# SOIL SURVEY OF IOWA

## GRUNDY COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils


Soil Survey Report No. 47
June, 1927
Ames, Iowa

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ic libraries.)

43 Soil Inoculation.
51 Soil Surveys, Field Experiments and Soil Management in Iowa.*
58 Use of Lime on Iowa Soils.*
82 Iowa Soil Survey and Field Experiments.*
97 The Use of Fertilizers on Iowa Soils.
102 Inoculation of Legumes.

RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
3 Influences of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*

tio
ed.
of

13 Montgomery County.
14 Black Hawk County.
15 Henry County.
16 Buena Vista County.
29 Mahaska County.
30 Fayette County.
31 Wright County.
32 Johnson County.
45 Des Moines County.
46 Benton County.
47 Grundy County.

June 1927 Soil Survey Report No. 47

# SOIL SURVEY OF IOWA

## Report No. 47—GRUNDY COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of W. E. Carson, L. W. Forman and R. E. Bennet

Fig. 1. A typical farmstead in Grundy County.

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

CONTENTS



# GRUNDY COUNTY SOILS*

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

Grundy County is located in central Iowa in the fourth tier of counties south of the Minnesota state line and in the fifth tier west of the Mississippi River. It lies partly in the Iowan drift soil area and partly in the Southern Iowa loess area. The soils of the county are, therefore, of glacial and loessial origin, the major portion of the area being covered by the loessial soils.

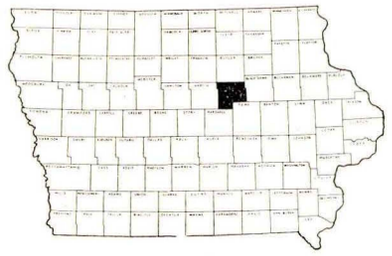


Fig. 2. A map showing the location of Grundy County.

The total area of the county is 501 square miles or 320,640 acres. Of this area, 311,531 acres or 97.2 percent is in farm land. The total number of farms is 1,733 and the average size of the farms is 180 acres. They are operated by 561 owners, 388 relative renters, 653 renters, 110 both owning and renting, and 21 unclassified. The following figures taken from the Iowa Yearbook of Agriculture for 1925, show the utilization of the farm land in the county:

| | |
|---|---|
| Acreage in general farm crops | 219,581 |
| Acreage in farm buildings, public highways and feed lots | 17,676 |
| Acreage in pasture | 69,773 |
| Acreage in waste land not utilized for any purpose | 101 |
| Acreage in farm woodlots used for timber only | 206 |
| Acreage in crop land lying idle | 7 |
| Acreage in crops not otherwise listed | 574 |

## THE TYPE OF AGRICULTURE IN GRUNDY COUNTY

The type of agriculture practiced in Grundy County at the present time consists of a system of general farming including the growing of corn, oats, wheat and hay; some dairying and the raising and feeding of livestock. Wheat serves as a cash crop in the county while a large part of the corn and oats produced is utilized for feeding purposes on the farms. The hay grown in the county is almost entirely used for feed. The dairy industry has been developed considerably and is carried on in practically all parts of the area. The income on many farms is derived chiefly from the sale of dairy products. The raising and feeding of hogs is an important industry and beef cattle are fed extensively. Sheep raising is of minor significance. In general it may be said that the farm income of the county is derived from the sale of dairy products, wheat, surplus corn and oats, beef cattle and hogs. On individual farms certain minor crops may become valuable and in many cases the farm income is considerably increased from the sale of special crops and frequently from the sale of poultry products.

The acreage in waste land in the county is not very large but in many cases

*See soil survey of Grundy County, Iowa, by E. M. Jones of the U. S. Department of Agriculture and W. E. Carson of the Iowa Agricultural Experiment Station. Field operations of the Bureau of Soils, 1921.

areas which are not at present utilized for any purpose may be reclaimed and made productive by proper methods of soil treatment. General recommendations regarding the handling of waste lands cannot be given as the causes of infertility are various. In a later section of this report, under the descriptions of individual soil types, suggestions will be offered regarding the reclamation of small areas of unproductive land in the individual soil types and treatments which are desirable under special soil conditions will be suggested. Advice regarding the handling of soils in special cases for more or less abnormal conditions, may be secured from the Soils Section of the Iowa Agricultural Experiment Station upon request.

## THE CROPS GROWN IN GRUNDY COUNTY

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

Corn is the most important crop, being grown in 1925 on 35.4 percent of the total area. Average yields in that year amounted to 42.5 bushels per acre. In favorable seasons very much larger yields are secured, sometimes amounting to 85 bushels per acre. Much of the corn grown in the county is used for feeding the work stock, fattening the cattle and hogs for market, the remainder of the crop being sold at the local grain elevators and shipped to outside markets.

The second crop in acreage and value is oats. This crop was grown in 1925 on 25.1 percent of the total farm land, with average yields estimated at 43 bushels per acre. In many cases even larger yields of oats are secured where the conditions are particularly favorable. The value of the oats crop is second only to that of corn in the county. A large part of the crop is utilized for feeding purposes on the farms, the remainder being sold on the markets.

The third crop in acreage and value is hay. The chief tame hay crop is a mixture of timothy and red clover. Some timothy and some clover are grown alone. In the case of both the timothy and clover, small areas are used for the production of seed. Average yields of the tame hay crop in 1925 amounted to 1.4 tons per acre. This was for the mixed clover and timothy. With clover alone the yields were about the same while the yield of timothy alone was somewhat less. There is some wild hay produced in the county and average yields of this crop amounted to 1.5 tons per acre in 1925. Practically all of the hay crop is utilized on the farms, only a small portion being sold outside of the county. In the northeastern section some of the hay is baled and sold in Waterloo.

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

| Crop | Acreage | Percent of total farm land of county | Bushels or tons per acre | Total bushels or tons | Average price | Total value of crops |
|---|---|---|---|---|---|---|
| Corn | 110,346 | 35.4 | 42.5 | 4,689,705 | $ 0.56 | $2,626,234 |
| Oats | 78,343 | 25.1 | 43.0 | 3,357,799 | 0.32 | 1,074,495 |
| Winter wheat | 354 | 0.1 | 21.0 | 7,434 | 1.36 | 10,110 |
| Spring wheat | 4 | 0.001 | 16.0 | 64 | 1.30 | 83 |
| Barley | 2,340 | 0.7 | 36.0 | 84,240 | 0.57 | 48,016 |
| Rye | 18 | 0.006 | 17.0 | 306 | 0.80 | 244 |
| Tame hay | 24,422 | 7.8 | 1.4 | 33,896 | 13.50 | 457,596 |
| Wild hay | 3,200 | 1.0 | 1.5 | 4,800 | 10.50 | 50,400 |
| Potatoes | 439 | 0.14 | 58.0 | 25,462 | 2.35 | 59,835 |
| Alfalfa | 149 | 0.04 | 2.6 | 387 | 17.50 | 6,772 |
| Pasture | 69,773 | 2.2 | .... | ..... | ..... | ..... |

*Iowa Yearbook of Agriculture 1925.



Potatoes are grown quite extensively and they are one of the important crops. Average yields amounted to 58 bushels per acre in 1925. In many seasons very much higher yields than this are reported. There is a considerable sale of potatoes out of the county.

Barley is grown to some extent and average yields of this crop in 1925 amounted to 36 bushels per acre. Practically all of the crop is utilized for feeding purposes.

Wheat is grown to some extent, chiefly the winter varieties, and average yields in 1925 amounted to 21 bushels per acre. Wheat serves as a cash crop on the farms. Very little spring wheat is grown.

Alfalfa is produced only to a limited extent but it is a profitable crop. When care is taken in seeding, the yields are quite satisfactory and it proves a particularly valuable crop on the dairy farm. For securing a good stand of alfalfa, it is very important that the soil should be limed, if it is acid, and that the seed be inoculated. In many cases the application of acid phosphate would also help in securing a good stand of alfalfa. Other precautions which must be taken in order to obtain a successful crop, are the securing of good seed, proper preparation of the seed bed, thoro drainage of the area, and in general any soil treatment which is necessary for good crop growth. Average yields of alfalfa in 1925 amounted to 2.6 tons per acre.

Crops of minor importance include rye, buckwheat, soybeans, and rape. On one farm popcorn serves as a cash crop. The raising of sunflowers is also a profitable industry in some areas.

Apples are produced in all parts of the county but chiefly for home use. Most of the orchards are very small in size and the production of apples is generally hardly adequate to meet the home demands. The Wealthy variety predominates; other varieties include the Oldenburg, Greening and Whitney, Grapes are produced on many farms to supply the home demand. Small fruits, including strawberries, are produced to a considerable extent in the county. There is very little sale of these crops, however, even on the local markets.

## THE LIVESTOCK INDUSTRY IN GRUNDY COUNTY

The following figures taken from the Iowa Monthly Crop Report of July 1, 1926, giving the January 1, 1926 estimates of the Division of Crop and Livestock Estimates of the U. S. Department of Agriculture, show the extent of the livestock industry in the county:

| | |
|---|---|
| Horses | 11,000 |
| Mules | 400 |
| All cattle | 48,200 |
| Hogs | 91,700 |
| Sheep | 3,100 |

Dairying is probably the most important livestock industry. The value of dairy products is considerable. The Holstein, Guernsey and Jersey are the

principal dairy cows. Shorthorns are also used to some extent. The milk is usually sold to creameries which are located in the vicinity of the farms. There the milk is separated, the skim milk returned to the farms and fed to the hogs and chickens.

There are many herds of beef cattle in the county. Aberdeen Angus, Hereford, Red Polled and Shorthorn are the favorite breeds. The feeding of cattle is an important industry. Cattle are shipped into the county, fattened and later shipped to the Chicago market.

Hogs are raised and fed on the great majority of the farms. On January 1, 1926, there were 91,700 hogs on the farms in the county. The income from the sale of hogs is very considerable thruout the area.

There are a few sheep in the county, but sheep raising is not an important industry. Some horses are raised on most of the farms, usually, however, to supply the home needs for work stock. Very few animals are sold. There are very few mules.

The raising of poultry is gradually becoming a rather important industry and there are many fine flocks. The most popular breeds are the White Leghorns, Rhode Island Reds, Black Minorca and Brown Leghorns. Other breeds that are favored are Barred Plymouth Rocks, White Plymouth Rocks and Silver Laced Wyandottes. Many of the farms at the present time are deriving considerable income from the sale of poultry and poultry products, and with more attention to this industry, the farm income may be considerably increased from this source.

## THE FERTILITY SITUATION IN GRUNDY COUNTY

The soils of Grundy County in general are quite fertile and crop yields in normal seasons are very satisfactory. However, it has been demonstrated by some experimental work and by much farm experience, that considerable increases in the yields of general farm crops may be secured by following proper methods of soil treatment.

Some of the soil types in the county are not as adequately drained as would be desirable and when this is true, the installation of tile is very necessary. The Clyde silty clay loam which occurs in depressions on the uplands, and the Muscatine silt loam which is found in extensive level stretches thruout the county, are both in need of drainage in many areas, if they are to be made satisfactorily productive. There are likewise certain areas, small in size, occurring in the Tama silt loam and the Carrington silt loam, where the installation of tile would be of value. On the terraces or second bottoms, the Fargo silty clay loam is in need of drainage. On the bottomlands, the Lamoure silty clay loam is very much in need of drainage, if it is to be cultivated. On all of these types the installation of tile will prove valuable for the growing of general farm crops.

All the upland soils in the county are acid in reaction and in need of lime if the best growth of general farm crops, and particularly of legumes, is to be secured. One of the terrace soils and one of the bottomland types show a content of lime, but with the exception of these, the Fargo silty clay loam on the terraces and the Lamoure silty clay loam on the bottoms, the soils of the county are all acid in reaction. It is very important, therefore, that with the exception

# SOIL MAP OF GRUNDY COUNTY, IOWA

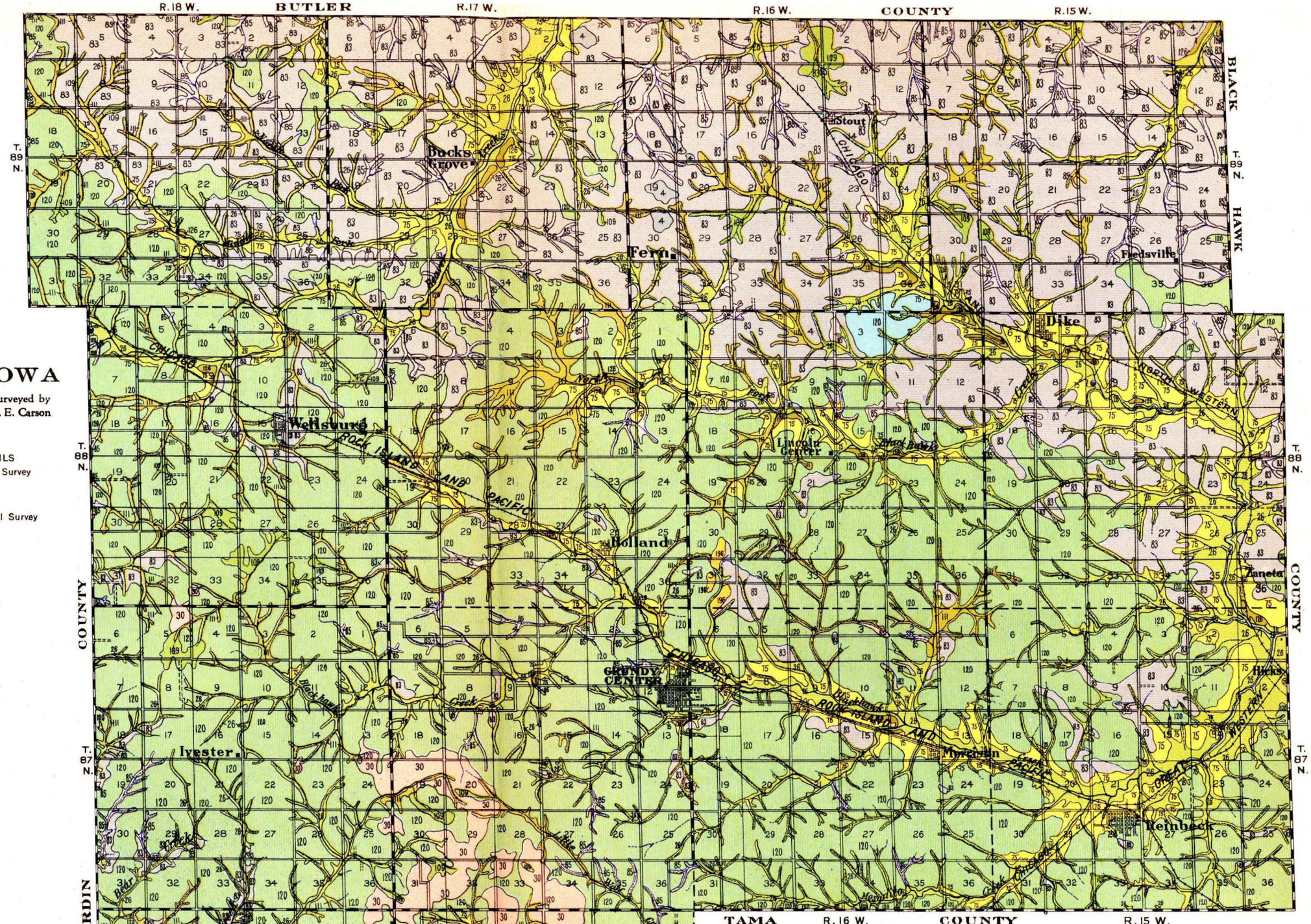

Thomas D. Rice, Inspector, Northern Division. Soils Surveyed by E. Melcom Jones of the U. S. Dept. of Agriculture and W. E. Carson of the Iowa Agricultural Experiment Station.

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

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


SCALE: 1 INCH TO 2½ MILES


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


## LEGEND

*Drift Soils*

| | |
|---|---|
| 83 Carrington silt loam | 85 Clyde silty clay loam |
| 4 Carrington fine sandy loam | 196 Shelby gravelly sandy loam |

*Loess Soils*

| | | | |
|---|---|---|---|
| 120 Tama silt loam | 30 Muscatine silt loam | 126 O'Neill sandy loam | 20 Meadow |

*Terrace Soils Swamp and Bottomland Soils*

| | | |
|---|---|---|
| 75 Waukesha silt loam | 26 Wabash silt loam | |
| 109 Fargo silty clay loam | 111 Lamoure silty clay loam | |

of these two types, all the soils of the county be tested for acidity or lime needs and that the amount of lime shown to be necessary according to the tests be applied. Only by the proper use of lime on such acid soils as these will it be possible to secure satisfactory yields of leguminous crops. Not only will leguminous crops be increased but frequently large increases are secured in the yields of general farm crops from the proper application of lime to these acid soils.

While the soils of the county are in general fairly well supplied with organic matter, there are one or two of the sandy types which are rather low in this constituent. On these soils, the application of farm manure or the turning under of leguminous green manure crops would be particularly valuable. But small applications of farm manure frequently bring about results on crop yields on some of the apparently richer types also. The liberal application of farm manure or the turning under of leguminous crops as green manures is very necessary on the sandy soils of the county, to build up and maintain the supply of organic matter. On the heavier types the use of small amounts of farm manure will be of considerable value, but the manure should not be applied on these heavy black soils preceding the small grain crop of the rotation, since it may cause the crop to lodge. The use of manure at other points in the rotation will, however, be of considerable value and the application of small amounts will show particularly large effects on newly drained areas.

The supply of nitrogen is quite adequate in most of the soil types in the county. Only in the case of the coarse-textured, sandy soils is there any inadequate supply. On these soils, the use of some nitrogen-containing fertilizer would be very desirable, but on all the soils of the county it is important in planning systems of permanent fertility, to include the use of some nitrogen-containing fertilizer in order to maintain the supply of this constituent in the soil. The use of leguminous crops as green manures is the very best and cheapest means of supplying nitrogen to the soil and the application of commercial nitrogenous fertilizers to the soils of the county will probably not be necessary. The nitrogen content may be more cheaply and quite as satisfactorily increased and maintained by the proper utilization of leguminous crops as green manures and the turning under of farm manure and crop residues.

The soils of the county are not well supplied with phosphorus and applications of phosphate fertilizers will certainly be very desirable in the near future. In many cases it would seem that the use of a phosphorus carrier would be valuable at the present time. Tests which have been carried out on some of the main soil types in this county, have indicated large, profitable increases in crop yields from the use of acid phosphate or rock phosphate on these soils. In some of these experiments, acid phosphate has seemed preferable while in others, rock phosphate has given quite as good returns. It is not possible yet to say which fertilizer will be the most desirable for general use, and hence it is recommended that farmers test the needs of their own soils for phosphorus and that in these tests they employ both acid phosphate and rock phosphate. Thus they may determine for their own conditions which fertilizing materials will give the more profitable returns.

The use of complete commercial fertilizers on the soils of Grundy County

cannot be recommended at the present time. In experiments which have been carried out, quite as beneficial effects on some of the main soils of this county have been secured from the use of acid phosphate or rock phosphate as when a complete commercial fertilizer was employed. Inasmuch as the phosphates are less expensive for application than the complete fertilizer, it is apparent that they would be more desirable for use, unless the complete fertilizers bring about very much larger crop increases than those occasioned by the phosphates. Tests should be carried out on small areas before an extensive application of any complete fertilizer is made. Such tests should compare the complete fertilizer with acid phosphate in order to determine which will be the more profitable for use. There is no objection to the use of complete fertilizers if profitable crop increases are secured.

Potassium fertilizers cannot be recommended for general application to the soils of the county at the present time. Indications have been secured, in certain experiments thruout the state, of value from the use of potash fertilizers but in general it would seem that there is sufficient potash present in the soils to supply all the needs of crops and the addition of commercial potassium fertilizers should not be needed. Tests of potassium carriers may be carried out, however, on a small scale on any soil type and if profitable crop increases are secured, then the potassium fertilizer may be used on a considerable area with the assurance of profit. Commercial potassium fertilizers should not be employed until tests under the particular soil conditions have shown them to be of value.

Erosion occurs to a limited extent in Grundy County, some of the more rolling areas of the Tama and Carrington soils showing the destructive effect of the washing action of water in many cases. The Shelby soils are particularly injured by erosion. Wherever erosion is evidenced, some means should be taken to protect the soils from further injury and to reclaim the areas which may have been injured by the formation of gullies or the carrying away of the surface soil. From among the methods suggested later in this report, some one may be chosen which will be suitable for use under any particular conditions. The prevention of the washing away of the surface soil and the formation of gullies, and the reclamation of badly washed or gullied land is very necessary for the most satisfactory crop production.

## THE GEOLOGY OF GRUNDY COUNTY

The geological history of Grundy County is of little significance from the standpoint of the present soil conditions in the county, except insofar as the deposits of glacial and loessial material are concerned. The native bedrock underlying the soils of the county has been so deeply buried by the deposits of glacial and loessial material of later ages, that there is no effect upon the soil conditions at the present time. The soils in the county are derived entirely from the glacial till or debris left by the glaciers or from the wind blown material known as loess.

At least twice during the glacial age, great ice sheets swept over the county and upon their retreat there was left behind a great mass of glacial till or debris which is known as drift. The earlier topographic features of the county were



largely obliterated by the first glacial deposit and the later glaciation has left very little evidence remaining of the topographic conditions established in the earlier glacial deposits.

The earlier glacier, which is known as the Kansan, deposited a thick layer of material, largely made up of boulder clay containing also sand and gravel and sometimes boulders. The Kansan deposit, in the deeper unoxidized portions, is a blue clay. Where it has been exposed and weathered, it has become a bright yellow to deep reddish-brown. Pockets of sand and gravel occur quite commonly. The depth of the deposit is extremely variable, ranging from a few feet to almost a hundred feet in thickness in some places. The later glacial deposits and the coverings of loess have buried this deposit so deeply that there is no significant effect from it on the soils of the county and none of the types mapped are derived in any part from the Kansan material.

At a later date, a second glacier invaded the county, burying the Kansan till, sometimes to a considerable depth. This glacier is known as the Iowan. The deposit left by it is rather variable, usually, however, being not more than 10 feet in thickness. It is a light to bright yellow in color and is somewhat sandier than the Kansan material. Boulders occur frequently. The Iowan drift deposit is exposed on the surface in all that part of the county north of the loess-covered area. The drift soils of the county are, therefore, derived from this Iowan drift material. The soils of the Carrington series and the Clyde series, are of Iowan drift origin. The Shelby gravelly sandy loam is formed from a gravelly variation of this drift material.

At a later date when climatic conditions were very different than at present, there was deposited over the southern part of the county, a covering of wind blown material known as loess. The deposit was made quite uniformly over the topographic features existing at that time. The Kansan and Iowan drift deposits were covered, sometimes to considerable depths, by this loessial deposit. Considerable amounts of the loessial material have since been washed away and at the present time the deposit ranges in depth from a few inches to six or seven feet. In an unweathered condition, loess is an even-grained material composed mainly of silt. It ranges in color from a light grayish-brown to a yellowish-brown. Organic matter has accumulated in the loessial deposits in varying amounts, depending upon the plant growth conditions in the area. The soils of the Tama and Muscatine series on the uplands are derived from this loessial deposit and they cover about two-thirds of the total area of upland in the county. The Tama soils have formed in the well drained, rolling areas of prairie. The Muscatine types have been formed in the more level, rather poorly drained prairie areas.

The terrace and bottomland soils in the southern part of the county where the uplands are covered with loess, have been formed very largely from loessial material, but in the drift upland section of the county, the terrace and bottomland soils contain considerable drift material. In practically all cases these soils show some admixture of drift and loess, the predominating material being determined by the character of the material on the adjacent uplands.

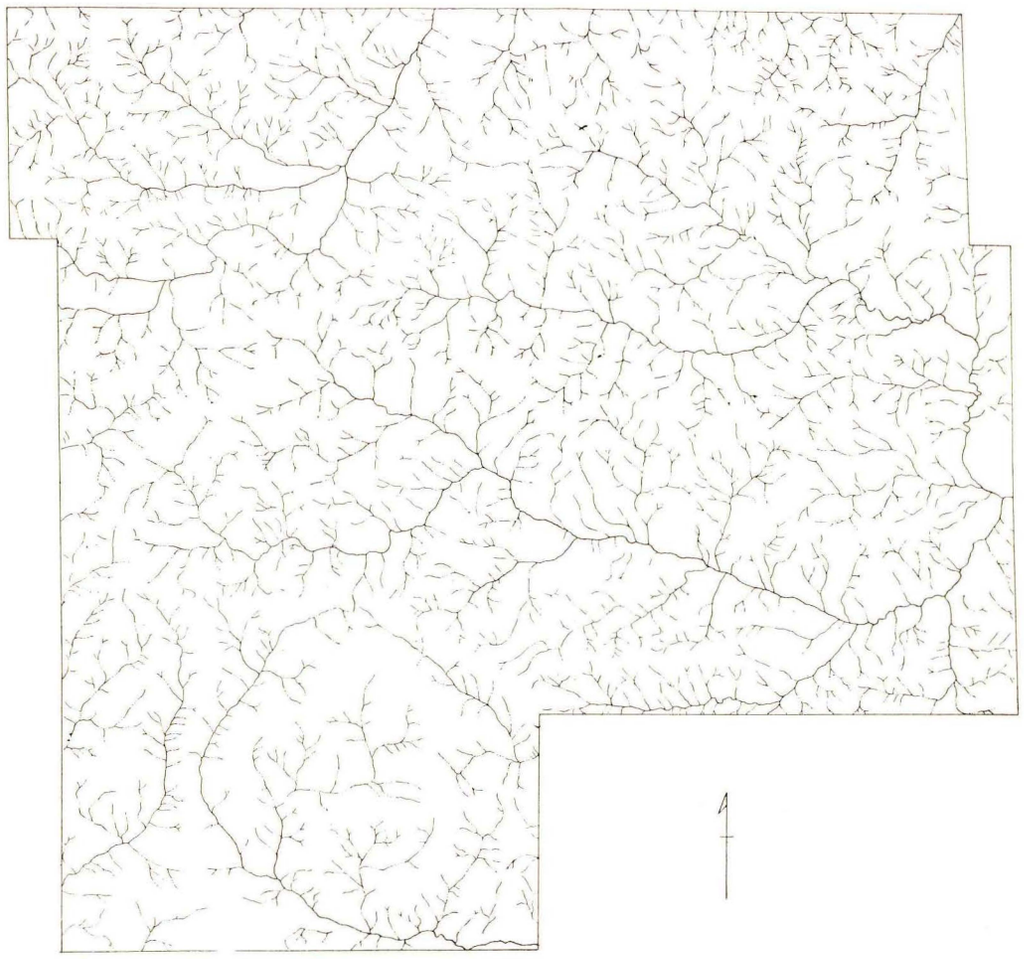


Fig. 3. Map showing natural drainage system of Grundy County.

PHYSIOGRAPHY AND DRAINAGE

The county as a whole is a gently rolling prairie, cut by the shallow valleys of the streams and showing rather extensive flat areas of upland between the streams and occasionally prominent ridges. Numerous ridges and hills known as "pahas," are found in the northwestern part of the county. These extend in a northwest and southeast direction. They are most noticeable northwest of Buck's Grove in Pleasant Valley and German Townships. In the northern part of the county where the drift soils occur, the topography is more rolling and boulders of considerable size are quite commonly noted. One which is located near the Black Hawk County line, two miles south of the Butler County line, is said to be the largest boulder in the state. Between Grundy Center and Conrad and in the areas about Conrad, there are flat to slightly depressed areas in the upland. These undoubtedly represent former lake beds.

In general the slopes to the streams of the county are gentle and smooth and there are no sharp topographic features. The valley of Black Hawk Creek has an average width of three-fourths of a mile, with terraces ranging in width from



a few rods to a half mile or more on either side. Occasionally small ponds occur in the vicinity of the larger streams. In general the streams follow a winding course and flow through shallow valleys.

The drainage of the county is brought about mainly by Black Hawk Creek and its tributaries. Beaver Creek drains the northwestern part of the county, entering from Hardin County northwest of Wellsburg and flowing northeasterly through Shiloh, German and Pleasant Valley Townships. With its chief tributary, Middle Fork Beaver Creek, it drains the major portion of these three townships. Black Hawk Creek flows in a southeasterly direction through the central part of the county and, with its tributaries, it drains the central townships. Most of the tributary streams are small and relatively unimportant, the largest being Mosquito Creek in the extreme southeastern part of the county. The North Fork Black Hawk Creek with its tributaries flows east and southeast, draining a large part of Colfax, Lincoln, Beaver, and Grant Townships, and the southwestern part of Fairfield Township. Hammers Creek, flowing north, provides the drainage of the southwestern part of the county, for Melrose, Felix and Clay Townships.

In general the natural drainage system of the county is good, as is evidenced by the accompanying drainage map. The various streams with their tributaries and intermittent drainageways, extend into practically all parts of the upland. In some places, however, the soils are not adequately drained and in such instances the installation of tile will easily provide all the drainage that is necessary, outlets being readily secured. For instance much of the land in the southwestern part of the county, is in need of better drainage. Wherever the topographic condition is level to flat or depressed, drainage conditions are poor. Thruout the central and northern parts of the county, natural drainage is much more satisfactory but even here the installation of tile is frequently necessary to provide for the best soil moisture conditions for crop growth.

## THE SOILS OF GRUNDY COUNTY

The soils of Grundy County are grouped into four classes according to their origin and location. These groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are those which have been formed from materials carried by the glaciers and deposited on the surface of the land when the glaciers retreated. They are variable in composition, containing pebbles and frequently boulders. Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by depressions in the river channels. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Grundy County are shown in table II.

Slightly more than one-quarter of the county, 27.2 percent, is covered by the drift soils. The loess soils cover a little more than half of the county, 50.3 percent. There is a small area in terrace soils, 5.7 percent, while the swamp and

bottomland soils are rather important, covering 16.8 percent of the total area of the county.

There are eleven individual soil types in the county, and these with the areas of meadow, make a total of twelve soil areas. There are four drift soils, two loess types, three terrace soils and three areas of swamp and bottomland. The various soil types are distinguished according to certain definite characteristics which are described more in detail in the appendix to this report. The names which are given to these soil types indicate certain group characteristics. The areas covered by the various soil types are given in table III.

The Carrington silt loam is by far the most extensive drift soil, covering 23.8 percent, or almost one-quarter of the county. The Clyde silty clay loam, the second largest drift soil, is very minor in extent, covering only 3.0 percent. The other two drift soils, the Carrington fine sandy loam and the Shelby gravelly sandy loam are of minor occurrence, covering only 0.3 and 0.1 percent, respectively.

The Tama silt loam is the most extensive soil type and the most largely developed loess soil. It covers almost one-half of the county, 46.8 percent. It is found on the undulating to gently rolling uplands thruout the entire central and southern parts of the county. The Muscatine silt loam is the second most extensive loess soil, covering 3.5 percent.

The Waukesha silt loam is the most extensive terrace type, covering, however, only 4.5 percent of the total area. The Fargo silty clay loam and O'Neill sandy loam, the two other terrace types, are minor in extent, covering 0.9 and 0.3 percent of the total area, respectively.

The Wabash silt loam is the most extensive bottomland type and the third largest soil area. It covers 12.1 percent of the total area of the county. The Lamoure silty clay loam, the second largest bottomland type, is much smaller in extent, covering 4.4 percent of the area. There is 0.3 percent of the area in meadow.

There is considerable variation in the topography of the uplands of the county and a certain relationship is evidenced between the topographic conditions and the particular soil type. On the drift uplands, the Carrington silt loam occurs on the gently undulating to rolling areas. The Carrington fine sandy loam and the Shelby gravelly sandy loam are found on the more steeply rolling to rough areas of drift upland. The Clyde silty clay loam occurs in the depressions in the uplands and the type is poorly drained. On the loessial upland, the Tama silt loam is found on the undulating to rolling areas, while the Muscatine silt loam occurs on the level to flat upland. The terraces show only minor variations in topographic conditions. The Waukesha and O'Neill soils on the terraces are older and higher, but show little in the way of topographic features. The Fargo silty clay loam on the terraces is found in the flat to depressed areas. The bottomlands show no topographic features which are of significance.

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

| Soil Group | Acres | Percent of total area of county |
|---|---|---|
| Drift soils | 86,784 | 27.2 |
| Loess soils | 161,280 | 50.3 |
| Terrace soils | 18,624 | 5.7 |
| Swamp and bottomland soils | 53,952 | 16.8 |
| Total | 320,640 | .... |



TABLE III. AREAS OF DIFFERENT SOIL TYPES IN GRUNDY COUNTY

| Soil No. | Soil Type | Acres | Percent of total area of county |
|---|---|---|---|
| | DRIFT SOILS | | |
| 83 | Carrington silt loam | 76,160 | 23.8 |
| 85 | Clyde silty clay loam | 9,536 | 3.0 |
| 4 | Carrington fine sandy loam | 832 | 0.3 |
| 196 | Shelby gravelly sandy loam | 256 | 0.1 |
| | LOESS SOILS | | |
| 120 | Tama silt loam | 150,016 | 46.8 |
| 30 | Muscatine silt loam | 11,264 | 3.5 |
| | TERRACE SOILS | | |
| 75 | Waukesha silt loam | 14,528 | 4.5 |
| 109 | Fargo silty clay loam | 3,008 | 0.9 |
| 126 | O'Neill sandy loam | 1,088 | 0.3 |
| | SWAMP AND BOTTOMLAND SOILS | | |
| 26 | Wabash silt loam | 38,720 | 12.1 |
| 111 | Lamoure silty clay loam | 14,272 | 4.4 |
| 20 | Meadow | 960 | 0.3 |
| | Total | 320,640 | .... |

## THE FERTILITY IN GRUNDY COUNTY SOILS

Samples were taken for analysis from each of the soil areas in the county except the Shelby gravelly sandy loam on the drift upland and the area of meadow on the bottomland. These soils were not sampled because of their limited areas and also because of the fact that they are of practically no significance agriculturally.

The more extensive soil types were sampled in triplicate, but only one sample was taken from each of the minor types. The samplings were all made with the greatest of care that the sample should be representative of the particular soil type and that any variations due to previous treatments should be eliminated. The samples were taken at three depths, 0–6 2/3 inches, 6 2/3 to 20 inches, and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

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

### THE SURFACE SOILS

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

The phosphorus content of the soils of the county is quite variable, ranging from 686 pounds per acre in the O'Neill sandy loam up to 2,222 in the Wabash

silt loam. There seems to be very little relationship between the phosphorus content of the soils and the particular soil group, altho the terrace types and the swamp and bottomland soils are a little higher on the average than the upland types. This might be expected inasmuch as there has been less production of crops on the bottomland soils and hence a smaller removal of the plant food constituents. However, the differences are not very great and the number of soil types in the various groups is too small to permit of very definite conclusions.

There are, however, much more definite indications of a relationship among the various soil series and soil types. Thus on the drift uplands, the Clyde soils are higher than the Carrington; on the loessial uplands, the Muscatine is a little higher than the Tama; on the terraces, the Fargo is higher than the Waukesha and O'Neill; and there is little difference on the bottoms altho the Wabash is a little higher in phosphorus. The relationship between the phosphorus content of the soil and the soil texture is not very clearly shown, inasmuch as there are only two soils of different texture mapped in the same series. The Carrington silt loam on the drift uplands is higher in phosphorus than the fine sandy loam.

In general, it is apparent that there is a distinct relationship between the phosphorus content of the soil and those characteristics which serve to distinguish the various soil series. The variations in phosphorus content undoubtedly reflect the characteristics which serve to distinguish the soil series, especially the topography, color and subsoil character. Thus the Clyde soils are level to depressed in topography. They are darker in color and they have a heavier, more impervious subsoil, and their phosphorus content is higher than that of the Carrington types. On the loessial uplands, the Muscatine silt loam has a more level topography, the surface soil is darker in color and the subsoil is heavier. It is better supplied with phosphorus in general than the Tama soils. On the terraces, the Fargo silty clay loam is level to depressed in topography, black in color, and has a very heavy impervious subsoil. It is higher in phosphorus than the Waukesha and O'Neill types. The Waukesha is better supplied than the O'Neill, due to its darker color and its heavier subsoil condition. There is little

TABLE IV. PLANT FOOD IN GRUNDY 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..... | 1,427 | 3,840 | 45,780 | ..... | 8,000 |
| 86 | Clyde silty clay loam..... | 1,522 | 7,460 | 98,100 | ..... | 3,000 |
| 4 | Carrington fine sandy loam | 848 | 1,360 | 18,530 | ..... | 8,000 |
| | LOESS SOILS | | | | | |
| 120 | Tama silt loam..... | 1,279 | 4,586 | 54,863 | ..... | 6,333 |
| 30 | Muscatine silt loam ..... | 1,320 | 5,020 | 66,217 | ..... | 4,000 |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam..... | 1,414 | 5,420 | 64,582 | ..... | 8,000 |
| 109 | Fargo silty clay loam..... | 2,007 | 8,980 | 107,513 | 19,744 | .... |
| 126 | O'Neill sandy loam..... | 686 | 2,260 | 26,705 | ..... | 6,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam..... | 2,222 | 9,360 | 111,180 | ..... | 4,000 |
| 111 | Lamoure silty clay loam... | 2,033 | 11,480 | 141,105 | 55,095 | .... |



difference in these characteristics between the Wabash and Lamoure types and little difference in phosphorus content.

The effect of texture on the phosphorus content is indicated only in the case of the Carrington silt loam and the fine sandy loam. In general, however, this bears out previous conclusions in showing that soils which are finer in texture are generally better supplied with phosphorus. Silt loams are richer than loams and sandy loams while silty clay loams are usually the highest in this constituent.

From the figures given in the table it is evident that there is no large supply of phosphorus in any of the soils of Grundy County. Phosphorus fertilizers will certainly be needed, therefore, on these soils in the very near future if crop yields are to continue to be satisfactory. It is evident, however, from experiments and from some farm experience, that the use of a phosphorus fertilizer might be very desirable on many of these soils at the present time. When the phosphorus content of soils is as low as it is in some of these types, there is a very inadequate production of available phosphorus and hence in spite of the fact that it would seem from these figures that there is sufficient phosphorus still left in these soils for many crops, the use of a phosphorus fertilizer will be desirable in order to supply available phosphorus. Either rock phosphate or acid phosphate should be used on many of the soils in this county. Definite conclusions regarding the relative value of the two materials have not yet been possible and it is urged that farmers test both materials on their own soils and determine for their particular conditions which will be the more profitable for use.

There is a considerable variation in the nitrogen content of the soils of the county, the amount ranging from 1,360 pounds in the Carrington fine sandy loam up to 11,480 pounds in the Lamoure silty clay loam. As was noted in the case of the phosphorus supply, there seems to be little relationship between the content of nitrogen in the soils of the county and the soil group, except for the fact that the terrace and bottomland soils are a little better supplied, on the average. Again this might be expected because of the lower yields of crops on these soils and hence the smaller removal of this plant food constituent. The largest supply of nitrogen is evidenced in the bottomland soils, but this is not entirely due to the particular soil group but to the fact that the two soils which are included in this group represent soil series in which the color, topographic position and other characteristics naturally lead to a high content of nitrogen.

The relationship between the nitrogen content of the soils and the various soil series is evidenced by these analyses. The Clyde silty clay loam on the drift uplands is very much richer than the Carrington soils. The Muscatine on the loessial uplands is richer than the Tama soils. The Fargo on the terraces is higher than the Waukesha and O'Neill while the Waukesha is better supplied than the O'Neill. On the bottomlands there is little difference altho the Lamoure seems to be a little better supplied than the Wabash. Both, however, are very high in nitrogen.

Again as in the case of phosphorus, it would seem that the characteristics, which serve to determine the various soil series, indicate in general the nitrogen content. Soils which are dark in color, more level to flat in topography and with heavy subsoils are higher in this constituent. The Clyde silty clay loam is black

in color and level in topography and has a heavy subsoil. It is richer in nitrogen than the Carrington. Similarly the Muscatine is darker in color, level in topography, and heavier in the subsoil and it is richer in nitrogen than the Tama. The Fargo on the terraces is higher than the Waukesha while the Waukesha is better supplied in nitrogen than the O'Neill due largely to its heavier subsoil and darker color. The influence of the texture of the soil is evidenced only in the case of the Carrington fine sandy loam which is lower in nitrogen than the Carrington silt loam. This is the only case where there are two types of different texture in the same series and the only place, therefore, where a comparison is possible.

In general it would appear from these results, that there is a distinct relationship between the color, topography, subsoil condition and the texture of soils and their nitrogen content. Soils which are dark in color and level to depressed in topography with heavy subsoils and with finer-textured surface soils are better supplied in this constituent.

While the soils of the county are in general fairly well supplied with nitrogen, this element must not be overlooked when systems of permanent fertility are planned for the county. The supply of nitrogen must be kept up by the proper utilization of some nitrogenous fertilizing material at regular points in the rotation. In the case of the sandier soils, the addition of nitrogen-containing fertilizers would be helpful at present.

Farm manure is the most important nitrogenous fertilizing material which can be employed and the liberal use of this material will aid considerably in keeping up the content of nitrogen in the soils of this county. The proper use of all crop residues will also aid materially in supplying this constituent. The turning under of leguminous crops as green manures may be very desirable in many cases to supplement the use of farm manure or as a substitute for that material in order to build up and keep up the supply of nitrogen.

The organic carbon content of the soils of the county varies quite as widely as was noted in the case of nitrogen. It ranges from 18,530 pounds in the Carrington fine sandy loam up to 141,105 pounds per acre in the Lamoure silty clay loam. These are the same two types which showed the lowest and highest content of nitrogen respectively.

The same relationships which were noted among the various soil types and soil series in the case of nitrogen, are evidenced when the organic carbon content of the soil is considered. Thus it seems that there is a somewhat larger amount of organic carbon in the bottomland soils than is present in the upland types. The differences are not very great in the case of the terrace soils. The relationships among the various soil series are very similar to those noted in the case of the nitrogen content. The Clyde soils are higher than the Carrington on the drift uplands; the Muscatine is higher than the Tama on the loessial uplands; the Fargo is higher than the Waukesha and the Waukesha is higher than the O'Neill on the terraces; and the Lamoure is somewhat higher than the Wabash on the bottoms. The Carrington fine sandy loam is lower in organic carbon than is the silt loam of the same series. This is the only case where a comparison of texture to organic carbon content is possible.

It is apparent that the soil characteristics which serve to distinguish series and types, are closely related to the organic carbon or organic matter content. Those types which are black in color, level in topography, with heavy subsoils and fine textured surface soils are generally much higher in organic matter and also in nitrogen. Coarse-textured types, light in color and rolling in topography and with light textured subsoils are almost certain to be more poorly supplied with these constituents.



The relationship between the carbon and nitrogen content of soils indicates the rapidity with which the plant food in the soils is being changed into an available form. In some of the types in Grundy County this relationship is such that it is evident that there is too slow a production of available plant food to supply crops properly. In the Carrington fine sandy loam and the O'Neill sandy loam, the poor relationship is particularly evident. Likewise, however, in the Carrington silt loam, the Tama silt loam and the bottomland soils, the relationship is such that there will not be the best production of available plant food. On all these types, therefore, the application of farm manure would be particularly valuable, inasmuch as this material supplies the microorganisms which bring about a more rapid decomposition of plant food constituents and a more rapid production of available plant food.

The use of farm manure is of very large value, however, on all the types in the county, and even when the supply of organic matter is not low and the soil is dark in color, small applications of farm manure have been found to bring about large crop increases. On such soil types it should not be applied preceding the growing of a small grain crop, since it may cause the crop to lodge, but small amounts may be applied with profit at other points in the rotation.

Many experiments and much farm experience have demonstrated the value of applications of farm manure to the soil types mapped in this county. Crop residues should be thoroly utilized on the farms of the county as they aid materially in keeping up the supply of organic matter in the soil. The use of leguminous crops as green manures will also be of value on many of these soils in increasing and keeping up the supply of organic matter. They also aid, as has been noted, in building up and maintaining the supply of nitrogen, hence they have a double value. The use of green manures is very desirable as a supplement to farm manure or as a substitute for that material.

With the exception of the Fargo silty clay loam on the terraces and the Lamoure silty clay loam on the bottomland, the soils of Grundy County are all acid in reaction and show no content of inorganic carbon. The acidity in these types is considerable as is evidenced by the high limestone requirement figures given in the table. The soils are not only acid in the surface, but the acidity extends thruout the subsurface and subsoil. It is evident, therefore, that all the soils of the county except the Fargo silty clay loam and the Lamoure silty clay loam, should be tested for lime requirement or acidity and the amount of lime shown to be necessary by these tests should be applied, if the best crop yields are to be secured. The figures for limestone requirement given in the table should be considered merely indicative of the needs of the soil. There is a wide variation in the lime requirement of various soils and even of soils in different fields, and hence before lime is applied to any area, the soils from that particular area should be tested in order that the proper application may be made.

Not only should tests be made on all the soils of the county except the Fargo and Lamoure at the present time but it will be necessary, at regular intervals in the future, to test these soils and apply lime as needed, probably once in every four-year rotation. It is very desirable that the soils be tested at least once in the four-year rotation just previous to the growing of the legume crop. In this way it will be possible to maintain the proper soil reaction for the best growth of the legume. The use of lime on acid soils is always particularly profitable where legumes are to be grown but considerable increases are frequently secured in the yields of other general farm crops also. It should be emphasized that applications of lime are very desirable on most of the soils of Grundy County in order to provide for the best crop growth.

### 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 the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

Unless there is a very large amount of some plant food constituent present in the lower soil layers, or a striking deficiency, there is very little effect on the fertility of the soil from the plant food present in the lower layers. In general the analyses of the surface soil may be considered to indicate fairly accurately the plant food content and crop producing power of the soil.

The content of the various plant food constituents is not very high and neither is it strikingly deficient in the soils of Grundy County, hence these analyses will not be considered in detail.

It may merely be noted here that the analyses of the subsurface soils and subsoils in this county serve to emphasize the conclusions which have been drawn from the analyses of the surface soils. It is evident that phosphorus fertilizers will certainly be needed on these soils in the very near future and it would seem that they might prove of value in many cases at the present time. The content of organic matter and nitrogen is not low in many of these soils, neither is it strikingly high in most cases. Apparently, therefore, care should be taken to

TABLE V. PLANT FOOD IN GRUNDY 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 | 2,208 | 4,000 | 46,870 | ..... | 8,000 |
| 85 | Clyde silty clay loam | 2,316 | 5,240 | 67,760 | ..... | 1,000 |
| 4 | Carrington fine sandy loam | 1,534 | 3,440 | 47,415 | ..... | 6,000 |
| | LOESS SOILS | | | | | |
| 120 | Tama silt loam | 2,354 | 5,583 | 64,581 | ..... | 6,666 |
| 30 | Muscatine silt loam | 1,992 | 5,600 | 78,480 | ..... | 4,000 |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 1,966 | 5,360 | 56,135 | ..... | 6,000 |
| 109 | Fargo silty clay loam | 3,368 | 7,000 | 91,369 | 5,641 | .... |
| 126 | O'Neill sandy loam | 1,642 | 3,640 | 43,600 | ..... | 6,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam | 2,532 | 9,200 | 130,250 | ..... | 2,000 |
| 111 | Lamoure silty clay loam | 4,390 | 11,720 | 179,729 | 14,291 | .... |



TABLE VI. PLANT FOOD IN GRUNDY 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 | 2,745 | 4,320 | 44,145 | ..... | 8,000 |
| 85 | Clyde silty clay loam | 2,988 | 3,720 | 45,780 | ..... | 1,000 |
| 4 | Carrington fine sandy loam | 1,818 | 3,120 | 42,510 | ..... | 4,000 |
| | LOESS SOILS | | | | | |
| 120 | Tama silt loam | 3,177 | 5,072 | 66,762 | ..... | 6,333 |
| 30 | Muscatine silt loam | 2,787 | 2,880 | 35,152 | ..... | 3,000 |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 2,667 | 3,840 | 35,970 | ..... | 6,000 |
| 109 | Fargo silty clay loam | 4,242 | 2,520 | 31,146 | 5,641 | .... |
| 126 | O'Neill sandy loam | 888 | 1,920 | 19,620 | ..... | 4,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 26 | Wabash silt loam | 2,787 | 6,840 | 125,077 | ..... | 1,000 |
| 111 | Lamoure silty clay loam | 6,060 | 7,080 | 177,651 | 564 | .... |

keep up the content of these constituents, if the soils are to continue to be satisfactorily productive. The proper use of farm manure, crop residues, and leguminous green manures is very necessary in order to maintain the supply of these plant foods in all the soils and to add these elements to certain of the sandier types. The soils of the county, with the exception of the Fargo and Lamoure types are all acid in reaction, the acidity extending thruout the three-foot soil section. This means that additions of lime are very necessary on all the other soils and they should be tested regularly and the amount of lime shown to be necessary by the test should be applied if the best growth of general farm crops and particularly of legumes, is to be secured.

## GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the soils from Grundy County in the effort to determine something regarding their fertilizer needs and the value of the application of various materials. These tests were carried out on the Tama silt loam and the Muscatine silt loam, two of the more extensive soil types in the county. Experiments are also included here on the Tama silt loam from Hardin County, on the Tama silt loam from Marshall County and on the Carrington silt loam from Black Hawk County, as these soils are the same as those occurring in Grundy County and the results may be considered to indicate quite definitely the needs of the same soil types in this county.

The fertilizer treatments employed were the same in all these experiments, and included the application of manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These materials were added in the amounts in which they are applied in the field and hence the results serve to indicate quite definitely what the fertilizer effects may be on the farm.

Manure was applied at the rate of 8 tons per acre, lime was supplied in sufficient amounts to neutralize the acidity of the soil and supply two tons additional, rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre, and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown,


Fig. 4. Greenhouse experiment with wheat on Tama silt loam from Grundy County.

the clover being seeded about one month after the wheat was up. In some cases only the yield of wheat was secured while in other instances the yields of both crops were taken.

### THE RESULTS ON THE TAMA SILT LOAM

The results secured on the Tama silt loam from Grundy County are given in table VII. The beneficial effects of applications of manure to this soil are indicated by the increased yields secured in the wheat and clover grown in this greenhouse experiment. The effects of the manure were particularly evident on the clover altho there was an appreciable gain also in the yield of wheat. Lime applied with the manure increased the wheat yield considerably and also showed a gain in the case of the clover. Ordinarily lime would not be expected to have any particular effect on the wheat, but in this case a rather definite influence was noted. The application of rock phosphate or acid phosphate with the manure and lime increased the yields of wheat to a very slight extent, and brought about a gain in the case of clover. The acid phosphate had a very appreciable effect on the clover but gave no effect on the wheat. The rock phosphate brought about a slight increase in the wheat and a gain in the clover. The complete commercial fertilizer gave an appreciable increase in the wheat but had less effect on the clover than did the acid phosphate.

It would seem from this test that this soil type will respond to applications of manure, lime and possibly a phosphorus fertilizer. The acid phosphate seems to be more effective in this particular case than rock phosphate but until more definite field tests have been carried out with the two materials, conclusions as to the relative merits of the two phosphates should not be drawn. Tests of acid phosphate and rock phosphate are recommended on this soil, and applications of manure and lime are urged as basic treatments. It would not seem that a complete commercial fertilizer would be as desirable as acid phosphate for use on



TABLE VII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, GRUNDY COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 9.3 | 11.8 |
| 2 | Manure | 9.8 | 20.4 |
| 3 | Manure+lime | 11.7 | 21.2 |
| 4 | Manure+lime+rock phosphate | 11.9 | 22.2 |
| 5 | Manure+lime+acid phosphate | 11.5 | 24.5 |
| 6 | Manure+lime+complete commercial fertilizer | 13.0 | 23.9 |

this soil. However, tests should be carried out before any definite conclusions are drawn.

### THE RESULTS ON THE MUSCATINE SILT LOAM

The results secured in the greenhouse experiment on the Muscatine silt loam from Grundy County are given in table VIII. The beneficial effects of manure on this soil type are evidenced by the increased yield of wheat and by the very large gain in the crop of clover. Lime with manure increased the wheat yields and also the clover yields to a very appreciable extent. The rock phosphate and acid phosphate with the manure and lime increased the wheat yields and also showed an increase in the case of the clover. The rock phosphate gave somewhat better results than the acid phosphate on the clover, but had slightly less effect on the wheat. The differences, however, were not very large and should not be considered conclusive. The complete commercial fertilizer gave a larger gain in the wheat than did the phosphates, but showed less effect on the clover.

On this soil type, apparently, the application of a small amount of manure at the proper place in the rotation would be very desirable. While the soil is high in organic matter and black in color, the use of manure has given a large increase in the crop yields. It should be emphasized, however, that manure should not be applied to this soil immediately preceding the growing of a small grain crop, since it may cause the crop to lodge. Small amounts applied at other points in the rotation are, however, very valuable. The use of lime is very desirable on this soil for increasing the yields of legumes and it may also have a very beneficial effect on the grain crops. The application of a phosphate fertilizer is strongly to be recommended. Whether rock phosphate or acid phosphate

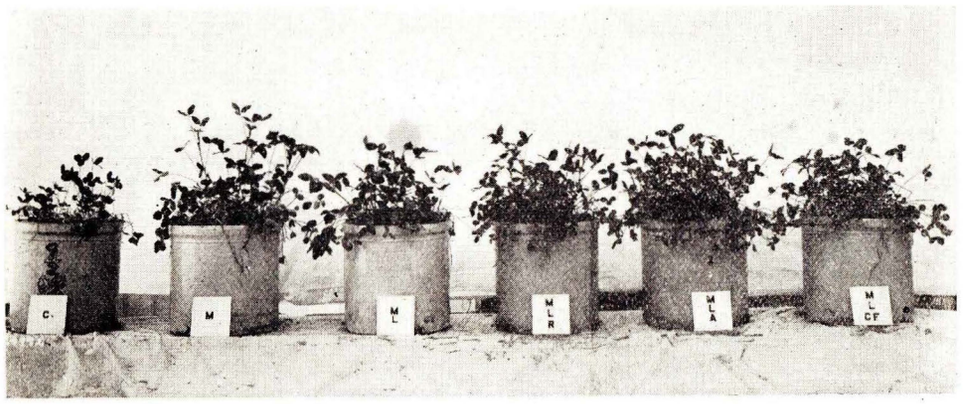



**Fig. 5.** Greenhouse experiment with clover on the Tama silt loam from Grundy County.

TABLE VIII. GREENHOUSE EXPERIMENT, MUSCATINE SILT LOAM, GRUNDY COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 7.3 | 7.9 |
| 2 | Manure | 8.6 | 21.4 |
| 3 | Manure+lime | 9.8 | 23.4 |
| 4 | Manure+lime+rock phosphate | 10.5 | 25.2 |
| 5 | Manure+lime+acid phosphate | 10.8 | 24.1 |
| 6 | Manure+lime+complete commercial fertilizer | 11.7 | 23.8 |

should be employed cannot be definitely stated. Tests of the two materials should be carried out. The use of a complete commercial fertilizer would not seem to be as desirable on this soil as the addition of a phosphate, owing to the greater cost of the complete material and the fact that it does not bring about sufficiently larger increases in crop yields.

### THE RESULTS ON THE TAMA SILT LOAM FROM HARDIN COUNTY

The results secured on the Tama silt loam from Hardin County appear in table IX, only the weight of the wheat grain being secured. The beneficial effect of manure on this soil is quite definitely shown by the increased yield secured. The large influence of lime is also apparent. This is not ordinarily expected but in many cases lime seems to bring about increases in the yields of some of the grain crops. The rock phosphate, the acid phosphate and the complete commercial fertilizer all brought about increases in crop yields, the phosphates giving larger effects than the complete fertilizer. The acid phosphate seemed to be slightly superior to the rock phosphate but the differences were not large and definite conclusions cannot be drawn regarding the relative value of the two phosphates.


Fig. 6. Greenhouse experiment with wheat on Muscatine silt loam from Grundy County.




Fig. 7. Greenhouse experiment with clover on Muscatine silt loam from Grundy County.

These results bear out the conclusions drawn from the tests on the Tama silt loam from Grundy County and indicate the value of manure to this soil. They show furthermore that lime may be of considerable value not only in increasing the legume crop but in bringing about increases in the non-legumes. The use of a phosphorus fertilizer will undoubtedly be desirable on this soil and tests of rock phosphate and acid phosphate are recommended to determine which will give the larger returns. The use of a complete commercial fertilizer is not recommended at the present time as it would seem probable that acid phosphate will be more profitable.

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

The data secured in the greenhouse experiment on the Tama silt loam from Marshall County are given in table X. Manure brought about a distinct increase in the wheat grown on this soil but showed little effect on the clover. Lime in addition to manure increased the wheat yields slightly but brought about a distinct increase in the clover. The rock phosphate had a small effect on the wheat but showed a distinct increase on the clover. The acid phosphate had a larger effect than the rock phosphate on both crops, the increase being particularly large in the case of the clover. The complete commercial fertilizer showed less effect than the acid phosphate on both crops but had a slightly larger effect than the rock phosphate on the clover.

These results bear out those secured on the same soil type from Grundy and Hardin Counties. They indicate the very large value of applications of manure and lime to this soil and the profit which may result from the use of a phosphate

TABLE IX. GREENHOUSE EXPERIMENT
Tama Silt Loam—Hardin County

| Pot No. | Treatment | Weight of wheat grain in grams |
|---|---|---|
| 1 | Check | 8.203 |
| 2 | Manure | 9.372 |
| 3 | Manure+lime | 10.897 |
| 4 | Manure+lime+rock phosphate | 12.280 |
| 5 | Manure+lime+acid phosphate | 12.800 |
| 6 | Manure+lime+complete commercial fertilizer | 11.459 |

fertilizer. Whether rock phosphate or acid phosphate should be employed must be determined by special tests carried out on individual areas.

### THE RESULTS ON THE CARRINGTON SILT LOAM FROM BLACK HAWK COUNTY

The results secured on the Carrington silt loam from Black Hawk County are given in table XI. On this type the beneficial influence of manure is shown both on the wheat and the clover. Lime brought about an increase in clover but showed no effect on the wheat. The rock phosphate with the manure and lime showed no influence either on the wheat or on the clover. The acid phosphate, however, used with the manure and lime, gave a decided increase in both crops, the effects being particularly evidenced in the case of the clover. The complete commercial fertilizer used with the manure and lime showed a greater influence on both the wheat and clover than did the acid phosphate, the increase from the complete fertilizer being particularly large in the case of the clover.

It seems evident that this soil type will respond in a very definite way to applications of manure, lime, and phosphorus. The treatments in all cases showed up particularly well on the clover but there were also some distinct gains in the wheat crop. Only in the case of rock phosphate was no effect evidenced. From the fact that acid phosphate increased the yield of both crops, however, it would appear that phosphorus is needed on this soil. Field tests should be carried out before definite conclusions are drawn regarding the relative value of acid phosphate and rock phosphate. While it seems from this test that the acid phosphate is much more desirable for use, field experiments might indicate superiority for the rock phosphate. The complete commercial fertilizer showed better results than the acid phosphate on the wheat and on the clover. It would not seem desirable, however, to use a complete commercial fertilizer in the field until comparative tests have been carried out, because of the larger cost of the material and the possibility that the increased crop yields secured may not warrant its use.

## FIELD EXPERIMENTS

A field experiment has been started in Grundy 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 Grundy County on the same soil types which occur extensively in this county. The results secured from these experiments will be included here, inasmuch as they indicate quite definitely the fertilizer effects which may be expected on these same soil types in Grundy County. Experiments on the Tama silt loam on the Hudson Field in Black Hawk County, on the Carrington silt loam on the

TABLE X. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 19.75 | 45.36 |
| 2 | Manure | 23.00 | 45.36 |
| 3 | Manure+lime | 23.50 | 49.89 |
| 4 | Manure+lime+rock phosphate | 24.00 | 54.43 |
| 5 | Manure+lime+acid phosphate | 27.50 | 72.63 |
| 6 | Manure+lime+complete commercial fertilizer | 24.00 | 63.50 |



TABLE XI. GREENHOUSE EXPERIMENT
Carrington silt loam—Black Hawk County

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 12.53 | 4.5 |
| 2 | Manure | 14.76 | 15.5 |
| 3 | Manure+lime | 14.67 | 22.5 |
| 4 | Manure+lime+rock phosphate | 13.93 | 21.0 |
| 5 | Manure+lime+acid phosphate | 15.22 | 28.5 |
| 6 | Manure+lime+complete commercial fertilizer | 16.75 | 36.5 |

Springville Field, series I and series II in Linn County, on the Carrington silt loam on the Osage Field in Mitchell County, on the Muscatine silt loam on the Delmar Field in Clinton County, and on the Lamoure silty clay loam on the Everly Field in Clay County are included here.

These field experiments have all been planned with the object of determining the value of certain soil treatments and they are laid out on land which is representative of the particular soil type. 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 crops to insure the securing of accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former system manure is applied while in the latter, crop residues are employed. The other fertilizing materials which were 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 of 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 neutralize the acidity of the soil. Rock phosphate is added at the rate of 2,000 pounds per acre once in a four-year rotation. Since 1925, rock phosphate has been applied at the rate of 1,000 pounds per acre once in four years. Acid phosphate is employed 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 a 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 HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field, series II, in Black Hawk County are given in table XII.

The beneficial effect of applications of manure on this soil type is evidenced by the increased crop yields secured in every season. In some cases very large increases were obtained, as for example on the oats in 1919, on the corn in 1920, on the oats in 1922, on the oats in 1924 and on the timothy in 1926. In every case the manure brought about very profitable increases in yields of the general farm crops which were grown. The application of lime with the manure increased the yields still more in every season, the beneficial effect being particu-

larly evidenced on the clover and timothy in 1925. Appreciable crop increases were also secured, however, on the corn and oats grown in the other seasons.

The application of rock phosphate with the manure and lime increased the yields of crops in most seasons. The beneficial effect was particularly evidenced on the oats in 1919, on the corn in 1920, on the oats in 1924 and on the timothy in 1926. The acid phosphate applied with the manure and lime showed slightly larger effects than the rock phosphate in one or two cases but in general the differences between the yields secured with the two phosphates were very slight. Only in the case of the clover and timothy in 1925 was there any great difference in favor of the acid phosphate. The complete commercial fertilizer had a larger effect than the phosphates in one or two seasons but in many cases it showed a smaller beneficial influence than did the acid phosphate. The oats in 1922 was increased considerably by the complete commercial fertilizer. The corn in 1923 showed a larger effect from the complete fertilizer than from the phosphate. In several seasons the differences were very slight.

The crop residues showed little effect on the crop yields, a beneficial effect being evidenced only in one or two cases. Lime with the crop residues increased the crop yields in every season, bringing about very pronounced gains in the case of the clover and timothy in 1925 and the timothy in 1926. In several seasons the oats and corn were increased to a very large extent by the use of lime, the effect being the greatest on the oats in 1922 and on the corn in 1923.

The rock phosphate with the crop residues and lime brought about increases in crop yields in most seasons. In general the gains were not very large, but in several seasons they were quite definite. The acid phosphate with crop residues

TABLE XII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY HUDSON FIELD SERIES II

| Plot No. | Treatment | (1) 1918 Corn bu. per A. | 1919 Oats bu. per A. | (2) 1920 Corn bu. per A. | (3) 1921 Corn bu. per A. | (4) 1922 Oats bu. per A. | (5) 1923 Corn bu. per A. | 1924 Oats bu. per A. | 1925 Clover and timothy tons per A. | (6) 1926 timothy tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 45.8 | 47.6 | 53.2 | ... | 44.8 | 54.0 | 40.3 | 1.43 | 0.88 |
| 2 | Manure | 49.3 | 54.7 | 62.8 | ... | 53.1 | 59.6 | 50.6 | 1.64 | 1.16 |
| 3 | Manure+lime | 54.4 | 59.2 | 67.4 | ... | 59.6 | 65.2 | 52.2 | 2.03 | 1.21 |
| 4 | Manure+lime+rock phosphate | 56.5 | 64.9 | 73.3 | ... | 58.1 | 61.4 | 63.4 | 2.02 | 1.55 |
| 5 | Manure+lime+acid phosphate | 57.4 | 62.2 | 73.3 | ... | 53.2 | 59.6 | 63.7 | 2.25 | 1.61 |
| 6 | Manure+lime+complete commercial fertilizer | 58.5 | 57.5 | 72.4 | ... | 62.2 | 68.4 | 60.0 | 2.09 | 1.64 |
| 7 | Check | 56.9 | 62.2 | 44.0 | ... | 41.4 | 54.8 | 50.6 | 1.84 | 1.21 |
| 8 | Crop residues | 54.7 | 62.2 | 65.2 | ... | 49.0 | 53.1 | 49.5 | 1.69 | 1.22 |
| 9 | Crop residues+lime | 57.9 | 64.6 | 71.3 | ... | 62.4 | 66.7 | 57.7 | 2.27 | 1.66 |
| 10 | Crop residues+lime+rock phosphate | 62.8 | 58.1 | 74.9 | ... | 59.6 | 65.7 | 66.4 | 2.32 | 1.70 |
| 11 | Crop residues+lime+acid phosphate | 55.6 | 55.8 | 74.9 | ... | 64.4 | 62.8 | 60.9 | 2.36 | 1.79 |
| 12 | Crop residues+lime+complete commercial fertilizer | 52.5 | 57.5 | 74.1 | ... | 71.3 | 62.8 | 61.5 | 2.52 | 2.03 |
| 13 | Check | 54.5 | 57.0 | 71.3 | ... | 59.7 | 50.2 | 48.7 | 1.94 | 1.43 |

1. Four tons lime. Hail damaged corn.
2. Yield on plot 7 evidently an error.
3. Corn cut and put in silo.
4. Not very ripe when cut.
5. Dry season.
6. High yields on crop residue series due to lower ground and more moisture.



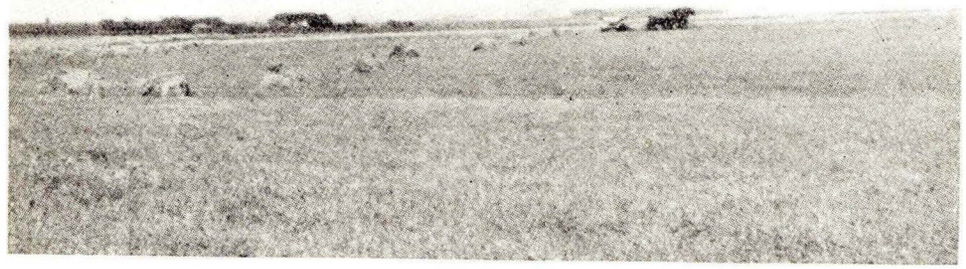


Fig. 8. A field of oats on the Tama silt loam.

and lime showed slightly larger effects than the rock phosphate in one or two cases but in general the yields secured were very similar to those secured on the rock phosphate treated plots. The complete commercial fertilizer with the crop residues and lime had larger effects than the phosphates in several cases. Pronounced gains were secured on the oats in 1922, on the clover and timothy in 1925 and on the timothy in 1926. In several other seasons the complete fertilizer showed no greater influence on the yields than did the phosphates.

These results indicate quite definitely the beneficial effect of applications of manure, lime and a phosphate fertilizer to the Tama silt loam. The value of manure is shown particularly well in this work, very large increases in crop yields being secured from the application of this material. The use of lime along with manure is shown to be very valuable, increases in the yields of general farm crops being obtained in every case. The addition of a phosphate fertilizer seems to be of value on this type, rock phosphate and acid phosphate both bringing about pronounced increases in yields of general farm crops. In some cases the acid phosphate seems to be somewhat preferable for use but in general the increases in yields from the two materials are very similar. Definite conclusions regarding the value of the two phosphates cannot, therefore, be drawn. Tests on individual farms are recommended. The use of a complete commercial fertilizer does not seem to be as desirable as the application of a phosphate. While increases in crop yields are secured in many cases, the increases are not sufficiently large to warrant the greater cost of the complete fertilizer.

### THE SPRINGVILLE FIELD

The results secured on the Carrington silt loam on the Springville Field, series I, in Linn County are given in table XIII. The application of manure to this soil type is apparently of very large value. Considerable increases in crop yields were secured in all but one season. In some cases the increases were very large, as for example, on the corn in 1920, on the corn in 1923, and on 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 and 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 gave better results than the rock phosphate in several cases but in general showed very much the same effect. 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 somewhat 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.

Little effect from the crop residues was evidenced 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.

TABLE XIII. 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. | 1925 Oats bu. per A. | 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 | 2.19 | 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, no results taken.



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 very large difference in the yields 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 on the same soil type in series II in the same field are given in table XIV. 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 effect from the application of the manure. The application of lime with the manure increased the crop yields in practically every season. The clover in 1921 was particularly benefited by the lime and the clover in 1925 showed a very definite increase. In 1922 and in 1923 the corn 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 gave slightly smaller effects. In general the difference between the influence of these 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 on this field. Lime with the crop 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 gave better results than the acid phosphate in one or two seasons but in several other cases it showed smaller effects.

It is apparent from these results that the Carrington silt loam will respond very profitably to applications of manure, lime and a phosphate fertilizer. The value of manure on this soil type is very clearly shown. The use of lime seems to be desirable particularly where legumes are to be grown. The application of a phosphate fertilizer appears to be of value on this soil. Whether acid phosphate or rock phosphate should be used cannot be determined from the data

TABLE XIV. 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. Carried as residual series. No applications made since spring of 1923.
6. Field damaged by hot winds and dry weather.

given inasmuch as the two phosphates brought about very similar crop increases. In some cases the acid phosphate was slightly preferable, while in other cases the rock phosphate gave quite as satisfactory results. Tests of the two phosphates on individual farms are recommended. The use of a complete commercial fertilizer was not as desirable as the application of a phosphate. Increases in crop yields were ordinarily secured but the gains are not sufficiently larger than those brought about by the phosphates to warrant the greater cost of the complete material.

## THE OSAGE FIELD

The results secured on the Carrington silt loam on the Osage Field, series I in Mitchell County, are given in table XV. Manure brought about a beneficial effect on the crops grown on this field in all but one season. In some cases very large yields were noted, as for example on the oats in 1920, clover in 1921, corn in 1922, corn in 1923, 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 cases very considerable increases were noted, as for example, on the corn in 1923 and on the clover in 1921 and 1925. The increased yields in the other seasons were in general quite definite.

The use of rock phosphate with the manure and lime increased the crop yields in practically every season. In some cases the gains were quite definite but in several cases very small increases were secured. The acid phosphate with the manure and lime showed better results 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 great. The complete commercial fertilizer with the manure and lime had a larger effect on the crop yields in



several seasons but in general the differences were not very great and in one or two cases 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, the oats in 1924, the clover and timothy in 1925, and the corn in 1926.

The rock phosphate with the crop residues and lime increased the yields in practically every season. Considerable gains were noted on the oats in 1920, and on the clover and timothy in 1925. In most of the other seasons, the gains were less definite. The acid phosphate with the crop residues and lime brought about better results than the rock phosphate in one or two cases but in several instances had a less beneficial influence. The differences were not very 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 definite increases. The differences were quite definite in one or two cases. In a few instances there was less beneficial effect from the complete fertilizer, however, than from the phosphates.

The results secured on this field bear out the conclusions drawn from the previous field experiments and indicate the large value on the Carrington silt loam of applications of manure, lime and a phosphate fertilizer. The large increases in the yields of general farm crops following the application of manure are very definitely shown. Lime with the manure brings about beneficial effects

TABLE XV. 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 | 51.5 |
| 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. Ice sheet killed out most of the clover in spring of 1925, good stand of timothy.

Fig. 9. Level topography of the Muscatine silt loam.

not only on the legume crops of the rotation but also on general farm crops. The use of a phosphate fertilizer is certainly very 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 results. It is recommended that farmers test acid phosphate and rock phosphate on their own soils, under their particular conditions, to determine which will be the more profitable for them to use. It would not seem that a complete commercial fertilizer should be recommended for use on this soil as acid phosphate or rock phosphate will prob-

TABLE XVI. FIELD EXPERIMENT—MUSCATINE SILT LOAM, CLINTON COUNTY
DELMAR FIELD

| Plot No. | Treatment | 1918 Corn bu. per A. | 1919 Corn bu. per A. | 1920 Barley bu. per A. | (1) 1921 Winter wheat bu. per A. | 1922 Corn bu. per A. | 1923 Oats bu. per A. | 1924 Clover and timothy tons per A. | 1925 Corn bu. per A. | (2) 1926 Oats bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 77.7 | 69.6 | 25.3 | 33.5 | 55.4 | 49.3 | 1.04 | 74.4 | 15.4 |
| 2 | Manure | 81.1 | 65.8 | 28.1 | 28.4 | 65.1 | 54.3 | 1.08 | 78.9 | 17.4 |
| 3 | Manure+lime | 83.3 | 76.1 | 24.9 | 34.9 | 64.6 | 61.1 | 1.08 | 82.7 | 15.6 |
| 4 | Manure+lime+rock phosphate | 88.8 | 75.3 | 32.7 | 30.0 | 71.1 | 61.1 | 1.57 | 91.2 | 23.0 |
| 5 | Manure+lime+acid phosphate | 81.1 | 72.2 | 32.7 | 25.8 | 71.6 | 56.1 | 1.52 | 96.5 | 23.2 |
| 6 | Manure+lime+complete commercial fertilizer | 75.0 | 77.4 | 40.3 | 32.9 | 73.6 | 67.7 | 1.44 | 94.9 | 28.3 |
| 7 | Check | 66.6 | 73.1 | 27.2 | 25.8 | 68.8 | 42.5 | 1.08 | 82.1 | 12.7 |
| 8 | Crop residues | 75.0 | 65.8 | 27.2 | 19.1 | 68.8 | 44.2 | 1.02 | 80.5 | 9.8 |
| 9 | Crop residues+lime | 76.6 | 70.9 | 27.2 | 33.6 | 67.4 | 45.8 | 1.17 | 88.0 | 17.2 |
| 10 | Crop residues+lime+rock phosphate | 78.3 | 69.2 | 34.9 | 27.6 | 70.0 | 62.8 | 1.31 | 94.9 | 17.2 |
| 11 | Crop residues+lime+acid phosphate | 76.6 | 71.4 | 32.2 | 31.3 | 75.7 | 69.7 | 1.44 | 92.2 | 23.6 |
| 12 | Crop residues+lime+complete commercial fertilizer | 70.5 | 70.5 | 32.7 | 29.1 | 73.4 | 61.1 | 1.56 | 89.6 | 20.5 |
| 13 | Check | 64.4 | 67.5 | 24.5 | 23.4 | 68.0 | 45.8 | 0.98 | 73.6 | 15.6 |

1. Wheat very uneven, mixed with rye, clover poor and plowed under.
2. Oats were late in ripening and badly lodged due to rust.



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

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

1. Clover killed out in spots.
2. Soil basic and no lime applied. Corn on plots 2 and 8 not husked.
3. Acid phosphate and potassium chloride (50 pounds per acre) applied to plots 3 and 9.
4. First cutting only.

ably bring about quite as large crop increases owing to the greater cost of the complete fertilizer.

### THE DELMAR FIELD

The results secured on the Muscatine silt loam on the Delmar Field, in Clinton County, are given in table XVI. The application of manure to this soil brought about increased crop yields in most seasons. In general the increases were not very large but in one or two cases, as for example on the corn in 1922, pronounced gains in crop yields were secured. The application of lime along with

Fig. 10. A field on the Waukesha silt loam. Note the gentle rise to the uplands in the background.

manure proved valuable on this soil, bringing about increased yields in most seasons. In several cases very pronounced gains were secured.

The rock phosphate with the manure and lime increased the crop yields in practically all cases. Very pronounced gains were secured on the barley in 1920, the corn in 1922, the clover and timothy in 1924 and the corn in 1925. The acid phosphate with the manure and lime showed no greater effect than the rock phosphate in most cases and in several seasons had a smaller influence. In general, however, the differences between the effects of these two phosphates were not very large. The complete commercial fertilizer with the manure and lime showed a greater effect than the phosphates in one or two cases but in general the differences were not very great and in several seasons there was less effect from the complete fertilizer than from the phosphates.

The crop residues had little effect on the various crops grown on this field. Lime with the residues increased the crop yields to a considerable extent in some seasons, as for example, on the winter wheat in 1921, and on the clover and timothy in 1924.

The rock phosphate with the crop residues and lime showed a beneficial effect on the crops grown in most seasons. In some cases very pronounced gains were secured, as for example, on the oats in 1923 and the clover and timothy in 1924. In several cases no large effects were evidenced from the rock phosphate. The acid phosphate with the crop residues and lime showed a larger effect on the crops grown in several seasons, but no very large differences were noted. The complete commercial fertilizer with the crop residues and lime had a lesser effect than the acid phosphate in most seasons.

The results secured on this field indicate that, altho the type is black in color, and high in organic matter, it will respond to applications of farm manure. Increases in crop yields will generally follow the application of this material and in many cases very large increases may be secured. Lime is necessary on the soil as it is acid in reaction. Not only will the yields of leguminous crops be increased by the use of lime but increases will be secured in many cases in the yields of other general farm crops. The use of a phosphate fertilizer is very desirable on this soil and tests on individual farms of rock phosphate and acid phosphate are recommended. In some cases acid phosphate seems to be preferable but in other instances rock phosphate gives quite as good returns. Definite conclusions regarding the relative value of these two materials cannot yet be drawn. It would not seem that a complete commercial fertilizer would be as desirable for use on this soil as a phosphate inasmuch as the increases secured are not sufficiently great to warrant the use of the more costly material.

### THE EVERLY FIELD

The results secured on the Lamoure silty clay loam on the Everly Field, series II, in Clay County are given in table XVII. The application of manure to this soil type brought about distinct increases in crop yields in most seasons. Very large gains were noted on the corn in 1921, the oats in 1922, the clover in 1923, the corn in 1924 and 1925 and the oats in 1926. This soil was basic in reaction and no lime was applied. The rock phosphate with the manure was beneficial on the various crops grown on this soil in practically every season. In some cases



very large increases were secured, as for example on the clover in 1923, and on the oats in 1926. In general the increases were very pronounced from the use of the rock phosphate. The acid phosphate applied with the manure showed a larger effect than the rock phosphate in practically every season. In several cases very large differences were noted, as for example on the clover in 1919 and on the clover in 1923. The potassium chloride applied with the acid phosphate and manure increased the crop yields in practically every season but the differences were not very large. The complete commercial fertilizer applied with the manure showed less effect on the crops grown than did the acid phosphate.

The crop residues showed little effect on the various crops grown on this field. The rock phosphate with the crop residues increased the crop yields in practically every season, in several cases showing very pronounced gains, as for example on the clover in 1923, on the corn in 1924, and on the oats in 1926. The acid phosphate with the crop residues had a larger effect on the various crops grown than the rock phosphate in practically every season. In some cases very pronounced gains were noted as for example on the corn in 1920, and the clover in 1923. The muriate of potash applied with the acid phosphate and crop residues showed no effect on the various crops grown. The complete commercial fertilizer with the crop residues showed a large effect on the crop yields in several seasons, particularly on the clover in 1919, on the oats in 1922, on the clover in 1923 and on the corn in 1925.

It is apparent that altho this soil type is high in organic matter and black in color it will respond to applications of farm manure. Small amounts applied at proper points in the rotation so that there may be no danger of causing lodging of the small grain, will bring about increases in the yields of general farm crops. The use of a phosphate fertilizer will be very desirable on this soil as rock phosphate and acid phosphate have both been found to bring about large increases in crop yields. In several cases acid phosphate seemed to be preferable for use but in many instances rock phosphate gave quite as large crop increases. Farmers are urged to compare the value of rock phosphate and acid phosphate on their own soils before they make a definite choice between these two. The use of muriate of potash along with acid phosphate gave indications of slight crop increases in several cases but tests of this material on a small scale are recommended before any considerable amounts are applied. Complete commercial fertilizers cannot be recommended for use over acid phosphate or rock phosphate inasmuch as the yields secured were not sufficiently greater to warrant the higher cost of the materials.

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

From the laboratory and greenhouse studies on the soils of Grundy County and from the results secured in the field experiments on the same soil types occurring in adjacent counties, some general conclusions may be drawn regarding the needs of the soils of the county. The results certainly indicate rather definitely the returns which may be secured from the utilization of certain fertilizing materials on the major soils occurring in this county. The treatments recommended are based on the practical experience of many farmers as well as

on experimental data, and no suggestions are offered except such as have been shown to be of value by practical experience.

Tests of certain fertilizing materials are recommended in some cases and these are such as may be carried out quite readily on any farm. It should be emphasized that farmers are quite generally testing the value of certain fertilizing materials on their own soils and they are securing some very interesting and valuable results from such tests. Simple experiments can be carried out on any farm and in this way, it may be determined for the particular soil conditions whether or not any fertilizing material will be valuable or whether one material will have a superior value over another. Wherever definite conclusions cannot be drawn regarding the response of different soils to fertilizer treatments, tests on small areas are recommended.

## LIMING

The soils of Grundy County except the Fargo silty clay loam on the terraces and the Lamoure silty clay loam on the bottoms are all acid in reaction and therefore, in need of lime. For the best growth of legumes such as clover and alfalfa and in general for the most satisfactory yields of general farm crops, lime should be present in the soil. It is important, therefore, that all the upland soils in Grundy County and all the terrace and bottomland types except the Fargo and Lamoure should be tested for acidity. Lime should be applied as the tests show it to be necessary, if the best yields of farm crops and particularly of legumes, are to be secured.

The figures given in the tables earlier in this report indicate only roughly the lime needs of the various soil types. There is a wide variation in the acidity and lime requirements of soils and even soils of the same type from different areas may show a wide divergence in lime requirement. It is necessary, therefore, that the soil in any field be tested for its lime needs before any application is made. Only in this way will it be possible to supply the proper amount of lime and thus secure the best results. Farmers may test their own soils for acidity but it will usually be much more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

Experimental data secured in the greenhouse and in the field as has been pointed out earlier in this report have shown some rather striking increases in crop yields where applications of lime have been made to the acid soils of this county. The beneficial effects of lime on crop yields have been shown likewise in considerable farm experience and wherever the soils are strongly acid, as is the case in this county, the use of lime has been found to be of large economic value. It is certainly evident, therefore, from experimental data and from experience that the use of lime on the acid soils of Grundy County will bring about very profitable effects.

Further information regarding the use of lime on soils, losses by leaching and other points connected with liming are given in Extension Bulletin No. 105 of the Iowa Agricultural Experiment Station. A list of companies prepared to furnish this material is also given in this bulletin.



## MANURING

The soils of Grundy County are in general fairly well supplied with organic matter and they are quite generally dark in color. In one or two cases there seems to be a very satisfactory supply of this constituent and particularly on the bottomland soils the supply of organic matter is high. In one or two cases, however, where the soil is coarse in texture as for example in the Carrington fine sandy loam and the Shelby gravelly sandy loam on the uplands and the O'Neill sandy loam on the terraces, the supply of organic matter it not high. On the two most extensive upland soils, the Tama silt loam and the Carrington silt loam, there is no very large content of organic matter altho the supply is sufficient to give these soils a dark brown to black color. It is very necessary, however, that organic matter be added to all the soils in the county at regular intervals if the supply is to be kept up. On those types which are rather low in this constituent the addition of fertilizing materials supplying organic matter is particularly necessary at the present time.

The most important natural fertilizing material which can be employed on the farm at the present time is farm manure. This plays a large part in the increasing, and maintaining of the supply of organic matter in the soil. It is valuable on those types which are sandy in texture and low in organic matter, but it also brings about large crop increases on soils which are apparently better supplied with organic matter and darker in color. The application of manure has been found to be extremely valuable on the Tama silt loam and the Carrington silt loam on the uplands of this county as well as on the Muscatine silt loam, which is blacker in color and richer in organic matter. Increases have also been secured on the Lamoure silty clay loam on the bottoms, a soil type which is very dark in color and high in organic matter. The effect of farm manure would be very large on the fine sandy loams and sandy loams on the uplands and terraces. On the heavy types, dark in color and rich in fertility, small amounts of manure may be of value. The application of the manure should not be made to such types immediately preceding the growing of small grain crops since it may cause the crop to lodge. When applied in small amounts at other points in the rotation, however, profitable crop increases are secured from the use of manure.

The ordinary application of manure to soils amounts to about 8 to 10 tons per acre once in a four-year rotation. Larger applications than this are rarely desirable except where the soils are very coarse in texture or where truck crops are to be grown. On average soils where general farm crops are to be grown the largest increases in crop yields per ton of manure are secured when 8 to 10 tons are employed.

All the crop residues produced on the farm should be returned to the land as they aid materially in keeping up the supply of organic matter and they also return to the soil considerable amounts of plant food constituents which have been removed by the crops grown. If they are burned or otherwise destroyed there is considerable loss of valuable fertilizing constituents. On the livestock farm, the residues may be used for feed or bedding and returned to the land with the manure. On the grain farm, they may be stored and allowed to decompose partially before being applied to the land or they may be applied directly.

Green manuring is frequently a very desirable farm practice. On grain farms where farm manure is not produced it is absolutely necessary if the supply of organic matter in the soils is to be kept up. On the livestock farms it is an important practice as a supplement to the use of farm manure. It is generally much more desirable to use legumes for green manuring purposes because of the fact that they not only supply organic matter but when well inoculated they take nitrogen from the atmosphere and thus they serve to increase the supply of this constituent in the soil. There are many cases where the use of legumes as green manures is very desirable in Grundy County. Care should always be exercised, however, when this practice is followed as undesirable results may occur if the conditions in the soil are not satisfactory for the best decomposition of the green material.

## THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of Grundy County is generally quite low and it is apparent, therefore, that phosphorus fertilizers will be needed on the soils of the county in the very near future. Furthermore it would seem quite probable that in many cases phosphorus carriers might be of very large value at the present time. Greenhouse and field experiments carried out on the leading soil types occurring in this county have indicated quite definitely the value of the application of phosphorus fertilizers on these soils.

There are two phosphorus fertilizers which may be employed, rock phosphate and acid phosphate. The acid phosphate provides the element phosphorus in the form immediately available for plant use. It is applied at the rate of about 150 to 200 pounds per acre annually. Rock phosphate, on the other hand, carries the element phosphorus in a form from which it is only slowly made available in the soil. The rock phosphate is applied at the rate of one-half to one ton per acre once in a four-year rotation, according to common practice. While the acid phosphate costs more per ton the larger application of the rock phosphate causes a greater outlay of money for the application. To determine the relative value of the two phosphates, tests must be carried out over at least one four-year rotation. The total cost of the application of the two materials must be compared with the value of the crop increases secured.

Experiments which have been reported on the main soil types occurring in the county have compared the value of rock phosphate and acid phosphate but definite conclusions cannot be drawn from these data. In some cases the acid phosphate seems to be preferable for use but in other instances the rock phosphate has given quite as satisfactory results. It is urged, therefore, that farmers test the two phosphate fertilizers on their own soils and thus determine for their particular conditions which material will be the more profitable. Simple tests may be carried out quite readily on any farm. Directions which may be followed in the conducting of such tests are given in circular 97 of the Iowa Agricultural Experiment Station.

While most of the soils of Grundy County are fairly well supplied with nitrogen, there are one or two cases where the content is not high and in these instances the addition of fertilizing materials containing nitrogen is very necessary. Even on those types which are better supplied, the use of nitrogen-containing fertilizers at regular intervals will be very necessary for the maintenance of permanent fertility in the soils of this county.



On livestock farms, the proper preservation and use of the farm manure will aid materially in keeping up the supply of nitrogen in the soil. On the grain farms some other nitrogenous fertilizer must be employed. In many cases on the livestock farms there is not sufficient manure produced to supply the needs of all the soils and in such cases some other nitrogenous fertilizer must be used.

The use of leguminous crops as green manures is the best method of supplying nitrogen to the soil. When the legume is well inoculated, it takes a large part of its nitrogen from the atmosphere and hence when the crop is turned under in the soil as a green manure there will be a correspondingly large increase in the nitrogen content of the soil. There are many cases in Grundy County where the turning under of legumes as green manures would be very profitable as a supplement to the use of farm manure or a substitute for that material.

The proper use of all crop residues will aid considerably in keeping up the supply of nitrogen in the soils of the county as these materials return to the land considerable amounts of the elements which have been removed from the soil by the crops grown.

It does not seem likely that commercial nitrogenous fertilizers will prove valuable on the soils of Grundy County at the present time. The nitrogen supply in the soils of the county may be built up and maintained more cheaply by the proper use of leguminous green manures, farm manure and crop residues. Small amounts of nitrates as top dressings might be of value in some cases but for general farm crops it is not likely that sufficiently large crop increases would be secured to warrant the cost of the application.

Earlier analyses have indicated that the soils of Grundy County are very well supplied with potassium and it would not seem that potassium fertilizers would prove profitable for general use at the present time. In some cases reports have indicated that small amounts of muriate of potash have yielded profitable crop increases on some of the soils of this county but from the experimental data which has been discussed earlier it would not seem that the increases are sufficiently large to warrant the cost of the potassium fertilizer. It may be that potassium fertilizers may be used with profit in some cases and it is recommended, therefore, that tests be carried out on small areas if farmers are interested in the use of these fertilizers. Applications should not be made to large areas until tests have indicated definite value for the use of the particular potassium fertilizer. Small amounts as top dressings might be desirable in some cases and in general it may be said that wherever tests on small areas have indicated profit from the application, the particular fertilizer may be applied extensively with the assurance of profit.

The general use of complete commercial fertilizers in the county cannot be recommended at the present time. Experiments which have been discussed earlier in this report have indicated quite as beneficial effects from the application of phosphate fertilizers as from the use of complete commercial fertilizers. Inasmuch as the latter materials are much more expensive for application it is obvious that they must bring about very much larger increases in crop yields than those occasioned by the phosphates if they are to prove economically more profit-

able. Tests of complete fertilizers may be carried out on the farm in comparison with the phosphates, however, and if beneficial effects are secured and the results from the use of the complete fertilizers prove them to be economically profitable then there can be no possible objection to their application. Before there is any large use of a complete commercial fertilizer, however, for general farm crops it is urged that tests be carried out on small areas in comparison with a phosphate. For truck crops and garden crops, certain brands of complete commercial fertilizers are of considerable value and may often be used with distinct profit.

## DRAINAGE

The natural drainage system of Grundy County is very well developed as has been indicated by the map given earlier in this report. The streams in the county with their tributaries and intermittent drainageways extend into practically all parts of the uplands. There are many areas, however, where the installation of tile would be of considerable value for improving the drainage condition. The Clyde silty clay loam which occurs in level to flat or depressed areas in the upland, is naturally poorly drained. The Muscatine silt loam which occupies broad level areas, on the loessial upland possesses a rather heavy impervious subsoil and drainage of this type is frequently very desirable. On the terraces the drainage of the Fargo silty clay loam is very necessary. The bottomland types are all poorly drained. There are some areas in the more extensive Tama and Carrington silt loams on the uplands also where drainage would be of help. The installation of tile is valuable in many places in this county. In general it may be said that wherever the soils are too wet, good crop yields will not be secured and the first treatment needed for satisfactory crop production is the installation of tile.

Tiling may be somewhat expensive but the results secured always warrant the outlay. Farmers in Grundy County should see that their land is well tiled out if they wish to secure the best crop yields. The application of fertilizers will give no returns if the areas are poorly drained. Considerable data are available to show the benefits of tiling out wet land and in many cases it may mean the difference between a crop failure and very satisfactory crop yields. In general it will mean the difference between a fair to poor crop yield and a very satisfactory one.

## THE ROTATION OF CROPS

It has become a very well recognized fact that the continuous growing of any one crop will very rapidly reduce the fertility of the soil and the yields of that crop will very quickly decline. Sometimes, however, the economic value of some crop will induce farmers to grow that crop on the same land year after year. Very quickly they will note decreases in crop yields, and soon the growing of the crop will become unprofitable. When a rotation is practiced the yields do not decrease so rapidly and even if the different crops grown in the rotation are somewhat less in money value, the total value of all the crops grown over a period of years will be very much greater where a rotation is practiced. For permanent fertility the rotation of crops is absolutely essential.

A number of rotations are being followed successfully in various parts of the state and while no particular tests have been carried out in Grundy County,



these rotations may be suggested and from among them some one may be chosen which will be suited to the conditions of this county. No one rotation can be recommended as the best rotation, but almost any one will serve provided it contains a legume crop and the money crop. From among the following suggested rotations some one may be chosen or a modification may be worked out for a suitable rotation for use in Grundy County.

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

Erosion occurs only to a limited extent in Grundy County but there are a number of areas in the upland where considerable washing has occurred. The Carrington fine sandy loam and the Shelby gravelly sandy loam are usually somewhat eroded. There are areas in the Tama silt loam and the Carrington silt loam where the topography is more rolling and here considerable erosion has taken place. The washing away of the surface soil has occurred to some extent and frequently gullying is noted. Wherever these effects of erosion occur some means of prevention or control of the destructive action should be adopted.

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, or 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 GRUNDY COUNTY †‡

There are 11 soil types in Grundy County and these with the area of meadow make 12 separate soil areas in the county. They are divided into four groups on the basis of their origin and location known as drift soils, loess soils, terrace soils, and swamp and bottomland soils.

### DRIFT SOILS

There are four drift soil types in the county classified in the Carrington, Clyde and Shelby series. Together they cover 27.2 percent of the total area of the county.

#### CARRINGTON SILT LOAM (83)

The Carrington silt loam is the most extensively developed drift soil in the county and the second largest soil type. It covers 23.8 percent of the total area. It is the chief upland type in the northern part of the county, being found in extensive areas thruout Fairfield, Beaver, Pleasant Valley, German, and Grant Townships. Other extensive areas of the type are found scattered thruout the

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

†Grundy County adjoins Black Hawk County on the east and Marshall County on the south. In places the soil maps of these areas do not agree along the boundaries. A part of the Tama silt loam as mapped in Black Hawk County is classed with the Carrington silt loam in Grundy County as the loess over the drift is now considered too shallow to allow the soil to be placed in the Tama series. The Carrington loam as mapped in Marshall County occupies such a small area in Grundy County that it has been included with the Carrington silt loam.

‡The descriptions of individual soil types given in this section of the report very closely follow those of the Bureau of Soils Report.



uplands in other parts of the county. It is the chief upland type in the drift section of the county which occupies about one-third of the total area. In the loessial upland section of the county, constituting the southern two-thirds, small areas of the Carrington silt loam are found adjacent to the bottomlands along the streams or intermittent drainageways which extend thruout the various parts of the county.

The surface soil of the Carrington loam is a dark brown silt loam, extending to a depth of about 12 inches. The upper subsoil is a brown silt loam to silty clay loam. The lower subsoil is a yellowish-brown gravelly silty clay loam, extending to a depth of three feet or more. In places it contains much coarse material, pebbles and boulders. In the northeastern part of the county and along the Black Hawk County line boulders are very common.

In topography the Carrington silt loam is undulating to gently rolling but there are a few areas where the topography is flat to level. Occasionally the type becomes strongly rolling in topography. This is the case in many areas of the type in German and Pleasant Valley Townships. The drainage of the soil is very well developed in general but there are a number of level or poorly drained areas.

All of the type is in cultivation. Corn is the chief crop grown, followed by oats, clover and timothy. The yields of general farm crops are very much the same as those secured on the Tama silt loam. Corn averages 45 bushels per acre, oats about 50 bushels per acre, and hay 1½ to 2 tons per acre.

Increased crop yields may be secured by proper methods of treatment of the Carrington silt loam. Experiments which have been reported earlier have indicated the large value of applications of manure to this type. Increases in the yields of general farm crops are considerable when manure is applied in ordinary amounts. The type is acid in reaction and will respond to additions of lime. It should be tested regularly for lime needs and the amount of lime necessary should be added for the best growth of general farm crops and particularly for securing satisfactory yields of legumes. The type will respond in a profitable way to applications of a phosphate fertilizer. Tests of rock phosphate and acid phosphate are recommended. The experiments which have been reported where these two phosphates have been applied to this soil have indicated the response to phosphorus fertilizers but they have not shown definitely whether acid phosphate or rock phosphate will be more profitable for use. Complete commercial fertilizers do not seem to be as desirable on this type as the use of a phosphate.

#### CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is the second largest drift soil, covering 3.0 percent of the total area. It is developed in small areas in practically all parts of the county. The most extensive development of the type is found in the northern part of German Township, near Stout in Beaver Township, east and northwest of Dyke near the Black Hawk County line north of Zaneta, and northeast of Lincoln Center. Many small areas are found thruout the southern two-thirds of the county. Here the type occurs along small draws extending for some distance up the slopes and into the uplands. In the drift areas it is found in depressed areas in the uplands.

The surface soil of the Clyde silty clay loam is a black heavy silt loam or silty clay loam to a depth of 5 to 6 inches. Below this point and extending to a depth of 10 or 12 inches there is a subsurface layer consisting of a black rather heavy silt loam to silty clay loam. The upper subsoil is a black silty clay loam to heavy silty clay, sticky when wet but breaking into a granular structure when dry. This passes into a dark gray and then into a gray silty clay loam, which in turn is underlaid by a grayish to light grayish silty clay, mottled with yellow and brown. Pebbles, sand and gravel occur in the subsoil and in many areas there are numerous boulders upon the surface and in the subsoil.

Included with the type there are many small areas where the drainage is poor. Here the surface soil is a black silty clay loam to a depth of 8 or 10 inches, underlaid by a gray to light gray heavy silty clay to clay, mottled with gray and yellow and in places with reddish-brown or red. Many of these areas are covered with boulders and utilized only for pasture. Another variation of the type consists of small areas in which there are no boulders, the drift or glacial material appearing only in the lower part of the three foot section.

In topography the Clyde silty clay loam is flat to level or depressed. Natural drainage is inadequate because of the topographic position and because of the rather impervious nature of the soil.

Most of the Clyde silty clay loam is cultivated, the remainder being utilized for pasture. Corn is the most important crop and in favorable seasons satisfactory yields are secured. Red clover is grown and soybeans and rape are sometimes produced.

Yields of general farm crops on this type may be considerably improved by proper treatment. The soil needs first of all to be well drained and the installation of tile is the first treatment needed to make it satisfactorily productive. Small applications of farm manure will be of value in stimulating the production of available plant food. Manure should not be applied to this type immediately preceding the growing of the small grain crop. Small amounts applied at other points in the rotation, however, will be of considerable value. The type is acid in reaction and will respond to lime for the best growth of legumes. The application of a phosphate fertilizer is strongly to be recommended. Tests of acid phosphate and rock phosphate are urged on this soil.

### CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county, covering only 0.3 percent of the total area. It is developed in a number of small areas in the northern drift section of the county, being found along the Butler County line in Fairfield Township, south of Wellsburg, near the Hardin County line west of Conrad, southeast of St. Petersburg, northeast of Buck Grove and near Salem Church. None of the areas of the type are very extensive, the largest being those near Salem Church.

The surface soil of the Carrington fine sandy loam is a dark brown fine sandy loam, extending to a depth of about 10 inches. The subsoil is a brown to yellowish-brown, rather heavy fine sandy loam, grading into a yellowish-brown fine sandy loam. The lower subsoil usually contains rather coarse sand to loamy sand. In many places the soil below 8 inches is a pale yellow silt loam. In



topography the type is undulating to rolling and drainage is good to excessive.

Practically all of the soil is under cultivation, some of it being used for growing watermelons and other early truck for the local markets. Corn, oats and other general farm crops are grown occasionally. The yields of general farm crops are rather low on this soil owing to its comparatively low fertility and sandy nature. Where it is used for general farm crops or for truck crops liberal applications of farm manure are very desirable. The turning under of leguminous crops as green manure would help the soil to retain moisture and to be more productive. The application of fertilizers would be valuable on the type for general farm crops and the use of acid phosphate would undoubtedly prove profitable. Where truck crops are to be grown applications of a complete commercial fertilizer would undoubtedly yield profitable returns. The type is acid in reaction and if legumes are to be grown the application of lime is necessary. The treatment most needed on this soil is the incorporation of organic matter and the addition of farm manure or the turning under of green manure.

### SHELBY GRAVELLY SANDY LOAM (196)

The Shelby gravelly sandy loam is a minor type in the county, covering 0.1 percent of the total area. It is found in the southwestern part of Lincoln Township, occurring in the region of the "pahas" on slopes where the sandy underlying drift material is exposed. There are several small areas of the type.

The surface soil of the Shelby gravelly sandy loam is a brown gravelly sandy loam to an average depth of 10 inches. The subsoil is a yellow to reddish-brown gravelly sandy clay or sticky gravelly sandy loam. In many places the surface soil and subsoil contain large amounts of coarse sand. Where the sand is of a finer texture the surface has a dark brown color. In topography the type is sharply rolling and drainage is good to excessive.

General farm crops are grown but the yields are usually low on this soil, as it is apt to be droughty. When it is to be cultivated it needs first of all to have liberal applications of farm manure applied. The turning under of leguminous crops as green manures would be of large value in making this soil more productive. The type is acid and should be limed for the best growth of legumes. The application of a phosphate fertilizer undoubtedly would be valuable for the growing of general farm crops. Tests of acid phosphate are recommended. The incorporation of organic matter with this soil will reduce the danger of crops suffering from drought and will make the soil more productive.

## LOESS SOILS

There are two loess types in the county, the Tama silt loam and the Muscatine silt loam. Together they cover 50.3 percent of the total area of the county.

### TAMA SILT LOAM (120)

The Tama silt loam is the largest individual soil type in the county and the most extensively developed loess soil. It covers 46.8 percent of the total area. It is the chief upland type in the southern two-thirds of the county, occurring in extensive areas thru all parts of the upland.

The surface soil of the Tama silt loam is a dark brown to almost black friable silt loam, 10 to 12 inches in depth. This is underlaid by a dark brown to brown heavy silt loam or clay loam. The subsoil at about 20 inches is a brown or

yellowish-brown friable silty clay loam. In some places a loose mellow dark brown silt loam extends from the surface to a depth of 36 or 38 inches. In other areas at a depth of 8 to 10 inches the soil has a slightly reddish tinge which continues downward to the yellowish lower subsoil.

In topography the Tama silt loam is gently undulating to slightly rolling, but in a few areas it is sharply rolling in topography. The drainage of the soil is naturally good but in some individual areas where the topography is more nearly level, drainage conditions may be improved thru the installation of tile.

Practically all of the Tama silt loam is under cultivation. Corn, oats and clover are the chief crops grown. Corn yields about 45 bushels per acre on the average, and in favorable seasons it yields 50 to 60 bushels per acre. Oats yield about 60 bushels per acre, frequently, however, showing very much larger yields. Red clover averages about 1¾ tons per acre; clover and timothy about 1½ to 2 tons per acre.

Altho this is naturally a very productive soil it will respond readily to applications of certain fertilizer treatments. The results given earlier in this report have indicated how valuable the application of farm manure is to this soil. Increased yields of general farm crops are quite commonly secured. The type is acid in reaction and will respond to applications of lime. The use of a phosphate fertilizer is recommended and tests of acid phosphate and rock phosphate under individual farm conditions are very desirable. Experiments reported with these two phosphate fertilizers have not permitted drawing definite conclusions regarding their value. In some cases acid phosphate seems preferable while in other instances rock phosphate is quite as good. It is safe to say that one or the other of these phosphates will certainly prove profitable for use on this soil where general farm crops are to be grown.

### MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the second largest loess soil in the county, covering 3.5 percent of the total area. It occurs in a number of rather extensive areas in the southwestern part of the county. The largest developments of the type are found in Palermo, Clay and Felix Townships. Other small areas occur in Melrose and Shiloh Townships.

The surface soil of the Muscatine silt loam consists of a very dark brown to almost black mellow silt loam, extending to a depth of 10 to 16 inches. This is underlaid by a brownish-gray, drab or slate colored silty clay loam to silty clay, faintly mottled with brown, yellow or gray. The subsoil to a depth of 36 inches is a compact brownish-gray or drab silty clay, mottled with brown or gray. Included with the type there are some small slightly elevated areas where the soil is very much like the Tama silt loam. These areas were too small to separate on the map. In them the surface soil is darker in color than the typical Tama and the subsoil is somewhat heavier in texture.

In topography the Muscatine silt loam is level to depressed, occurring where there were former shallow lakes. In most cases the topography is flat to depressed and hence the drainage is poor. The heavy subsoil condition also tends to limit the natural drainage.

Practically all of the type is under cultivation and in favorable seasons very satisfactory crop yields are secured. General farm crops grown include corn, oats, timothy and clover. Average yields of corn are from 50 to 60 bushels per acre, oats about the same and clover and timothy about 2 tons per acre.



The needs of this soil to make it more productive include first of all adequate drainage which can readily be accomplished thru the proper installation of tile. Only when the type is well drained will the large yields which it is capable of producing be secured. The soil is acid in reaction and additions of lime are necessary for the best growth of legumes. While the type is high in organic matter and dark in color, small amounts of farm manure have been found to be of considerable value for the growth of general farm crops. This material should not be applied preceding the growing of the small grain crop of the rotation but applications of small amounts at other points in the rotation are of value. The use of a phosphate fertilizer is strongly to be recommended. Tests with acid phosphate and rock phosphate have indicated large returns from the use of one or the other of these phosphates. A definite choice between the two cannot yet be made. Farmers are urged to test both acid phosphate and rock phosphate under their own conditions to determine which will be the more profitable for use.

## TERRACE SOILS

There are three terrace types in the county classified in the Waukesha, Fargo and O'Neill series. Together they cover 5.7 percent of the total area of the county.

### WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the most extensively developed terrace soil, covering 4.5 percent of the total area. It occurs in numerous areas on the high terraces along the various streams of the county. The most extensive occurrences are found along Black Hawk Creek, North Fork Black Hawk Creek, and Beaver Creek. The largest areas of the type occur in the vicinity of Dyke, Reinbeck, Morrison and where Beaver Creek leaves the county. Other areas are mapped along Hammers Creek, Beaver Creek and Black Hawk Creek and its tributaries.

The surface soil of the Waukesha silt loam is a dark grayish-brown silt loam, extending to a depth of about 12 inches. The subsoil is a brown to light brown silty clay loam. In some places the surface soil is a black silt loam and the subsurface layer is a much darker brown than in the typical soil. The subsoil is brown in color.

Small areas of gravelly material which were not large enough to map separately have been included with the Waukesha silt loam on the outer edges of the terraces along the stream bottoms. Where these areas are of sufficient size they are mapped as the O'Neill sandy loam. With the Waukesha silt loam, small areas are also included where the lower subsoil is composed of a gritty sandy loam. In topography the type is nearly level to gently undulating. The natural drainage is good but there are a few places where the areas occur in low basin-like situations which were formerly shallow lakes. These areas would be improved by tiling. The type occurs on the second bottoms well above overflow.

The Waukesha silt loam is all under cultivation, general farm crops including

corn, oats and hay being grown. The yields of these crops are very much the same as those secured on the Tama silt loam on the uplands.

The type will respond in a very large way to applications of farm manure and liberal amounts of this material should be employed. It is acid in reaction and additions of lime will be of value where legume crops are to be grown. The addition of a phosphate fertilizer will be useful on this soil and tests of acid phosphate and rock phosphate are recommended.

### FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is the second largest terrace soil in the county, covering 0.9 percent of the total area. It occurs in numerous small areas in various parts of the county, the largest developments of the type being found in the western townships, particularly in Shiloh and Melrose Townships. There is a rather considerable development of the type also north of the North Fork Black Hawk Creek in Beaver and Fairfield Townships. The largest individual area of the type is north of Stout.

The surface soil of the Fargo silty clay loam is a black silty clay loam to a depth of 6 to 8 inches, underlaid by a black silty clay, extending to a depth of 14 to 18 inches. The subsoil is a yellow and gray or drab mottled silty clay, high in content of lime. The subsoil is heavy when moist and upon drying assumes a granular structure. In some places the surface soil shows a white coating in dry seasons. These spots are locally known as "alkali" spots. In topography the soil is flat to level or depressed and the natural drainage conditions are poor.

Practically all of the Fargo silty clay loam is under cultivation and, in favorable seasons, good yields of general farm crops are secured. The type needs, first of all, to be thoroly drained if crop yields are to be entirely satisfactory. When this is accomplished the application of small amounts of farm manure will be of value in stimulating the production of available plant food. Farm manure should not be applied to the soil, however, preceding the growing of small grain crops, since it may cause the crop to lodge. The type will undoubtedly respond to applications of a phosphate fertilizer and tests of rock phosphate and acid phosphate are recommended. Where the so-called "alkali" condition occurs in this soil, the treatments needed are the thoro drainage of the particular areas where the "alkali" has appeared. Following thoro drainage, the plowing under of large applications of fresh horse manure or the turning under of sweet clover, red clover or other green crops has been found to be very desirable in stimulating the removal of the excess content of salts which characterizes these spots.

### O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a minor type in the county, covering only 0.3 percent of the total area. It is found in irregular narrow strips on the high terraces along the east side of Beaver Creek, west and south of Dike, south of Zaneta, northwest of Morrison, near Lincoln Center, northwest of Wellsburg and south of Beaman.

The O'Neill sandy loam is a dark brown sandy loam, extending to a depth of about 8 inches. The subsoil is a dark brown heavy sandy loam, underlaid at about 18 inches by a yellowish-brown sandy loam. In places the underlying material seems to be a coarse sand or gravel. The type mapped near Dike consists of a dark brown to black silt loam surface soil to a depth of 8 to 10 inches, underlaid by 10 or 12 inches of a brown silt loam or brown to light brown silty clay loam, which in turn is underlaid by a gravelly fine sandy loam to gravelly loam. In topography the soil is level but in general the drainage is good to excessive.



All the type is either in cultivation or in pasture, corn and clover being the chief crops grown with some oats, rye and soybeans. The type is well suited to melons and other truck crops.

The crop yields on the O'Neill sandy loam are rather low owing to the droughty character of the soil. It will respond readily to applications of farm manure and liberal amounts of this material should be employed. The turning under of leguminous crops as green manure would be valuable in improving the condition of this soil for crop growth. The application of lime is necessary for legume growth as the soil is acid. The use of a phosphate fertilizer would be very desirable for general farm crops and tests of acid phosphate are recommended. Where truck crops are to be grown the use of a complete commercial fertilizer would undoubtedly prove valuable.

## SWAMP AND BOTTOMLAND SOILS

There are two swamp and bottomland soils in the county, classified in the Wabash and Lamoure series, and an area of meadow. Together they cover 16.8 percent of the total area of the county.

### WABASH SILT LOAM (26)

The Wabash silt loam is the largest bottomland soil and the third most extensively developed type, covering 12.1 percent of the total area. It is extensively developed on the bottomlands along the streams in practically all parts of the county. The largest development of the type is found along Black Hawk Creek and North Fork Black Hawk Creek in the eastern part of the county. There are also rather extensive areas of the type along Beaver Creek in Pleasant Valley Township.

The surface soil of the Wabash silt loam consists of a dark brown to black friable mellow silt loam, extending to a depth of about 13 inches. The subsoil is a black silty clay rather stiff and sticky when wet but granular under ordinary moisture conditions. In some areas the subsoil is a dark drab to gray heavy silty clay loam. In the lower part of the 3 foot section there may be a somewhat sandy material of a yellowish-brown color with faint mottlings. In some areas which are included with the type, the surface soil consists of a black silt loam to an average depth of about 12 inches, overlying a grayish sand to very fine sandy loam. In the area along the Black Hawk County line near Hicks the type is less well drained and the soil is a rather heavy silt loam to silty clay loam. In topography the soil is flat to depressed and natural drainage is fairly well established. Where the soil is protected from overflow it is fairly well drained.

The major part of the Wabash silt loam supports an excellent pasture. When it is cultivated general farm crops are grown, corn and oats and hay being produced chiefly. Corn yields from 40 to 60 bushels per acre, oats about the same and hay 1½ to 2 tons per acre. This type needs first of all to be protected from

overflow if general farm crops are to be successfully grown year in and year out. Some of the areas of the type need to be drained after protection from overflow has been provided. Small applications of farm manure will be of value on this soil in increasing the yields of general farm crops. Large applications should not be made preceding the growing of the small grain crop. Small amounts at other points in the rotation will bring about large crop increases. The type is acid and applications of lime will be of value. The use of a phosphate fertilizer would undoubtedly be valuable on this soil and tests of acid phosphate and rock phosphate are recommended.

### LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is the second largest bottomland soil, covering 4.4 percent of the total area. It occurs rather extensively in various parts of the county on the first bottoms along some of the smaller streams and smaller tributaries of the larger streams. The largest developments of the type are north of Colfax Center Church, north of Morrison, southwest of Lincoln Center, east and northeast of Fern, and between Fredsville and Stout.

The surface soil of the Lamoure silty clay loam is a dark brown to black heavy friable silt loam or silty clay loam, extending to a depth of about 12 inches. This is underlaid by a dark drab or black silty clay to a depth of 36 inches. In some areas, in the lower part of the three foot section there are faint mottlings of drab or gray and yellowish-brown. Lime occurs in considerable amounts thruout the entire soil section.

In the areas where the soil is more poorly drained, the subsoil is rather plastic and mottlings occur extensively. In these areas the surface soil is often a rather heavy silty clay loam. In some of the better drained locations, the type consists of a heavy silt loam to a depth of nearly three feet, and the color is usually black from the surface thruout the entire soil section.

In topography the Lamoure silty clay loam is nearly level but there are some slight depressions or basin-like, poorly drained areas. The natural drainage of the soil is poor owing to the topographic position and to the heavy, impervious character of the subsoil material.

Practically all of the Lamoure silty clay loam is under cultivation, only the poorly drained areas being left in pasture or in native hay. The most important crops grown are corn, oats and hay. Some alfalfa and sweet clover are produced. Crop yields are good on this soil when it is well drained and seasonal conditions are satisfactory. The first treatment needed for better growth is the installation of tile and the thoro drainage of the soil. Small applications of manure will be of value on this soil as has been indicated by the field experiments discussed earlier in this report. Manure should not be applied preceding the growing of small grain crops but small amounts at other points in the rotation will bring about pronounced increases in the yields of general farm crops. The application of a phosphate fertilizer would undoubtedly be valuable and tests of acid phosphate and rock phosphate are recommended. The data presented have indicated greater value from the use of acid phosphate but in many cases rock phosphate might be quite as desirable for use. Farmers are urged to test both phosphates under their own individual conditions.



### MEADOW (20)

There is a small area of meadow in the county, covering 0.3 percent of the total area. It has been mapped in narrow strips of land which is subject to overflow, on the bottoms northeast of Reinbeck, along Black Hawk Creek and along the North Fork Black Hawk Creek and in a narrow strip 5 miles long on Beaver Creek.

Meadow consists of bottomland soils which are so variable in texture that it is impossible to separate them into distinct soil types. It includes soils ranging from sands to clays. The sands often occur in patches varying in depth from 10 inches to 2 feet or more.

Most of the area in meadow is used for pasture and blue grass seems to provide a very good pasture. In a few areas where it is cultivated, fairly satisfactory crop yields are secured. In these areas larger yields might be secured by proper methods of treatment. The land should, first of all, be well drained and protected from overflow, it will then respond to small applications of farm manure, the application of lime to remedy acid conditions and the use of a phosphate fertilizer.

# 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.

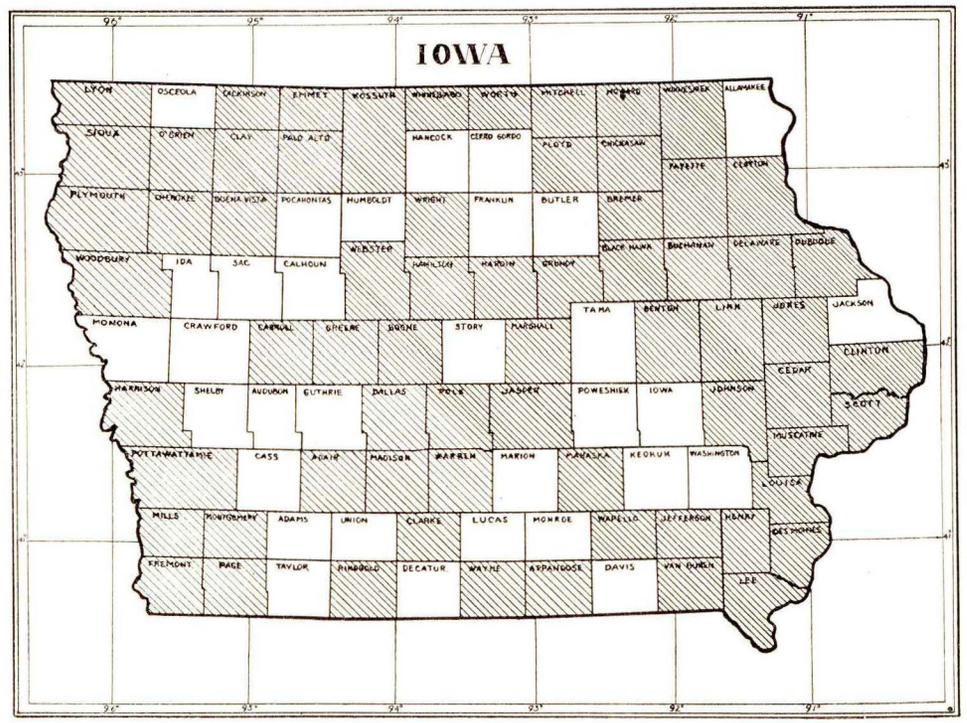



Fig. 11. Map of Iowa showing the counties surveyed.



### *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-inocu-

lated 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. 12.

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

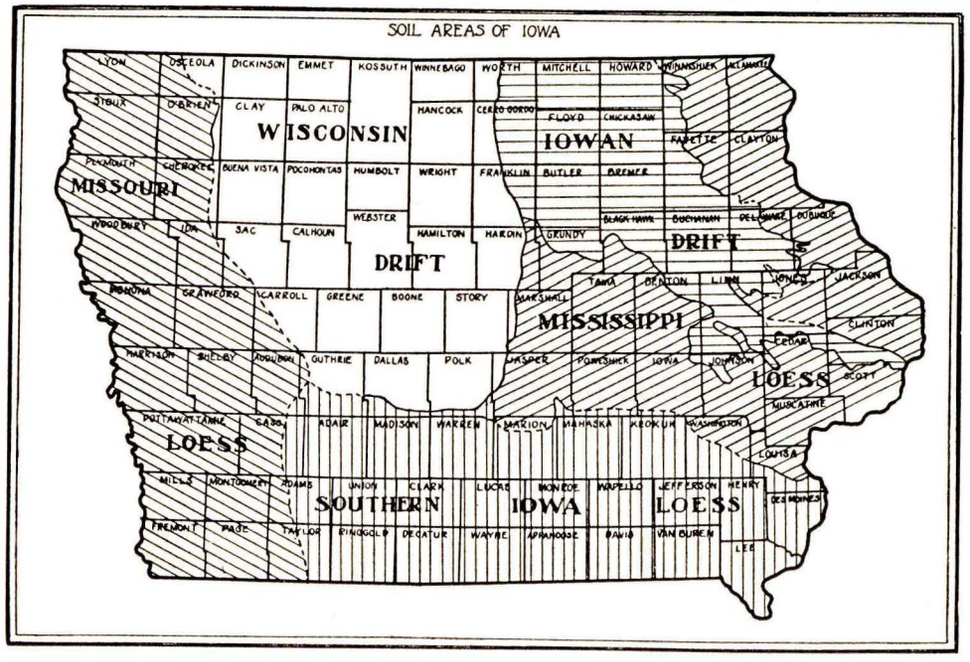



Fig. 12. Map showing principal soil areas in Iowa.

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.* |
| | Gravel—32—2.0 mm. |
| | Very coarse sand—2.0—1.0 mm. |
| | Coarse sand—1.0—0.5 mm. |
| | Medium sand—0.5—0.25 mm. |
| | Fine sand—0.25—0.10 mm. |
| | Very fine sand—0.10—0.05 mm. |
| | 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.