here. In all the proposed rotations where clover is designated it is understood that the crop may be red or white, sweet or Hubam clover. Various modifications may be made as seems desirable in such rotations.

### 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 system)

### 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 and straw 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 sweet clover)
*Third year*—Sweet clover (The clover may be mixed clovers and used largely as pasture and green manure)
(This may be changed to a two-year rotation by plowing the sweet clover under the following spring for corn)

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

## THE PREVENTION OF EROSION

Erosion is the carrying away of the surface soil by the free movement of water over the land, known as sheet erosion or the washing away of the soil with the formation of gullies, gulches or ravines.

Erosion occurs to a very limited extent in Worth County. Only in the areas of the rolling phase of the Carrington loam and the rolling phase of the Clarion loam is there any erosion of significance. In most of the other types very little washing has occurred. Erosion occurs usually where the topography is undulating to rolling. Wherever serious washing of the land occurs and gullies are formed, it is very desirable that some means be taken to prevent the loss of fertility which occurs.

Various methods are followed for the control and prevention of erosion in Iowa. These methods differ somewhat depending upon the type of erosion. Erosion occurring due to "dead furrows" may be controlled by "plowing in", by "staking in," or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven wire dams, concrete dams. They may be prevented from occurring by thoro drainage or by the use of sod strips. Large gullies are similarly filled or prevented from occurring. Erosion in bottomlands is prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion is controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.*

## INDIVIDUAL SOIL TYPES IN WORTH COUNTY†

There are 24 individual soil types in the county and these with the rolling phase of the Carrington loam, the rolling phase of the Clarion loam, the deep phase of the O'Neill loam, the areas of muck and peat make a total of 29 soil areas. They are grouped into four groups according to their origin and location. These groups are known as drift soils, terrace soils, swamp and bottomland soils and residual soils.

### DRIFT SOILS

There are 15 drift soils in the county and with the rolling phase of the Carrington loam, the rolling phase of the Clarion loam, a total of 17 individual drift soil areas. They represent the Carrington, Clarion, Clyde, Webster, Lindley, Floyd, Dickinson, Pierce and Dodgeville soil series and together they cover more than three-fourths or 78.3 percent of the total area of the county.

#### CARRINGTON SILT LOAM (83)

The Carrington silt loam is the largest drift soil and the most extensively developed type. It covers 22.8 percent of the total area.

*See Bulletin 183. Soil Erosion in Iowa. Iowa Agricultural Experiment Station and Extension Service Bulletins 93, 94, 95, 96. Agricultural Extension Service, Iowa State College.

†The descriptions given in this section of the report very closely follow those in the Bureau of Soils report.

It is the most extensively developed upland soil in the eastern part of the county. Large areas of the type occur in Deer Creek, Barton and Union Townships, the three eastern townships. It is also extensively developed in Lincoln and Kensett Townships. Small areas of the type occur in Grove Township and in Danville Township.

The surface soil of the Carrington silt loam is a dark brown to dark grayish-brown silt loam extending to a depth of 12 to 15 inches. The upper subsoil to about 24 inches is a grayish-brown to brown heavy silt loam to silty clay loam. The lower subsoil to 36 inches is a yellowish-brown to yellow silt to silty clay or clay. Iron stains occur in the lower part of the soil section.

There are some variations from the typical soil as described. In a few areas in the southeastern part of the county the surface soil is not over 10 inches in depth, and the subsoil has a uniform buff color to the three foot depth. An area showing these characteristics is found at the cross roads three miles east of Manly. In some areas where the topography is relatively level the surface soil may be 16 to 17 inches in depth with a brown or yellowish-brown subsoil, mottled with yellow and brown in the lower part. In some places the lower subsoil is heavier than the typical. Natural drainage is sometimes deficient in these areas. In some locations the subsoil below 30 inches is a yellow sand which may extend to a depth of several feet or may be only a few inches or a foot in thickness. These areas are very small in extent and are included with the type as there is very little effect on the fertility of the soil.

In topography the Carrington silt loam varies from undulating to moderately rolling. The general topography is gently rolling. In the area along the county line in Danville Township, the topography is more pronounced, ranging from rolling to gently rolling. Here it is difficult to draw a boundary line between the silt loam and the loam and the lines are rather arbitrarily placed. The drainage conditions on the Carrington silt loam are usually good. On some areas where the subsoil is rather heavy there is need of tiling. Some small areas of Clyde silt loam have been included with the type as they could not be shown on the map. All these areas need to be tiled in order to produce satisfactory drainage conditions.

The major portion of the Carrington silt loam is under cultivation. Corn, oats, timothy and clover, some wheat and truck crops are the chief crops grown. Corn yields from 40 to 50 bushels per acre, and on some of the better areas the yields will range from 50 to 65 bushels per acre. Oats yield from 40 to 45 bushels per acre. Timothy and clover supplies the chief hay crop, yielding from one to three tons per acre. Some wild hay is grown with yields of from one to one and one-half tons per acre. Winter wheat is grown to a limited extent, yields ranging from 10 to 15 bushels per acre. The uncultivated portion of the type is taken up largely by ponds, sloughs, and permanent pasture. Some truck crops are grown on small areas on this type consisting chiefly of potatoes, onions, and cabbage. Trucking is not practiced extensively in the county but very satisfactory yields of these crops may be secured.

The needs of the Carrington silt loam to make it more productive include the installation of tile in all areas not properly drained at present. The experiments, which have been discussed earlier in this report, have indicated value from the application of farm manure to this soil and liberal applications of this fertilizing material should be made. Large increases in the yields of general farm crops will follow its use. The type is acid in reaction and the application of lime is very desirable for the best growth of leguminous crops and for the most satisfactory production of general farm crops.

The use of a phosphate fertilizer would be very desirable on this soil and tests have indicated the value of applications of acid phosphate or rock phosphate. Farmers are urged to test both phosphates under their own conditions and thus determine whether or not their soil will respond to a phosphorus fertilizer and which fertilizer will give them the more profitable returns. The use of a complete commercial fertilizer does not seem to be as desirable on this soil as the application of a phosphate carrier, at least as far as the comparative experiments would indicate. While the commercial fertilizers bring about quite as large increases in crop yields as acid phosphate, they are more expensive and, hence, would be less economically profitable. Tests of any complete commercial fertilizer should be carried out on the farm in comparison with acid phosphate on a small area before any general application is made.

A potassium fertilizer or a commercial nitrogenous fertilizer should not be used on this soil until tests have been carried out in the field and definite indications have been secured of profit from the use of the fertilizer. Where truck crops are grown, the use of complete commercial fertilizers is quite likely to be of value. The application of particular brands, which are made up for special crops will often bring about very large increases in the yields of the particular truck crops.

## CARRINGTON LOAM (1)

The Carrington loam is the second largest individual soil type and the second most extensively developed drift soil. Together with the rolling phase which is much smaller in extent, it covers 21.4 percent of the total area. This soil type is most extensively developed in the western central part of the county, and the largest development is found in Danville, Brookfield and Hartland Townships. There are areas of the type in practically all parts of the county except the eastern parts of the three eastern townships.

The surface soil of the Carrington loam is a dark brown to very dark brown mellow loam, extending to a depth of 12 inches. Below this point to a depth of 20 inches there is a lighter brown silty loam to silt loam containing some sand. The lower subsoil to 36 inches is a still lighter brown to yellow, heavy silt loam to silty clay or clay loam, containing some sand and rock or gravel. The subsoil varies somewhat in the content of sand and gravel, but the general texture is heavy. Boulders occur frequently on the surface of the soil and thru the soil section.

On some of the hills and slopes, the surface soil is somewhat thinner and lighter in color, while on the lower slopes the soil is deeper and more silty in texture. In some areas the subsoil is rather open and porous, but these are too small to show on the map. This particular variation from the typical soil occurred only in a narrow strip running north and south thru the west central part of the county, following a high ridge a couple miles east of Joice. In some areas there are small spots or "pot holes" made up of Clyde silt loam, muck, peat or a soil of the Webster series. They are too small to show on the map. They are naturally poorly drained and in some places are swampy.

In topography the Carrington loam is gently rolling to moderately rolling and the natural drainage system is good.

Most of the soil is under cultivation, corn, small grain, and hay being the chief crops grown. Corn yields from 30 to 60 bushels per acre, with an average of 45 bushels. Under favorable conditions it yields as high as 70 to 80 bushels per acre. The yields of hay, consisting chiefly of clover and timothy, are from one to two tons per acre.

While the Carrington loam is generally satisfactorily drained, there are small areas included within the type where artificial drainage is necessary. In these areas the installation of tile would be of large value. The type will respond profitably to applications of farm manure, and liberal amounts of this material should be applied. Where farm manure is not available for use, the turning under of leguminous crops as green manures would be of value. This type is acid in reaction and lime should be applied in order to secure the best growth of legume and general farm crops. The use of a phosphate fertilizer is very desirable and tests on individual farms of acid phosphate and rock phosphate are recommended. Experiments which have been carried out on this soil type have indicated large returns from the applications of manure, lime, and a phosphate fertilizer. In many cases acid phosphate has proven distinctly profitable while in other instances rock phosphate has proved quite as good. It is impossible at present to make a selection between these two phosphates and hence, farmers are urged to determine the response of their own particular soils to these two phosphate fertilizers. Complete commercial fertilizers will probably not be as desirable for general use on this soil as acid phosphate. However, tests of any complete brand may be carried out on the farm in comparison with acid phosphate and if profitable increases in crop yields are secured, then the complete fertilizer may be applied extensively to that soil type.

### CARRINGTON LOAM (ROLLING PHASE) (197)

The rolling phase of the Carrington loam is minor in importance, covering 3.7 percent of the total area. This phase of the typical soil occurs in areas of varying size thruout the central and western parts of the county, being developed chiefly in the vicinity of Silver Lake and extending northeast of the lake along the county line as far east as Goose Creek. It is developed also along Elk Creek east and a little south of Joice and northwest of Fertile.

The surface soil of the rolling phase of the Carrington loam consists of a dark brown loam extending to a depth of 8 to 12 inches. The subsoil is a brown loam to silt loam to a depth of 18 inches. Below this point, it becomes a yellowish-brown to yellowish silt loam to silty clay or clay to a depth of 36 inches. The lower subsoil contains considerable gritty material and occasionally rock fragments or gravel. On some of the ridges and slopes the surface soil is lighter colored and yellower than the typical. Some areas of this phase include small bodies of the typical Carrington loam which were too small to separate on the map.

As the name indicates, this phase of the typical Carrington loam has a strongly rolling topography and in some cases the topography is even broken. The natural drainage is good to excessive.

Most of the soil is under cultivation and general farm crops are grown. Corn yields from 25 to 50 bushels per acre. Oats yield 25 to 50 bushels per acre, the hay crop, one to two tons per acre.

This soil will respond to liberal applications of farm manure. Leguminous crops should be used as green manures in order to supplement the use of farm manure or as a substitute for that material. The building up of the soil in organic matter content is very desirable in order to improve its water-holding power and liberal additions of fertilizing material supplying organic matter will be of value. The type is acid in reaction and applications of lime are necessary for the best growth of legumes and general farm crops. The use of a phosphate fertilizer would be valuable on this type and applications of acid phosphate or rock phosphate are recommended. Farmers are urged to use both rock phosphate and acid phosphate in tests on their own soils in order to determine which will be the more profitable for general use. The use of a complete commercial fertilizer would probably be less desirable than the application of acid phosphate. The type is subject to considerable erosion and on the rougher to broken areas much washing has occurred. This is particularly true if the areas have been under cultivation. It is very important that in all those places where surface washing is occurring or where gullying has taken place, some means of prevention and control of erosion or the reclamation of gullied areas be adopted.

### CLARION LOAM (138)

The Clarion loam is the third largest soil type and the third most extensively developed drift soil. Together with rolling phase which is somewhat smaller in extent, it covers 14 percent of the total area of the county. It is the chief upland soil in the three western townships and is extensively developed in Bristol and Fertile Townships. Large areas also occur in Silver Lake Township. In the other townships to the east, there are small areas of the type but there is no extensive development except in the extreme western part of the county.

The surface soil of the Clarion loam is a dark brown to very dark brown mellow friable loam, extending to a depth of 12 to 14 inches. The upper subsoil is a brown loam or silty loam containing sand and extending to about 20 inches. Below this point there is yellowish-brown to yellow silt loam or silty clay having a slight grayish or whitish appearance and extending to a depth of 36 inches. The gray or white appearance of the lower subsoil is due to the presence of lime which occurs in considerable amounts in the lower layers of this soil type.

There is some variation from the typical soil in the areas adjoining the Carrington loam on the uplands to the east. Here the lime does not occur in sufficient quantities in the subsoil to effervesce when the soil is tested with acid. There are traces in the lower layers, however, sufficient to give it a whitish cast and thus distinguish it from the Carrington loam. In many places the location of the boundary line between the Clarion loam and the Carrington loam is fixed rather arbitrarily. There is often a gradual change from the one soil to the other.

In topography the Clarion loam is undulating to moderately rolling. The natural drainage is good. Only in a few swales or depressions is there need of tiling.

Most of the type is utilized for cultivated crops. Corn, oats, and hay are the chief crops grown. Corn yields from 40 to 60 bushels per acre, oats from 35 to 55 bushels and hay from one to two and one-half tons per acre.

This soil will respond to the same treatments recommended for the Carrington loam and in a very similar way. Applications of farm manure, lime and a phosphate fertilizer will certainly prove profitable. Tests of acid phosphate and rock phosphate are recommended on individual farms.

### CLARION LOAM (ROLLING PHASE) (150)

The rolling phase of the Clarion loam is smaller in extent than the typical soil but it is the fifth largest soil type, covering about 6 percent of the total area. It occurs only in the three western townships being closely associated with the typical Clarion loam on the uplands, in those townships. The largest developments of this phase are found in Silver Lake Township in the northwestern corner of the county and in Fertile Township in the southwestern part of the county.

The surface soil of the rolling phase of the Clarion loam is very similar to the typical soil, being a dark brown to a very dark brown loam. In many places, however, it is somewhat lighter colored than the typical soil and in general it is shallower in depth extending for only 10 to 12 inches. The subsoil is similar to that of the typical soil containing lime in varying amounts.

The topography of the phase is strongly rolling to broken. The natural drainage is good and in a few places is excessive.

A large part of the phase is used for general farm crops and yields are very much the same as on the rolling phase of the Carrington loam. Considerable areas of the type are in timber.

This soil will respond to the same treatments which were recommended for the rolling phase of the Carrington loam. Liberal applications of farm manure should be made. The addition of lime will prove of value and the application of a phosphate fertilizer, either acid phosphate or rock phosphate will prove profitable. Wherever erosion occurs the soil should be protected from further action and the gullied areas should be reclaimed.

### CLYDE SILT LOAM (84)

The Clyde silt loam is the fourth largest soil type, covering 7.6 percent of the total area. It is developed in a number of areas, varying widely in size, in the eastern part of the county in association with the Carrington silt loam on the uplands. The largest areas on the type are found in the central portions of Deer Creek and Barton Townships. Numerous small areas of the type occur in other parts of these townships and in the other eastern townships, Union, Lincoln, Kensett, and Grove. Only a few small areas of the type are found west of the central line of the county.

The surface soil of the Clyde silt loam is a very dark grayish-brown to nearly black silt loam, extending to a depth of 16 inches. The upper subsoil to 24 inches is a drab or gray silty clay to clay loam somewhat stained with iron. The lower subsoil is a mottled gray, brown and yellow clay loam to heavy clay loam or clay containing some sand and gravel. Boulders are occasionally found on the surface and thru the soil section.

Numerous variations from the typical soil are found. In many places the lower subsoil contains considerable sand to a depth of 30 inches. A few areas mapped with the type are really a silty clay loam but they were too small to warrant separation on the map. In an area about one-eighth of a mile east of the southwest corner of Section 10 of Barton Township, the surface soil is a dark brown loam 12 inches in depth, overlying a grayish-brown loam slightly mottled. At 20 inches it changes into a sandy loam or sandy clay, yellow in color. In another area in the southwest quarter of Section 9 of Grove Township, the surface soil is a loam in texture. In some of the more poorly drained areas of the type, water stands on the soil for a long period of time, and the surface soil is somewhat mucky in spots to a depth of 1 to 3 inches.

In topography the Clyde silt loam is flat to depressed. The natural drainage is deficient.

The greater part of the type is in need of artificial drainage if the crop yields are to be satisfactory. When undrained, this land is utilizable only for the production of wild hay or for grazing. General farm crops are grown on the well-drained cultivated areas and yields of corn may be as high as 50 bushels per acre.

The first treatment needed for the Clyde silt loam to make it more productive is the installation of tile. When thoro drainage is accomplished, the soil will respond to applications of farm manure in order to stimulate the production of available plant food. The type is acid in reaction and applications of lime will prove of value. The use of a phosphate fertilizer is strongly recommended, and tests of acid phosphate and rock phosphate should be carried out under individual farm conditions. The experiments which have been conducted in the field on this soil type have indicated the value of applications of manure, lime, and a phosphate fertilizer.

## WEBSTER SILT LOAM (113)

The Webster silt loam is the fifth largest drift soil, covering 3.0 percent of the total area. It is developed in many small areas in the western townships. The largest development of the type is found in Hartland and Brookfield Townships. Small areas of this type are also found scattered thru the other western townships. There are no large individual areas of the type. The largest area is found just south of Tenold.

The surface soil of the Webster silt loam is a black or nearly black silt loam, extending to a depth of 15 inches. The upper subsoil to a depth of 24 inches is a drab or gray clay loam. The lower subsoil is a gray, brown, and yellow mottled clay loam to clay, containing iron stains and sufficient lime to cause effervescence with acid.

In a few areas there are a variation from the typical soil. Sometimes the subsoil does not show the typical mottled gray or drab color. Occasionally the surface soil shows a small content of sand but not enough to change the texture. Very small depressions, heavier in texture than the silt loam, are included with the type as they are too small to show on the map. In some places the subsoil contains small gravel, and in some spots it may be a sandy clay or brown sand below 30 inches.

In topography the Webster silt loam is flat to depressed. The natural drainage is deficient.

Most of the type is under cultivation altho there are some areas still in virgin sod. The general farm crops grown are corn, yielding from 40 to 70 bushels per acre, oats 40 to 60 bushels, and hay 1½ to 3 tons per acre.

The needs of this soil to make it more satisfactorily productive include first of all adequate drainage. When the land is thoroly tiled out, the yields of general farm crops will ordinarily be quite satisfactory. Small applications of farm manure would be of value on this type to stimulate the production of available plant food. Large amounts of manure should not be applied, however, and the manure should not be applied preceding the growing of a small grain crop. The use of a phosphate fertilizer would be of value on this soil and tests of acid phosphate and rock phosphate are recommended. The experiments which have been carried out on the soil have indicated the value of applications of manure and the phosphate fertilizers. In general, the surface soil of the type is high in lime and additions of lime are unnecessary. If the soil is tested and shown to be acid in the surface soil, then the use of lime will be of value for the best growth of leguminous crops.

## LINDLEY LOAM (65)

The Lindley loam is the sixth largest drift soil, covering 2.8 percent of the total area. It is extensively developed in the central part of the county in Brookfield and Hartland Townships. There is a large development of the type on the eastern edge of these townships and extending over the township lines. Small areas of the type are also found to the west.

The surface soil of the Lindley loam is a grayish-brown to brown loam, extending to a depth of 8 to 10 inches. The upper subsoil is a yellowish-brown or gray silty layer extending to 18 to 20 inches. Here the subsoil becomes a yellowish-brown to yellow silty clay to clay loam, having considerable gritty material and some rock fragments.

In topography the Lindley loam is rolling to rough or broken. Most of the type has the typical rolling topography. Natural drainage is good.

Much of the soil has been cleared and brought under cultivation. General farm crops are grown on the cultivated areas and the yields are very much the same as those secured on the Lindley silt loam. The yields are lower on these types than those secured on the Carrington and the Clarion soils on the uplands.

This soil will respond profitably to proper fertilizer applications for the growth of general farm crops. The liberal application of farm manure is very desirable. Large increases in farm crops will be secured from the use of manure. The type is acid in reaction and applications of lime are of value. The use of a phosphate fertilizer would be of value on this soil and tests of acid phosphate and rock phosphate are recommended. Probably acid phosphate would be of more value at the present time because of the low organic matter content of the soil.

The soil is subject to considerable injury thru erosion and the washing away of the surface soil and the formation of gullies, and it is very important that it be protected from this destructive action. The rougher areas should undoubtedly be left in forest or pasture. On the cultivated areas the incorporation of organic matter with the soil will protect it from serious washing and some means must be taken to prevent further washing and the formation of gulies and to reclaim areas which are already gullied.

### FLOYD SILT LOAM (198)

The Floyd silt loam is the seventh largest drift soil, covering 1.9 percent of the total area. It is found in a number of areas varying widely in size, in the eastern part of the county, being developed mainly in Deer Creek and Barton Townships. Areas are also found, however, in the other eastern townships. The largest areas of the type occur in the central sections of Deer Creek Township northeast of Bolan and southeast of Grafton. Many other areas of the type somewhat smaller in extent are found on the upland in association with the Carrington silt loam and the Clyde silt loam.

The surface soil of the Floyd silt loam is a very dark brown to black smooth silt loam, extending to a depth of about 16 inches. The upper subsoil extending to a depth of 24 inches is a grayish-yellow or gray silty clay to clay loam, frequently stained with iron. The lower subsoil is a yellowish-brown to yellow silty clay to clay loam mottled with yellow and brown and stained with iron. Glacial pebbles commonly occur in the subsoil and occasionally boulders are found.

There are some variations from the typical soil and a few sand pockets occur just below 30 inches but they are not extensive and are of little significance from the standpoint of productivity of the soil. The topography of the Floyd silt loam is flat to sloping. The natural drainage is deficient.

Practically all of the soil is under cultivation. General farm crops are grown, corn yielding 40 to 65 bushels, oats 40 to 60 bushels per acre, and clover and timothy hay 1¾ to 2½ tons per acre.

The chief needs of the Floyd silt loam to make it more productive are adequate drainage and the application of manure and lime and a phosphate fertilizer. The type should be thoroly drained before satisfactory crop yields can be secured. The application of manure will be of value in improving the physical condition and making the type more productive. It is acid in reaction and the use of lime is necessary for best growth of legumes and general farm crops. The use of a phosphate fertilizer would undoubtedly be of value on this soil and tests of rock phosphate and acid phosphate are recommended.

### WEBSTER LOAM (55)

The Webster loam is the eighth largest drift soil, covering 1.3 percent of the total area. It occurs in a number of small areas thruout the western townships and in one area in Deer Creek Township. There are no large individual areas of the type. The largest developments are found south of Silver Lake in Hartland Township, and in the southwestern section of Brookfield Township. Many small areas of the type occur thruout the upland in the level to depressed areas in the western part of the county in association with the Clarion and Carrington soils.

The surface soil of the Webster loam is a black to very dark grayish-brown or nearly black loam, extending to a depth of about 15 inches. The upper subsoil is a drab or gray silt loam or heavy silt loam to about 22 inches. The lower subsoil is a mottled gray, brown, and yellow silty clay to clay stained with iron. Pebbles and fragments of lime and other rock occur thru the soil section and in some places on the surface. The lower subsoil contains sufficient lime to effervesce with acid.

There are some variations from the typical soil but in general it is quite uniform. In the depressions, the soil is generally more silty.

In topography the Webster loam varies from flat to gently undulating. Some of the areas have a depressed topography. In some places it seems to occupy areas where formerly there were sluggish streams. The natural drainage of the type is poor and tiling out of these areas is very necessary if satisfactory crop yields are to be secured. Much of the Webster loam has been drained and brought under cultivation and general farm crops are produced. Yields are very much the same as those secured on the Webster silt loam.

Large increases in crop yields may be secured on drained areas of the type thru the application of farm manure and the addition of a phosphate fertilizer. Small amounts of manure will give large returns. The manure should not be applied preceding the growing of small grain crops, however, as it may cause the crops to lodge. The application of a phosphate fertilizer will be of large value on this soil and tests of acid phosphate and rock phosphate are recommended. The soil is usually high in lime content, and therefore, it is not in need of applications of lime. If the surface soil is acid, however, as sometimes is the case, the addition of lime may be of value in providing suitable conditions for the early growth of leguminous crops.

## DICKINSON SANDY LOAM (199)

The Dickinson sandy loam is a minor type, covering only 0.9 percent of the total area. It occurs in a number of small areas scattered thruout the eastern and central townships. The largest developments of the type are found in the northwestern sections of Barton Township, north of Northwood, extending almost to the county line in Grove Township, northwest of Northwood along the Shellrock River, extending to the county line in Hartland Township. Many other small areas of the type are found developed in various parts of the central townships.

The surface soil of the Dickinson sandy loam is a dark brown to dark grayish-brown sandy loam, extending to a depth of about 10 inches. This is underlaid by a brown sandy loam to loamy sand to a depth of 24 inches. The lower subsoil consists of a brown or yellow fine sand.

In topography of the Dickinson sandy loam is gently rolling to rolling. The natural drainage of the type is excessive.

General farm crops are grown on this soil. The yields, however, are low, being slightly lower even than those secured on the Dickinson loam.

The type will respond very profitably to applications of farm manure and the turning under of leguminous crops as green manures. The building up of the organic matter content of the soils is very necessary if satisfactory crop yields are to be secured. The type is acid in reaction and will respond to additions of lime, especially for the best growth of legumes. The incorporation of organic matter with the soil will reduce the danger of injury to crops in dry seasons. The application of a phosphate fertilizer would undoubtedly be of value on this soil and tests of acid phosphate are recommended. It would seem that acid phosphate would be preferable for use on this soil because of the low organic matter content.

### DICKINSON LOAM (174)

The Dickinson loam is a minor type, covering 0.7 percent of the total area. It is found in a number of areas of limited size in various parts of the county, the largest developments of the type occurring in Bristol Township, north and west of Bristol, and in the northwest sections of Brookfield Township. Other small areas of the type are found in other parts of the county.

The surface soil of the Dickinson loam is a dark brown to very dark brown friable loam, extending to a depth of 12 to 13 inches. The upper subsoil is a brown or yellowish-brown loam or silty loam to a depth of 20 to 24 inches. The lower subsoil is somewhat variable and may consist of sand or gravel or of a mixture. The two largest areas of the type which have been mentioned have a gravelly subsoil and the rest of the areas of the type in the county show a sandy subsoil condition.

In topography the Dickinson loam is undulating to gently rolling and in a few places rolling. The natural drainage is good to excessive.

A large part of the type is under cultivation and general farm crops are grown. The uncultivated areas support a growth of wild grasses, and are used for wild hay or pasture land. Crop yields on the cultivated areas are variable depending on the treatment and moisture supply. In favorable years corn yields 30 to 45 bushels, oats 30 to 40 bushels and hay 1 to 2 tons per acre. In dry seasons, the yields are very much lower.

This soil will respond profitably to applications of fertilizing materials supplying organic matter. Liberal additions of farm manure should be made and leguminous crops should be turned under as green manures in order to build up the organic matter supply. The crops will be less in danger in periods of dry weather when the organic matter content of the soil is increased. The type is acid in reaction and applications of lime would be of value in order to secure the best growth of leguminous crops. The addition of a phosphate fertilizer would undoubtedly be of value and tests of acid phosphate are recommended. Acid phosphate is undoubtedly preferable for use on this soil because of the low organic matter content.

### LINDLEY SILT LOAM (32)

The Lindley silt loam is a minor type, covering only 0.5 percent of the total area. It occurs in numerous small areas in various parts of the county, being developed chiefly in the central townships along the Shellrock River. There are no large individual areas of the type. Small scattered areas are found in various parts of the county.

The surface soil of the Lindley silt loam is a grayish-brown or brown, somewhat ashy or flour-like silt loam, extending to a depth of about 10 inches. The subsoil is a grayish-brown or yellow smooth silt loam grading at about 18 inches into a yellowish-brown heavy silty clay to clay, usually showing some mottling. In some places, the subsoil is solid in color, while in other areas there is a good deal of mottling in the lower subsoil. Glacial pebbles and rock fragments occur at the lower depths. Iron stains are frequently found. In the lower subsoil the material is a firm, sticky, gritty clay containing some sand. In the forested areas the surface soil, one to three inches in depth, has a dark brown color. Below the color is lighter. The upper subsoil is somewhat variable being grayish in places. Where the type occurs in swales and draws, the surface soil is darker colored than the typical.

In topography the Lindley silt loam is undulating to gently rolling or in some instances rolling. The natural drainage is good, but not excessive.

Most of the type is under cultivation, general farm crops being grown. Corn yields from 38 to 40 bushels per acre, oats 25 to 45 bushels per acre, hay one to two tons per acre.

Crop yields on this soil type may be improved considerably thru proper applications of manure, lime, and a phosphate fertilizer. The soil is particularly in need of organic matter and liberal applications of farm manure should be made. The turning under of leguminous crops as green manures would also aid in building up the organic matter content of the soil. The type is acid in reaction and lime would be of value for the best growth of leguminous crops. The application of a phosphate fertilizer would undoubtedly prove profitable and tests of acid phosphate are recommended. Owing to the low content of organic matter, the use of acid phosphate would probably be more desirable on this soil than rock phosphate.

### PIERCE SANDY LOAM (191)

The Pierce sandy loam is a minor type, covering only 0.4 percent of the total area. It occurs most often in kames and eskers in long, narrow or round, knob-like formations, rising 15 to 30 feet above the surrounding surface. The type is mapped along Elk Creek, along Beaver Creek west of Fertile, and in a few isolated bodies in the western and north central parts of the county.

The surface soil of the Pierce sandy loam is a brown to dark brown sandy loam, extending to a depth of 6 to 8 inches. The subsoil to 36 inches is variable containing all grades of sand, gravel, and rock with practically no clay or silt. The surface soil varies somewhat, ranging from a loamy sand to a sand.

This type is of practically no value for cultivated crops. The only utilization is for pasture land and it supports only a very poor growth of wild grasses. The chief use made of it, when accessible, is as a source of road building material.

### CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is a minor type, covering only 0.4 percent of the total area. It occurs in only a few small areas. The largest development of the type is in the Sections 7, 8, 17, and 18 of Barton Township, north of Bolan. Many of the small areas of the type occur thruout the central townships and in Fertile and Brookfield Townships.

The surface soil of the Carrington sandy loam is a dark brown sandy loam, 10 inches in depth. The subsoil is a brown to yellowish-brown sandy loam to 20 inches. The lower subsoil to 36 inches is a yellowish-brown to yellow sandy loam to sandy clay or clayey sand. In some places where the topography is more rolling, the surface soil contains less organic matter and is a brown or grayish-brown in color.

In topography the Carrington sandy loam is gently rolling to rolling and natural drainage is good to excessive.

The type is all under cultivation and general farm crops are grown. The yields, however, are lower than those secured on the adjacent upland soils of the Carrington series.

The soil is in need of organic matter to be made more productive. Liberal applications of farm manure and the turning under of leguminous crops as green manure would be of large value. The type is acid and the addition of lime would aid in securing the best growth of leguminous crops. The use of a phosphate fertilizer is desirable on the soil and tests of acid phosphate are recommended.

### WEBSTER CLAY LOAM (56)

The Webster clay loam is a minor type, covering only 0.3 percent of the total area. It is found in a number of small areas, chiefly in the central western townships. Small areas are found, however, in other parts of the county.

The surface soil of the Webster clay loam is a very dark grayish-brown to black clay loam, extending to a depth of 15 to 18 inches. The subsoil is a drab or gray clay loam stained with iron, grading at about 24 inches into a gray and brown or yellow mottled clay containing lime in sufficient quantities to effervesce with acid.

In topography the Webster clay loam is flat to depressed and the natural drainage is poor. Tiling is necessary if the land is to be cultivated. When well-drained, this soil is productive and satisfactory yields of general farm crops will be secured. The yields are much the same in drained areas as those secured on the Webster loam and Webster silt loam areas. This soil needs first of all, thoro drainage if it is to be cultivated. When this is accomplished, yields of general farm crops will be very good. Small applications of farm manure would be of value on newly drained areas and would stimulate the production of available plant food. The manure should not be applied, however, preceding the growing of a small grain crop as it may cause the crop to lodge. The type is well supplied with lime in general and is not in need of additions. If the surface soil is found to be acid, however, the use of lime may be of value in securing a good early growth of legumes. The turning under of leguminous crops as green manure would also be of value. The use of a phosphate fertilizer on this type would undoubtedly be profitable and tests of rock phosphate and acid phosphate are recommended.

In some of the low spots of this type, there may be so-called "alkali" accumulations. These are evidenced by the appearance of a whitish powder on the surface of the soil in periods of dry weather. These areas may be reclaimed by being properly tiled out and supplied with fresh horse manure or with green manure. By these treatments the excess of alkali salt may be readily removed from the soil.

### DODGEVILLE SILT LOAM (204)

The Dodgeville silt loam is a minor type, covering only 0.3 percent of the total area. It is developed only along the Shellrock River in the south central township, the largest developments of the type being along the river and north of Kensett, southeast of Kensett, and almost on the county line south and east of Manly.

The surface soil of the Dodgeville silt loam is a very dark brown silt loam, extending to a depth of 10 to 14 inches. The upper subsoil to 24 inches is a brownish silt loam somewhat heavier than the surface soil but still a silt loam in texture. The lower subsoil is a yellowish-brown silt loam to heavy silt loam or silty clay. Limestone bedrock is encountered at depths varying from 20 inches to 8 or 9 feet. There is generally a layer of soil material an inch or two in thickness immediately above the bedrock and this is a heavy waxy clay slightly mottled brown in color.

In topography the Dodgeville silt loam is gently rolling and natural drainage is good.

In the areas where the bedrock does not occur close to the surface, the soil is used for general farm crops. The yields are very much the same as those secured on the Carrington silt loam. In the areas where the surface soil is very shallow, the type has little agricultural value.

In order to secure better crop yields on this soil, applications of farm manure should be made. Leguminous crops turned under as green manures would also increase the productivity. The type is acid in reaction and additions of lime would aid in securing the best growth of legumes. The use of a phosphate fertilizer is recommended and tests of acid phosphate and rock phosphate should be carried out on this soil.

## TERRACE SOILS

There are five terrace types in this county classified in the O'Neill, Benoit, Bremer and Waukesha series and these with the deep phase of the O'Neill loam make six separate soil areas.

### O'NEILL LOAM (108)

The O'Neill loam is the second largest terrace soil, being somewhat less extensively developed than the deep phase of the same type. Together the two make up 7.5 percent of the total area. It occurs on the terraces along most of the streams of the county. The largest developments of the type are found along the Shellrock River, Elk and Beaver Creeks. In the vicinity of Northwood there is a large individual area surrounding the city and extending south on the terraces along the Shellrock River to the junction of that river with Elk Creek.

The surface soil of the O'Neill loam is a dark brown friable loam to a depth of 12 inches. Below this to a depth of 18 to 24 inches, there is a brown loam to sandy loam or loamy sand. The lower subsoil consists of sand and gravel.

In topography the O'Neill loam is flat, sloping or gently undulating. It lies 10 to 20 feet above present overflow. Natural drainage is good to excessive. Crops are in need of moisture in dry seasons.

The soil is used for cultivated crops and in good seasons corn yields 30 to 45 bushels, oats 20 to 40 bushels and hay three-fourths to one and one-half tons per acre. In dry seasons the yields are very much lower.

This soil is particularly in need of additions of organic matter in order to be made more satisfactorily productive. Liberal applications of farm manure should be made, and leguminous crops should be turned under as green manures in order to build up the supply of organic matter and make the soil more resistant to drought. The type is acid in reaction and will respond to additions of lime especially for the best growth of legumes. The application of a phosphate fertilizer would undoubtedly be of value on this soil and tests of acid phosphate and rock phosphate are recommended. Probably acid phosphate would be of more value at the present time because of the low organic matter content of the soil. The use of a complete fertilizer would probably be of less value than the application of acid phosphate owing to the greater cost of the complete material.

### O'NEILL LOAM (DEEP PHASE) (200)

The deep phase of O'Neill loam is somewhat more extensively developed than the typical soil. Together with the typical O'Neill loam, it covers 7.5 percent of the total area. It is the most extensive terrace soil in the county, being developed principally along the larger creeks and along the Shellrock River. The most extensive developments of the type are found south and west of Northwood and east of the city and extending south on both sides of the Shellrock River and on both sides of Elk Creek. It is also found rather extensively developed in areas in the southwestern part of the county along Beaver Creek.

The surface soil of the deep phase of the O'Neill loam is a dark brown to very dark brown, mellow, friable loam 12 inches or 13 inches in depth. The subsoil is a brown to yellowish-brown or yellow silty loam to silt loam or heavy silt loam becoming more sandy at about 30 inches. Below that point, there is a coarse sand or fine gravel subsoil. There is some variation in the soil in two areas, one in Section 29 of Deer Creek Township and the other comprising parts of Sections 13 and 24 of Lincoln Township and 18 and 19 of Union Township. In these areas the surface soil is a silt loam. Occasionally the silty character of the subsoil continues to a greater depth, and the sand or gravel layer is not encountered above 33 to 36 inches.

In topography the deep phase of the O'Neill loam is flat or sloping. It lies on terraces 5 to 20 feet above overflow. Drainage is good and in places excessive.

Most of the type is cultivated and yields of general farm crops are quite satisfactory in favorable seasons. Corn yields 35 to 55 bushels per acre, oats 35 to 50 bushels, and clover 1 to 2 tons per acre.

This soil will respond to the same treatments which have been recommended for the typical O'Neill loam. Liberal applications of farm manure are of large value on the soil. The turning under of leguminous crops as green manures would be of profit. The soil is acid in reaction and the application of lime would be of value for the best growth of legumes. The use of a phosphate fertilizer should be recommended and tests of rock phosphate and acid phosphate should be carried out under individual farm conditions. Probably acid phosphate would prove more profitable for general use than rock phosphate owing to the low organic matter content of the soil.

## BENOIT SILT LOAM (201)

The Benoit silt loam is the second largest terrace soil, covering 1.5 percent of the total area. It occurs on the terraces along the Shellrock River chiefly in the vicinity of Northwood, the largest areas of the type being east of Northwood and southeast of the city. Small areas of the type are found in other parts of the county limited, however, to the north central townships.

The surface soil of the Benoit silt loam is a black or nearly black silt loam 10 to 15 inches in depth. The upper subsoil to a depth of 24 to 26 inches is a gray or drab silty clay to clay. The lower subsoil is a coarse sand or gravelly sand. In places the sandy subsoil ranges in thickness from 12 inches to 3 feet with clay below. In places the surface soil contains an excess of so-called "alkali" salts. As a rule the subsoil does not contain sufficient lime to effervesce with acid. Exceptions to this are found in the area two miles northeast of Northwood and in Hartland and Kensett Townships where the subsurface layer as well as the subsoil is high in lime.

In topography the Benoit silt loam is flat. Natural drainage is poor in spite of the sandy character of the lower subsoil, and tiling is generally necessary to secure the best crop yields.

Part of the type is under cultivation, a considerable part remaining in native grasses and utilized for pasture or hay land. Crop yields are quite variable. Corn yields from 25 to 60 bushels per acre, oats from 30 to 60 bushels, and clover hay from 1 to 2 tons or more per acre.

This soil will respond to liberal applications of manure. When it is acid in reaction, the use of lime is desirable in order to insure the best crop of legumes. The addition of a phosphate fertilizer would be of value and tests of acid phosphate and rock phosphate are recommended. Drainage is necessary as the first treatment in order to make this soil most satisfactorily productive. Where alkali spots occur in the type, the drainage of the areas and the incorporation of fresh horse manure are the most desirable treatments in order to reclaim the areas.

## BREMER SILT LOAM (88)

The Bremer silt loam is the third largest terrace type, covering 1.4 percent of the total area. It occurs in a number of areas in various parts of the county, being developed chiefly along the Shellrock River, Deer Creek and some of the tributary streams. The largest areas of the type are found on the terraces near the junction of Elk Creek with Shellrock River, southeast of Northwood, east of the Shellrock River, and along Deer Creek in the extreme eastern part of the county.

The surface soil of the Bremer silt loam is a dark brown or nearly black smooth silt loam, extending to a depth of 15 inches. The subsoil is a drab or gray silty clay containing stains of iron to a depth of 24 inches. The lower subsoil is a gray clay loam or clay, mottled with gray, brown and yellow.

There are many variations from the typical soil. In some areas, sand occurs below depths of 33 to 35 inches. Such areas are found in parts of Sections 35 and 36 of Deer Creek Township, and in parts of Sections 14 and 15 of Kensett Township. In the west half of Section 31 of Danville Township, the surface soil is calcareous and somewhat lighter in color than the typical surface soil, and this chalk like layer of calcareous material appears at about 35 inches. The surface here has numerous hummocks and the area lies at higher elevations than the surrounding bottomlands. An area occurring in the west half of Section 13 of Lincoln Township varies from the typical in that the subsoil is mottled brown and yellow below a gray upper subsoil. In the west half of Section 1 and the northeast quarter of Section 2 of Barton Township, the type has a grayish silt loam surface soil with a mottled ashy gray or grayish-brown and gray subsoil of stiff waxy clay.

The topography of the Bremer silt loam is flat or sloping. The natural drainage is deficient to fair. Most of the type is under cultivation and general farm crops are grown. Corn yields 40 to 60 bushels per acre, oats 45 to 60 bushels, clover hay 1½ to 2½ tons.

The first need of this soil is the installation of tile. When this is accomplished, small applications of farm manure would be of value to stimulate the production of available plant food. Farm manure should not be applied to this soil, however, in large amounts nor should it be added just preceding the growing of a small grain crop as it may cause the grain to lodge. The type is acid in reaction and will respond to additions of lime for the best growth of legumes. The use of a phosphate fertilizer would be valuable on the soil and tests of rock phosphate and acid phosphate are recommended.

### WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the fourth largest terrace soil, covering 1.1 percent of the total area. It is found in numerous small areas along the Shellrock River, Elk Creek, Deer Creek and Beaver Creek. The largest development of the type is along Elk Creek just north and west of Kensett. Further considerable developments of the type are found south of Northwood along Shellrock River and north of Northwood extending to the county line.

The surface soil of the Waukesha silt loam is a dark brown to very dark brown smooth silt loam to a depth of 12 to 14 inches. The upper subsoil is a brown smooth silt loam to a depth of about 20 inches. The lower subsoil is a yellowish-brown to yellow heavy silt loam to clay loam or silty clay, compact but not impervious. The surface soil in places is more nearly a loam than a silt loam. In Section 10 of Kensett Township the surface soil is a loam. The area in Section 12 of Lincoln Township is a loam in the surface soil. The subsoil is a brownish loam.

In topography the Waukesha silt loam is flat or sloping. The drainage is good. It occurs on terraces 5 to 20 feet above overflow.

The type is used for the production of general farm crops and quite satisfactory crop yields are secured. Corn yields 30 to 60 bushels per acre, oats 35 to 55 bushels per acre, and clover hay 1 to 2½ tons per acre.

This soil will respond profitably to applications of farm manure in order to make it more productive, and liberal amounts of this material should be applied. The turning under of leguminous crops as green manures would be of value. The soil is acid and additions of lime would improve the fertility conditions.

The application of a phosphate fertilizer would bring satisfactory results and tests of rock phosphate and acid phosphate are recommended.

### O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a minor terrace type, covering only 0.4 percent of the total area. It occurs in a number of small areas on the terraces along the Shellrock River and Beaver Creek. There is no large development of the type. Most of the areas are found along Beaver Creek, east of Fertile.

The surface soil of the O'Neill sandy loam is a brown to dark brown sandy loam 12 inches in depth. Below this, the subsoil is a brown sandy loam to loamy sand to a depth of about 20 inches, at that point grading into a yellowish-brown to yellow sand. In some places the surface soil is a brown rather sandy loam, containing patches of a loamy sand.

In topography the O'Neill sandy loam is flat or gently undulating. Natural drainage is good to excessive. Crops suffer for moisture in dry seasons.

General farm crops are grown on the soil, corn yielding 15 to 30 bushels per acre, oats about the same, and hay ½ to 1 ton. In dry seasons the yields are very poor.

This soil will respond to additions of fertilizing materials supplying organic matter. The building up of organic matter is very necessary if satisfactory crop yields are to be secured. Liberal applications of farm manure should be made and legumionus crops should be turned under as green manures in order to secure better crop yields on this type. It is acid in reaction and additions of lime would be of value in order to secure the best yields of legume crops. The application of a phosphate fertilizer would undoubtedly be profitable on this soil and tests of acid phosphate are recommended. The acid phosphate would undoubtedly be more preferable than rock phosphate because of the low organic matter content of the soil.

## SWAMP AND BOTTOMLAND SOILS

There are three swamp and bottomland soil types in the county classified in the Wabash, Lamoure and Cass series. These with the areas of muck and peat make a total of five bottomland areas.

### MUCK (21a)

Muck is the most extensive bottomland type, covering 2.8 percent of the total area. It occurs in many areas, chiefly in the western part of the county, west of the Shellrock River. These areas are found in depressions or intermittent drainageways or along the streams. Rather extensive areas occur west of the Shellrock River, along Elk Creek in the southwestern part of the county north of Hanlontown, and in the northwestern corner of the county.

Muck is derived from peat representing the same material in a further stage of decomposition. It is black in color, smooth in texture, being light and fluffy, containing no evidence of the original form of the plants from which it was derived. It varies from 8 to 10 inches to 4 or 5 feet in depth. Most of it, however, will come within a range of 18 to 26 inches in depth. The underlying material is generally a black silty clay which may extend for a considerable depth or may change into a gray or yellowish or mottled gray, brown and yellow clay loam or clay. In topography areas of muck are nearly always flat. They are not smooth, however, and may be hummocky like peat. Much of it is poorly drained and under water in wet seasons of the year. Many areas have been tiled and in such cases drainage is well established.

Proper drainage is the first requirement for the reclamation of muck areas. When this has been accomplished, it is usually best to seed down to timothy and alsike clover before attempting to grow general farm crops. Corn and oats do not do well on newly drained areas. Vegetable crops, however, such as onions, potatoes, tomatoes and sugar beets are grown very well on drained areas of muck. The use of certain complete fertilizers may be desirable on these areas where truck crops are to be grown. The application of acid phosphate and muriate of potash, which is sometimes recommended, may be of considerable value in increasing the production of these truck crops.

### WABASH SILT LOAM (26)

The Wabash silt loam is the second largest bottomland soil covering 2.2 percent of the total area. It occurs in many areas in various parts of the county along the streams, creeks, and intermittent drainageways in narrow ribbon-like areas. There are no large areas of the type, but the largest development in the county is found along Deer Creek and along the Shellrock River in the vicinity of Northwood and south of Northwood.

The surface soil of the Wabash silt loam consists of 15 to 18 inches of a black, smooth silt loam underlaid by a drab or gray clay loam containing iron stains and sometimes mottlings of gray, brown and yellow. Occasionally the subsoil contains small quantities of fine sand. In places the lower subsoil is as heavy as a clay. In some areas the surface soil is a silty clay loam in texture, but this variation was not developed extensively enough to warrant a separate mapping. Such areas occur in Section 34 of Danville Township, Section 35 of Brookfield Township, and along the ditch running thru Sections 29, 30 and 31 of Deer Creek Township. The Wabash silt loam mapped along Deer Creek in Section 1 of Barton Township is variable, ranging in surface texture from a loam to a silt loam. In the southeast quarter of Section 31 of Danville Township, the soil is a dark brown loam with no change thruout the entire three foot section.

In topography the Wabash silt loam is generally flat to very gently sloping. Most of the type is subject to flooding. The areas, which are less frequently overflowed, are utilized for the production of general farm crops. Corn yields 30 to 60 bushels per acre, oats 30 to 50 bushels per acre, and hay 1 to 2 tons. The uncultivated areas are used for pasture and the production of wild hay.

In order to secure better crop yields on the cultivated areas of this type, it would be desirable to apply farm manure, to add lime to remedy the acid condition of the soil, and to apply a phosphate fertilizer. Tests of acid phosphate and rock phosphate would be very desirable. In order to insure good crop yields on this soil, it should be protected from overflow and thoroly drained.

### PEAT (21)

There is a rather considerable area of peat covering 2.2 percent of the total area. It is found in numerous areas of varying size in the western townships.

The largest developments of peat are found in what was originally Rice Lake, in large areas in the southwestern part of the county west of Hanlontown, and in areas west of the Shellrock River in Hartland and Brookfield Townsips. Numerous other smaller areas are found scattered thruout the western townships.

Peat is partially decayed organic matter which has retained the original form of the plant from which it was derived, at least in part. It ranges in color from reddish-brown to deep chocolate brown. It is somewhat variable, but usually extends to a depth of 18 to 20 inches where it is underlaid by a black, smooth mucky material which may contain considerable amounts of mineral soil particles. The raw surface peat varies in depth from 8 to 10 inches to 5 or 6 feet. The underlying materials are also variable, ranging from sand to clay in texture and from a gray to yellow in color.

In topography, peat is rough to hummocky. It supports a luxuriant growth of wild grasses and many kinds of weeds. The unreclaimed areas are used as pasture land.

Drainage is the first treatment necessary in order to reclaim areas of peat. When this has been accomplished, thoro cultivation and the seeding of the areas to timothy and alsike clover and utilizing them for pasture for several years is the most desirable treatment. It is unsatisfactory to seed corn and small grains on newly drained peat. The yields will be very unsatisfactory. Vegetable crops may sometimes be grown on partially decomposed peat areas. Such crops as tomatoes, potatoes, sugar beets, onions, and celery will grow well. A general statement regarding the reclamation of peat and treatments needed, has been given earlier in this report.

### LAMOURE SILT LOAM (153)

The Lamoure silt loam is a minor type, covering only 1.6 percent of the total area. It is developed chiefly in the western part of the county in a number of small areas in the bottomlands and along intermittent drainage channels in association with the calcareous upland soils.

The surface soil of the Lamoure silt loam is a very dark brown to nearly black silt loam 15 inches in depth. The subsoil is a gray or mottled gray and brown calcareous silty clay to clay. There is a high lime content in the subsoil usually extending thru the surface soil.

The type occurs on the first bottoms along the streams and it is subject to overflow. In topography it is level to flat. A very small part of the soil is under cultivation and much of it is in native grasses used for pasture and the production of hay. On the cultivated areas, the yields are much the same as those secured on the Wabash silt loam.

The treatments recommended for that type will also apply in this case. Applications of farm manure would be of value on newly drained areas and the use of a phosphate fertilizer is recommended.

### CASS SILT LOAM (106)

The Cass silt loam is a minor type covering only 0.3 percent of the total area. It occurs in a number of small areas along the streams of the county. The largest development is found one mile east of Manly. Another area is mapped about one mile northwest of Kensett along Elk Creek.

The surface soil of the Cass silt loam is a very dark grayish-brown or nearly black smooth silt loam. The subsoil is a mottled gray, brown, and yellow silty clay. It contains considerable sand, grading below 24 inches into a brown or yellowish-brown incoherent sand.

In topography the Cass silt loam is flat, sloping slightly toward the streams. It occurs on the first bottoms and is subject to overflow. It is used almost exclusively for pasture or wild hay land. The areas not subject to overflow would be suitable for the growth of cultivated crops. If cultivated the soil would respond to applications of farm manure and the turning under of leguminous crops as green manures. The use of lime would be of value to remedy acidity. The application of a phosphate fertilizer would undoubtedly prove profitable.

## RESIDUAL SOIL

There is one residual soil in the county, the Sogn silt loam, poorly drained phase. It covers only 0.7 percent of the total area.

### SOGN SILT LOAM (POORLY DRAINED PHASE) (202)

The Sogn silt loam ocurs in small areas along the Shellrock River and Beaver Creek. Most of the areas are long and narrow and not very extensive. The largest development of the type is found south of Northwood.

The surface soil of the poorly drained phase of the Sogn silt loam is a dark brown or nearly black silt loam, extending to a depth of 16 inches. The subsoil is a gray or drab silty clay loam containing some mottlings of brown and yellow. Below 24 inches it is a grayish-brown or gray or mottled gray, brown and yellow silty clay to clay loam. The lower inch or two of material, resting on the bedrock, contains particles of limestone. In typical areas the bedrock is usually encountered at depths between 30 and 40 inches. Numerous variations occur within areas of this type along the Shellrock River. The surface soil may be a light textured to rather sandy loam, black in color. The sandy texture may continue to the bedrock or may grade into a drab colored subsoil just above the bedrock. The depth to which the bedrock occurs varies from 8 to 10 inches to the normal depth of 30 to 40 inches.

In topography the Sogn silt loam is flat to depressed and the natural drainage is poor. Areas, bordering the Shellrock River, are subject to flooding and are undoubtedly made up in part of alluvial material.

The type is not important agriculturally. The areas along the river banks are unsuitable for cultivation. They are utilizable only for pasture purposes. In the areas which can be cultivated, drainage is the first treatment necessary. The application of farm manure and the use of a phosphate fertilizer would be desirable.

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

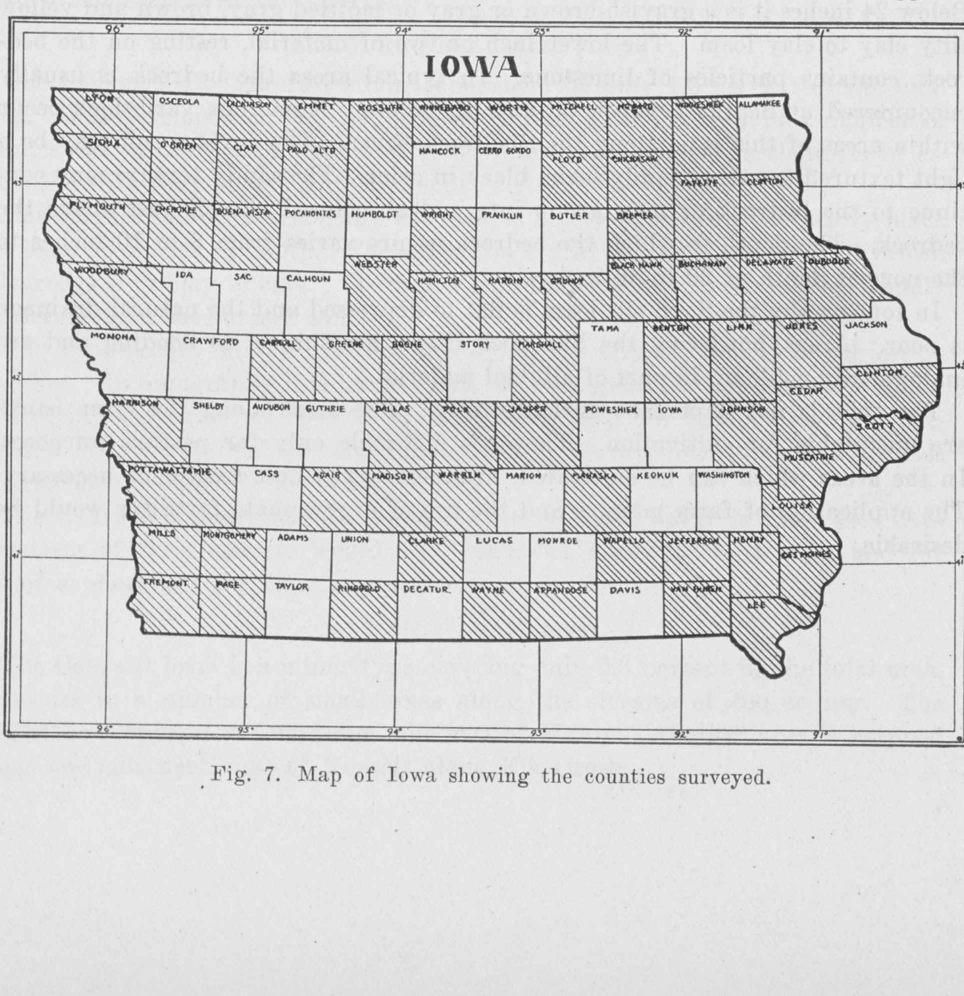



Fig. 7. Map of Iowa showing the counties surveyed.

## *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 surfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing method 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 surfur 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, surfur 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 solution 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 surfur 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 acid phosphate, 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 reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$) ), Phosphorus (P) at 12c (Acid Phosphate), 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 |

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 lease 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 loss.

## 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 percent of the corn and 35 to 40 percent 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 systems 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 plan 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 of 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 is a third explanation 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 rotation the time between two different crops of the same plant is long enough to allow the ''toxic'' substance 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 reason 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 nitrigen 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 soils need be resorted to.

### THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible 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 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 result sof 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, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. 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 acid phosphate 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. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

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 and then an additional amount of one or two tons per acre.

## *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 soil areas. The various areas are shown in the map, fig. 8.

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 sails 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 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.

## 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

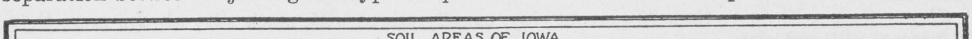



Fig. 8. Map showing principal soil areas in Iowa.

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 percent or more of organic matter, sometimes mixed with more or less sand or soil.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*Gravels*—More than 50 percent 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.

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

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.