5-1919

Soil Survey of Iowa, Report No. 12—Clay County

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

Follow this and additional works at: http://lib.dr.iastate.edu/soilsurveys

Part of the Agriculture Commons, Agronomy and Crop Sciences Commons, and the Soil Science Commons

Recommended Citation

This Report is brought to you for free and open access by the Extension and Experiment Station Publications at Iowa State University Digital Repository. It has been accepted for inclusion in Soil Survey Reports by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
SOIL SURVEY OF IOWA
CLAY COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 12
May, 1919
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

BULLETINS

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

No.
78 Drainage Conditions in Iowa.*
82 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
96 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.*
150 The Fertility in Iowa Soils.
151 The Fertility in Iowa Soils (Popular edition).
151 Soil Acidity and the Liming of Iowa Soils.*
151 Soil Acidity and the Liming of Iowa Soils (Abridged).
157 Improving Iowa’s Peat and Alkali Soils.
161 Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa.
167 Rotation and Manure Experiments on the Wisconsin Drift Soil Area.
177 The Alkali Soils of Iowa.
183 Soil Erosion in Iowa.

CIRCULARS

2 Liming Iowa Soils.*
7 Bacteria and Soil Fertility.
8 The Inoculation of Legumes.
9 Farm Manures.
10 Green Manuring and Soil Fertility.
16 Testing Soils in Laboratory and Field.
24 Fertilizing Lawn and Garden Soils.
43 Soil Inoculation.
51 Soil Surveys, Field Experiments and Soil Management in Iowa.

RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
8 Bacteria at Different Depths in Some Typical Iowa Soils.*
9 Amino Acid and Acid Amides as Sources of Ammonia in Soils.*
11 Methods for the Bacteriological Examinations of Soils.*
13 Bacteriological Studies of Field Soils, III.
17 The Determination of Ammonia in Soils.
18 Sulfation in Soils.
25 Bacterial Activities and Crop Production.
34 Studies in Sulfatation.
35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.
43 The Effect of Sulphur and Manure on the Availability of Rock Phosphate in Soil.
44 The Effect of Certain Alkali Salts on Ammonification.
45 Soil Inoculation with Azotobacter.

SOIL REPORTS

1 Bremer County.
2 Pottawattamie County.
3 Muscatine County.
4 Webster County.
5 Lee County.
6 Sioux County.
7 Van Buren County.
8 Clinton County.
9 Scott County.
10 Ringgold County.
11 Mitchell County.
12 Clay County.
SOIL SURVEY OF IOWA

Report No. 12--CLAY COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson, T. H. Benton and M. E. Olson

Webster silty clay loam produces excellent hay crops

IOWA AGRICULTURAL
EXPERIMENT STATION

C. F. Curtiss, Director
Ames, Iowa
CONTENTS

Introduction ......................................................................................................................... 3
Geology of Clay county ........................................................................................................ 6
   Physiography and drainage .............................................................................................. 6
Soils of Clay county .............................................................................................................. 8
   Fertility in Clay county soils .......................................................................................... 9
   Greenhouse experiments ............................................................................................... 15
   Field experiments ......................................................................................................... 17
   Rotation experiments .................................................................................................... 19
   Continuous corn experiment ....................................................................................... 21
The needs of Clay county soils as indicated by laboratory, field and greenhouse tests .... 22
   Drainage ...................................................................................................................... 22
   Manuring ..................................................................................................................... 23
   Use of commercial fertilizers ....................................................................................... 25
   Liming .......................................................................................................................... 26
   Crop rotations .............................................................................................................. 27
   Prevention of erosion .................................................................................................... 27
Individual soil types in Clay county .................................................................................. 33
   Drift soils ...................................................................................................................... 33
   Terrace soils .................................................................................................................. 38
   Swamp and bottomland soils ....................................................................................... 40
Appendix: The soil survey of Iowa .................................................................................. 45
CLAY COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of G. E. Corson, T. H. Benton, and M. E. Olson

Clay county is located in northwestern Iowa, in the second tier of counties south of the Minnesota state line and the third tier east of the Missouri river. It is bounded by Dickinson county on the north, O'Brien county on the west, Buena Vista county on the south, and Palo Alto county on the east. It is entirely within the Wisconsin drift soil area and most of the soils are of glacial drift origin.

The total area of the county is 563 square miles or 360,320 acres. Of this area 328,280 acres or 91.8 percent is in farm land. The total number of farms is 1,627 and their average size is 201.7 acres.

The utilization of the farm land of the county is shown in the following figures taken from the Iowa Yearbook of Agriculture for 1917:

- Acreage in general farm crops: 229,090 acres
- Acreage in pasture: 74,755 acres
- Acreage in gardens: 114 acres
- Acreage in orchards: 369 acres
- Acreage in farm buildings, feed lots and public highways: 17,818 acres
- Acreage in waste land: 3,664 acres
- Acreage in crops not otherwise listed: 537 acres

The type of agriculture followed in Clay county consists of general farming combined largely with hog raising. Beef cattle production and dairying are, however, rapidly becoming of more importance. Horses and sheep are also raised in considerable numbers. Market gardening is carried on in a small area around Spencer. Orcharding, consisting mainly of the growing of apples, is practiced to a small extent but the industry is not of commercial importance and insufficient fruit is produced for home consumption.

The acreage in waste land in the county is large and methods of reclamation of such land should be adopted. It is impossible to make general recommendations for the reclaiming of waste areas as the causes of infertility are so varied. In the descriptions of individual soil types given later in this report, however, suggestions will be offered for putting those areas which are not cultivated at present, in condition to produce good crops. Advice regarding treatment in special cases will be given by the Soils Section of the Iowa Agricultural Experiment Station upon request.

The general farm crops grown in Clay county in the order of their importance are corn, oats, hay, potatoes, barley, alfalfa, wheat, and rye. The acreage, yields, and value of these crops in the county are given in table I.

Com is the chief money crop in the county and it occupies the largest acreage. The average yields of this crop amount to 43 bushels per acre much larger yields than this are secured in many cases. In general over fifty percent of the corn produced is used for feeding dairy stock, fattening hogs and

---

1 Soil Survey of Clay county, Iowa, by E. H. Smies of the United States Department of Agriculture and T. H. Benton of the Iowa Agricultural Experiment Station.
TABLE I. ACREAGE, YIELDS AND VALUE OF CROPS GROWN IN CLAY COUNTY

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm-land in county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>113,000</td>
<td>34.3</td>
<td>43</td>
<td>4,859,000</td>
<td>8.97</td>
<td>$4,713,230</td>
</tr>
<tr>
<td>Oats</td>
<td>76,000</td>
<td>23.1</td>
<td>41</td>
<td>3,116,000</td>
<td>0.61</td>
<td>1,900,760</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>550</td>
<td>0.1</td>
<td>18</td>
<td>9,900</td>
<td>1.94</td>
<td>19,206</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>100</td>
<td>0.3</td>
<td>22</td>
<td>2,200</td>
<td>1.97</td>
<td>4,334</td>
</tr>
<tr>
<td>Barley</td>
<td>2,900</td>
<td>0.8</td>
<td>25</td>
<td>72,500</td>
<td>1.15</td>
<td>83,375</td>
</tr>
<tr>
<td>Rye</td>
<td>100</td>
<td>0.3</td>
<td>12</td>
<td>1,200</td>
<td>1.58</td>
<td>1,896</td>
</tr>
<tr>
<td>Potatoes</td>
<td>640</td>
<td>0.1</td>
<td>144</td>
<td>92,200</td>
<td>1.32</td>
<td>121,704</td>
</tr>
<tr>
<td>Tame hay</td>
<td>22,200</td>
<td>6.7</td>
<td>1.1</td>
<td>24,400</td>
<td>18.82</td>
<td>461,408</td>
</tr>
<tr>
<td>Wild hay</td>
<td>12,000</td>
<td>3.9</td>
<td>1.0</td>
<td>12,900</td>
<td>14.79</td>
<td>190,791</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>700</td>
<td>0.2</td>
<td>3.5</td>
<td>2,450</td>
<td>25.40</td>
<td>57,330</td>
</tr>
<tr>
<td>Pasture</td>
<td>74,755</td>
<td>22.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cattle and feeding work stock, the remainder being sold out of the county. In some few localities where more livestock feeding is practiced, the production of corn is insufficient for home consumption.

Oats is the second crop in acreage and value in the county. Average yields of 41 bushels per acre are secured, larger yields than this being quite common in favorable seasons. About one-half the oat crop is fed on the farms, the remainder being shipped to outside markets.

Hay is grown on a considerable area, tame hay occupying about twice as large an acreage as wild hay. The area in wild hay is gradually decreasing as the poorly drained areas are put in condition for the growth of cultivated crops by the installation of tile drains or drainage ditches. Clover and timothy mixed is the most important tame hay crop although, in many cases, timothy and clover are each grown alone. The mixture gives an average yield of 1.1 tons per acre. The hay produced, both wild and tame, is practically all fed on the farms and, in some instances, considerable quantities must be shipped in for feeding purposes.

Potatoes are grown on practically all farms and the average yields secured in favorable seasons are high. The crop is usually sufficient to supply home needs but only rarely is there any surplus for sale out of the county. Barley is grown to some extent, average yields of 25 bushels per acre being secured. Some of the crop is fed on the farms but the greater part is sold on outside markets. Alfalfa is increasing in acreage and proves a valuable crop. Average yields of 3.5 tons per acre are secured, three or four cuttings a year being obtained.

Wheat is grown on a relatively small acreage at the present time, the spring varieties being produced much more extensively than the winter varieties. Average yields of eighteen bushels per acre are obtained for the former and twenty-two bushels per acre for the latter. Rye is produced on a small area and is a relatively unimportant crop.

The sale of hogs is a large source of income on most farms, and the industry brings considerable revenue to the county. Dairying is becoming more extensive and the income from milk and butter is now very important. The sale of beef cattle, horses, and sheep also adds much to the income of the county.

The value of land in Clay county is quite variable depending upon a number of factors, chief of which are the soil, topography, location, and distance from market. Unimproved land ranges from $100 to $125 per acre while improved

---

1 Iowa Yearbook of Agriculture, 1917.
land brings $175 to $200 per acre. In the southwestern part of the county the values are slightly higher, ranging from $125 for unimproved land to $225 for the most improved areas.

The extent and character of the livestock industry in Clay county are shown in the following figures taken from the Iowa Yearbook of Agriculture for 1917:

- Horses (all ages) ................................................................. 13,489
- Mules (all ages) ........................................................................ 331
- Swine (on farms, July 1, 1916) .............................................. 74,382
- Cattle (cows and heifers kept for milk) ................................. 41,282
- Cattle (total, all ages) ............................................................. 51,253
- Sheep (all ages, on farms) ....................................................... 2,774
- Sheep (total pounds wool clipped) ......................................... 18,485

The extent and character of the livestock industry in Clay county are shown in the following figures taken from the Iowa Yearbook of Agriculture for 1917:

- Horses (all ages) ................................................................. 13,489
- Mules (all ages) ........................................................................ 331
- Swine (on farms, July 1, 1916) .............................................. 74,382
- Cattle (cows and heifers kept for milk) ................................. 41,282
- Cattle (total, all ages) ............................................................. 51,253
- Sheep (all ages, on farms) ....................................................... 2,774
- Sheep (total pounds wool clipped) ......................................... 18,485

The yields of general farm crops in the county are generally quite satisfactory but in many cases they are not as large as they should be and practically everywhere proper methods of soil treatment and management would result in greater crop growth and larger incomes from the farms.

Some of the soils are acid in reaction and where that is the case, applications of lime would be of much value for the growth of legumes, especially clover and alfalfa. While the supply of organic matter is good in most cases, many of the types will respond profitably to applications of farm manure and this material should be used in as large amounts as are practicable. Green manures may also prove profitable in some cases.

The supply of phosphorus in practically all of the upland soils of the county is low and the use of phosphorus fertilizers may prove distinctly profitable in many instances. If they are not of value now, they will certainly be needed in the future to permit of the continuous production of satisfactory crops. Complete commercial fertilizers are probably unnecessary but they may prove of value in some instances and where such is the case, there is no objection to their use.

Definite recommendations cannot be made at the present time regarding the use of either phosphorus fertilizers or complete commercial fertilizers. Field tests are now under way to determine the value of these materials and when several years’ results are secured more complete information will be available. For the present it can merely be urged that farmers test the use of these materials on a small scale and if found profitable applications may be made to large areas.

The drainage conditions in the county have recently been made much more satisfactory than was formerly the case and large areas, which were practically useless for agricultural purposes, have been made productive. There are still some areas, however, where drainage is necessary and when that is the case no other methods of soil treatment will prove profitable. The first treatment necessary for much of the waste land in Clay county is drainage which may be secured by the use of tile or of drainage ditches or both.

The proper cultivation of the soil, the utilization of crop residues and the rotation of crops are other methods of soil treatment quite essential for increasing and maintaining the productive capacity of the soils of the county.
A thick covering of drift extends over the entire surface of Clay county and the underlying rock material is buried so deeply that it has no influence on the character of the soils.

Two great glaciers swept over the county during the glacial age and upon their retreat left behind vast deposits of debris which are called drift. The first glacier, known as the Kansan, was later followed by the Wisconsin and hence there are two rather distinct layers of drift material. The Kansan drift layer is from thirty to sixty feet in thickness and it consists mainly of a so-called "blue clay," somewhat sandy or mixed with gravel. Numerous small bowlders or "niggerheads" are commonly present. Underneath this drift there occur the pre-Kansan sands and these layers are the sources of the water supply of the county.

The surface layer of Wisconsin drift varies in thickness from a few inches to 150 feet or more. It consists chiefly of clay with varying amounts of sand, silt, gravel, and bowlders. Sometimes it rests directly on the "blue clay" of the Kansan drift and sometimes it is separated by a layer of sand or gravel. In the eastern part of the county there are found small, scattered knolls and ridges of sand, bowlders, and gravel mixed with clay and silt.

Since the deposition of this surface drift material, it has been modified considerably by leaching and by plant growth and the effects of variations in these two factors as well as the influence of drainage have led to the formation of the different soil types which now make up the uplands. These same factors and also the action of the stream waters have brought about the formation of various bottomland soils and so-called terrace or second bottoms.

PHYSIOGRAPHY AND DRAINAGE

The surface of Clay county is, in general, nearly flat or gently undulating, as is typical of drift areas. Small hills and knolls occur in the eastern part of the county in the lake region and hence the topography there becomes rather rough. The slopes along the larger streams are gently rolling except in the southern part of the county along Elk creek and the Little Sioux river where the streams have cut more deeply into the drift.

High terraces occur along the larger streams in all parts of the county but they are more extensive along the Little Sioux and Ocheyedan rivers. These areas are quite level and show little relief except where they are cut by streams issuing from the uplands. The bottomlands are generally nearly level in topography but along the larger streams they are broken by tributary streams and old channels.

The drainage of Clay county is brought about mainly by the Little Sioux river which crosses the county from the northwestern part, southeastward into Buena Vista county, turning westward along the boundary line of the two counties and northward across the southwest corner of Clay county and finally reaching the Missouri river. The main tributaries of the Little Sioux are the...
Ocheyedan river, Elk creek, Stony creek and Willow creek and these with the Little Sioux itself extend well over the county except in the extreme eastern part. There the drainage is southeastward into the Des Moines river and finally into the Mississippi.

The Little Sioux flows through broad plains, which reach their greatest width where the Ocheyedan joins it. The tributary streams flow through rather narrow flood plains. Where the Little Sioux and the Ocheyedan unite, the flood plain is about seventy-five feet below the level of the upland. Beyond that point the channel is 125 to 175 feet below the upland and the flood plain becomes very narrow. North of Gillet Grove it is scarcely one-fourth of a mile wide.

The slopes along the Little Sioux in the southern part of the county are rather rolling and this is the case also along Elk creek. The other main streams are quite generally approached by gentle slopes from the uplands. Some of the small intermittent tributary streams are characterized by steep slopes and these are subject to considerable washing. These small tributaries are quite short, however, and erosion is not extensive in the county.

Fig. 1. Natural drainage system of Clay county.
North and east of the Little Sioux river except along Elk creek, the drainage is poor as the topography is quite level. This area is characterized by numerous sloughs and lakes and much of the land is useless for agricultural purposes until adequate drainage has been secured. In the southwestern part of the county, the drainage of much of the upland is also poor but few marshy sloughs occur.

Along the Sioux river, the Ocheyedan river, Stony creek and Willow creek drainage is well-established and hence throughout much of the county the installation of drainage systems is not necessary. In many cases, however, the use of tile would prove distinctly profitable and where the drainage is not as complete or as rapid as desirable, crop production will not be at the best. The accompanying map indicates clearly the character and extent of the natural drainage of the county.

THE SOILS OF CLAY COUNTY

The soils of Clay county are grouped into three classes according to their origin and location. These classes are drift soils, terrace soils, and swamp and bottomland soils.

Drift soils are those which are formed from the material deposited by a glacier on its retreat and they contain rock material from various sources and sometimes pebbles and bowlders. Terrace soils are those which were once bottomlands and were raised above overflow by a decrease in volume of the streams or a deepening of the river channels. Swamp and bottomland soils are those which occur in low, poorly drained areas or those found along streams and subject to more or less frequent overflow.

<table>
<thead>
<tr>
<th>Soil Groups</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>264,256</td>
<td>73.4</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>33,856</td>
<td>9.4</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>62,208</td>
<td>17.2</td>
</tr>
<tr>
<td>Total</td>
<td>360,320</td>
<td></td>
</tr>
</tbody>
</table>

Table II shows the occurrence of these groups of soils in Clay county. The drift soils are by far the most extensive, covering 73.4 percent of the total area of the county. The terrace soils are much less extensive, covering only 9.4 percent of the county while the swamp and bottomland soils are about twice as extensive, covering 17.2 percent of the county.

There are fourteen distinct soil types in Clay county and an area of Muck and Peat making fifteen separate soil areas. Six of these are drift soils, four are terrace types and five, including the Muck and Peat are swamp and bottomland soils. These various types are distinguished on the basis of rather definite characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the different soil types in the county are shown in Table III.

The drift soils are classified in the Carrington, the Shelby and the Webster series. The terrace types are of the O'Neil, the Fargo and the Waukesha series. The bottomland types are classified in the Wabash and Lamoivre series.
SOIL MAP
OF CLAY COUNTY

U. S. DEPT. OF AGRICULTURE
Bureau of Soils
Milieu Whitney, Chief
Curtis F. Merrier, in charge Soil Survey

Thomas D. Dias, Inspector Northern Division.
Soils surveyed by F. H. Ewing, A. U. S. Department
of Agriculture, in charge, and E. B. Bonham, of the
Iowa Agricultural Experiment Station.

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtin, Director
W. H. Stevenson, in charge Soil Survey
F. L. Brown, Associate in charge

LEGEND
Drift Soils

Carrington loam
Carrington loam steep phase
Webster silty clay loam
Carrington silt loam
Carrington fine sandy loam
Shelby fine sandy loam

Terrace Soils

O'Neill loam
O'Neill fine sandy loam
Fargo silty clay loam
Waushara silt loam

Swamp and
Bottomland Soils

Lamoure silty clay loam
Wabash silt loam
Wabash loam

Muck and Peat

Lamoure loam

Scale: 1 inch = 2½ miles.
# Clay County Soils

## Table III. Areas of Different Soil Types in Clay County

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Types</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>102,272</td>
<td>31.3</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>10,496</td>
<td>3.1</td>
</tr>
<tr>
<td>107</td>
<td>Webster silt loam</td>
<td>72,768</td>
<td>20.2</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>54,144</td>
<td>15.0</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>29,416</td>
<td>5.7</td>
</tr>
<tr>
<td>92</td>
<td>Shelby fine sandy loam</td>
<td>4,160</td>
<td>1.2</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>29,184</td>
<td>8.1</td>
</tr>
<tr>
<td>109</td>
<td>Fargo silt clay loam</td>
<td>2,112</td>
<td>0.6</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>2,048</td>
<td>0.6</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>42,944</td>
<td>11.9</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>10,688</td>
<td>2.9</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>4,032</td>
<td>1.1</td>
</tr>
<tr>
<td>21</td>
<td>Muck and peat</td>
<td>3,520</td>
<td>1.0</td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>1,024</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>360,320</strong></td>
<td></td>
</tr>
</tbody>
</table>

The Carrington loam is the most important soil type in the county, as well as the most extensive drift soil. Together with the steep phase which is small in area, it covers 31.3 percent of the total area of the county. The Webster silt loam is the second drift soil in size of area and the second most extensive type in the county. It covers 20.2 percent of the county. The Carrington silt loam is the third type in area in the county, covering 15.0 percent of the county. The Carrington fine sandy loam and the Shelby fine sandy loam are much smaller in area, covering 5.7 and 1.2 percent of the total area of the county, respectively.

The O'Neill loam is the most important terrace type and it is the only one which is at all extensive in the county. It covers 8.1 percent of the total area of the county. The Fargo silt clay loam, O’Neill fine sandy loam and Waukesha silt loam are all very minor in area.

The Lamoure silty clay loam is the most important bottomland soil, covering 11.9 percent of the total area of the county. It is the fourth soil type in area in the county. The Wabash silt loam, Wabash loam, and Lamoure loam are all minor types, the Wabash silt loam, the most extensive, covering 2.9 percent of the county. There is only a small area of Muck and Peat and it is quite unimportant.

The drift soils, with the exception of the steep phase Carrington, are usually undulating to gently rolling in topography. The Shelby fine sandy loam is more rolling than the other types and usually occurs on hills, knolls, and ridges. The Webster silt loam is quite level in character, much more so than in the case with the Carrington soils. The terrace and bottomland types are all quite level in character only occasionally becoming gently rolling.

## The Fertility in Clay County Soils

Samples were drawn from all the soils in the county except the Wabash loam, a minor bottomland type and the Muck and Peat. The more important soil types were sampled in triplicate while only one sample was taken from each of the minor types. All the samples were drawn with care that they should repre-
sent accurately the individual soil types and that all differences due to location or treatments should be eliminated.

Samples were taken at three depths, 0 to 6½ inches, representing the surface soil; 6½ to 20 inches, representing the subsurface soil and 20 to 40 inches, representing the subsoil.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon, and limestone requirement. The official methods were followed in the phosphorus, nitrogen, and carbon determinations and the Veitch method for the limestone requirement determinations. The results given in the tables are the average of duplicate determinations on all the samples of each type analyzed, hence where more than one sample was taken, the results are the average of six determinations.

THE SURFACE SOILS

Table IV gives the results of the analyses of the surface soils. The figures are calculated on the basis of pounds per acre of two million pounds of surface soil.

The phosphorus content of all the soils in the county is not high and it is evident that this element must be considered in all systems of permanent fertility applicable in the county. There is no very distinct relationship between the phosphorus content of the various groups of soils, wide variations occurring among the types in each group. The bottomland soils, however, do seem to average slightly higher than the drift or terrace soils. This might be expected inasmuch as the upland and terrace soils are cultivated much more extensively and hence have lost more of their original stock of plant food.
### TABLE IV. PLANT FOOD IN CLAY COUNTY, IOWA SOILS

Pounds per acre of two million pounds of surface soil (0-6"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,165</td>
<td>5,553</td>
<td>57,232</td>
<td>0</td>
<td>3,724</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,549</td>
<td>5,640</td>
<td>64,100</td>
<td>4,700</td>
<td>2,039</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,354</td>
<td>7,773</td>
<td>104,800</td>
<td>0</td>
<td>8,389</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,317</td>
<td>3,429</td>
<td>41,900</td>
<td>0</td>
<td>6,702</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>540</td>
<td>3,900</td>
<td>44,800</td>
<td>0</td>
<td>6,119</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>1,538</td>
<td>5,000</td>
<td>57,333</td>
<td>0</td>
<td>6,313</td>
</tr>
<tr>
<td>109</td>
<td>Fargo silty clay loam</td>
<td>1,819</td>
<td>6,260</td>
<td>81,740</td>
<td>16,660</td>
<td>Basic</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>1,367</td>
<td>2,929</td>
<td>35,600</td>
<td>0</td>
<td>6,616</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,000</td>
<td>7,140</td>
<td>86,200</td>
<td>0</td>
<td>4,080</td>
</tr>
<tr>
<td></td>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>1,908</td>
<td>5,433</td>
<td>139,166</td>
<td>3,633</td>
<td>Basic</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,553</td>
<td>6,146</td>
<td>72,866</td>
<td>0</td>
<td>1,554</td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>1,600</td>
<td>1,000</td>
<td>119,440</td>
<td>33,960</td>
<td>Basic</td>
</tr>
</tbody>
</table>

The Carrington loam, the chief upland type in the county is not high in phosphorus. The steep phase Carrington, the Webster silty clay loam, the Carrington silt loam, and the Carrington fine sandy loam are somewhat better supplied, while the Shelby fine sandy loam is lower in phosphorus.

The Waukesha silt loam is the poorest in phosphorus of all the terrace types. The O’Neill loam, the largest terrace type, is somewhat higher, and the Fargo silty clay loam and the O’Neill fine sandy loam are also higher.

Among the bottomland soils, the Lamoure silty clay loam contains the largest amount of phosphorus and indeed it contains more than any of the other soils in the county. The Lamoure loam and Wabash silt loam are lower in this element than the Lamoure silty clay loam but they are both higher than most of the other types in the county.

There seems to be some relationship between the character, color, and topographic position of the soils and the phosphorus which they contain. Thus the fine sandy loams and the lighter types are as a rule lower in phosphorus than the heavier types. The level, poorly drained types are also apt to be richer in that element than the more rolling, better drained soils. In general, however, little can be judged regarding the phosphorus in soils, from the type, appearance, or location of the soil. An analysis is always necessary.

It is apparent from these results that phosphorus will be needed on the soils of the county in the near future and the use of phosphorus fertilizers might prove profitable in some cases now. Recommendations regarding the use of these materials cannot be made now but it is hoped that the results of the field experiments which are under way will permit of definite advice along this line in the near future. These experiments must be continued for several years before conclusions can be drawn. In the meantime, farmers are urged to test the use of phosphorus on their own soils and thus not only solve their own particular problem but aid in the general solution of the problem for the state. It can merely be said here that the indications point strongly to the fact that phosphorus fertilizers may prove of value on some of the soils of this county.
The nitrogen content of the soils of the county is much greater than the content of phosphorus, but the amount is not so large that nitrogen can be disregarded in systems of permanent fertility. The variations in amount of nitrogen present in the different soil types are considerable and no definite relationships can be established. There seems to be no relation between the groups of soils and the nitrogen present but, as in the case of phosphorus, the heavier, dark colored types are generally richer in nitrogen than the sandy, light colored soils. Those level in topography and less thoroughly drained are likewise higher in the element than the rolling, well drained types.

With continued cultivation and the removal of crops, all the soils of the county, regardless of their present content of nitrogen, will eventually become in need of that element. Crop residues, farm manure, and green manures are the natural materials to be used on soils to keep them supplied with nitrogen and these materials should be applied regularly on all soils if nitrogen is not to become deficient. Such materials also contain organic matter and hence they serve also to keep the soil supplied with that necessary constituent.

The organic carbon present in the soil is a measure of its content of organic matter and it indicates also the amount of nitrogen present for soils low in organic matter are low in nitrogen and vice versa. The soils of Clay county are not strikingly low in organic matter but in some cases the amount is inadequate for securing the best crop yields.

There is no definite relation between the groups of soils and their organic matter content but the bottomland types, as might be expected are somewhat higher on the average than the terrace and drift soils. Again, as in the case of nitrogen the amount of organic matter seems to be related to the character, color, and location of the type. The heavier soils and those darker in color and level in topography are in general richer in organic matter than the sandy, light-colored, rolling types. The color of the soil is the most definite indication of content of organic matter and often serves to show quite distinctly the need of adding humus-forming materials.

The Webster silty clay loam is richer in organic matter than any of the other upland or terrace types. The Carrington silt loam and the Fargo silty clay loam, and Waukesha silt loam are also well supplied. The other upland and terrace soils are, however, considerably lower in organic matter and especially is this true of the fine sandy loams. The bottomland types are all well supplied with organic matter, the two Lamoure soils showing a very large content.

Organic matter must be supplied to all soils from time to time to keep them permanently fertile and Clay county soils are no exception to this rule. Even where there is considerable present the application of farm manure proves of much value and on the sandy types it is quite essential for good crop production. Crop residues should always be completely utilized and green manures may also often be used to advantage. Farm manure, however, is the most valuable material for use in keeping up the supply of organic matter in the soil.
The relation between organic carbon and nitrogen in soils indicates the rapidity of production of available plant food. In most of the types in Clay county, this relation is such that the decomposition processes which make plant food available are probably proceeding sufficiently rapidly. In some cases, however, these processes should be stimulated. This may be brought about by the use of farm manure, which has a threefold action, supplying organic matter, adding plant food and introducing bacteria which are the agencies bringing about decomposition and the production of available plant food. The use of farm manure on some of the soils of the county is, therefore, especially desirable.

Four of the soils in the county contain some inorganic carbon and hence these types are not acid in reaction and not in need of lime at the present time. They are indicated as basic in the table. They are the steep phase Carrington loam, the Fargo silty clay loam, the Lamoure silty clay loam and the Lamoure loam. In the case of the three latter types, the presence of lime is quite characteristic and it is largely on the basis of their lime content that they are separated and named. These types are not likely to be in need of lime for many years to come. There is generally no lime present in the Carrington loam and hence that type will need lime in the near future. All the other types are acid in reaction and need lime if the best crop growth, particularly of legumes, is to be secured.

The amounts of lime needed are quite variable and depend upon many factors. The figures given merely indicate the needs of the soils and should not be taken to show the absolute limestone requirements of the soils. The acidity of soils is extremely variable even among different samples of the same type and lime should always be applied in amounts shown to be necessary by actual tests. The soils of Clay county, with the exception of the types listed above, should all be tested for acidity and lime applied as necessary if they are to be kept in condition for the best crop growth.

TABLE V. PLANT FOOD IN CLAY COUNTY, IOWA SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,121</td>
<td>6,300</td>
<td>88,600</td>
<td>0</td>
<td>5,527</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,400</td>
<td>6,646</td>
<td>135,120</td>
<td>107 Webster silty clay loam</td>
<td>1,120</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,480</td>
<td>8,673</td>
<td>101,466</td>
<td>0</td>
<td>16,130</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,200</td>
<td>4,140</td>
<td>50,200</td>
<td>0</td>
<td>12,238</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>680</td>
<td>5,700</td>
<td>62,000</td>
<td>0</td>
<td>16,902</td>
</tr>
<tr>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>920</td>
<td>5,913</td>
<td>38,800</td>
<td>0</td>
<td>8,644</td>
</tr>
<tr>
<td>109</td>
<td>Fargo silty clay loam</td>
<td>1,280</td>
<td>8,160</td>
<td>85,960</td>
<td>29,140</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>720</td>
<td>5,500</td>
<td>28,800</td>
<td>0</td>
<td>13,404</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,200</td>
<td>9,940</td>
<td>116,800</td>
<td>0</td>
<td>5,826</td>
</tr>
<tr>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>2,333</td>
<td>10,620</td>
<td>136,760</td>
<td>14,000</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,973</td>
<td>8,486</td>
<td>113,866</td>
<td>0</td>
<td>1,833</td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>2,400</td>
<td>10,180</td>
<td>121,360</td>
<td>72,640</td>
<td>13,404</td>
</tr>
</tbody>
</table>
SOIL SURVEY OF IOWA

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 four million pounds of subsurface soil and six million pounds of subsoil.

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

Pounds per acre of six million of subsoil (20"–40"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phos-</th>
<th>Total nitro-</th>
<th>Total organic</th>
<th>Total inorganic</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>phorus</td>
<td>gen</td>
<td>carbon</td>
<td>carbon</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,340</td>
<td>4,840</td>
<td>49,920</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,200</td>
<td>1,400</td>
<td>17,640</td>
<td>200,760</td>
<td>Basic</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,720</td>
<td>5,000</td>
<td>50,400</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,820</td>
<td>6,600</td>
<td>70,200</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1,440</td>
<td>2,840</td>
<td>37,500</td>
<td>0</td>
<td>14,701</td>
</tr>
<tr>
<td>92</td>
<td>Shelby fine sandy loam</td>
<td>960</td>
<td>5,600</td>
<td>62,400</td>
<td>0</td>
<td>15,058</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>1,193</td>
<td>5,100</td>
<td>54,000</td>
<td>0</td>
<td>4,499</td>
</tr>
<tr>
<td>109</td>
<td>Fargo silty clay loam</td>
<td>1,620</td>
<td>4,910</td>
<td>135,240</td>
<td>42,360</td>
<td>Basic</td>
</tr>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>660</td>
<td>2,240</td>
<td>24,600</td>
<td>0</td>
<td>13,113</td>
</tr>
<tr>
<td>75</td>
<td>Wankeshia silt loam</td>
<td>1,720</td>
<td>7,700</td>
<td>85,200</td>
<td>0</td>
<td>2,522</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>2,640</td>
<td>6,120</td>
<td>89,500</td>
<td>8,900</td>
<td>Basic</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,940</td>
<td>7,320</td>
<td>92,600</td>
<td>0</td>
<td>840</td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>3,000</td>
<td>10,160</td>
<td>102,180</td>
<td>102,420</td>
<td>Basic</td>
</tr>
</tbody>
</table>

Unless there is a considerable supply of plant food in the lower soil layers, the actual amount present has very little influence on the fertility of the soil. The lower soil layers in Clay county are not rich in any of the necessary plant food constituents and hence the results of the analyses will not be considered in detail. The needs of the soils as shown by the analyses of the surface soils are borne out by the subsurface and subsoil results. Phosphorus will be needed in the near future and may be of value now. Nitrogen must be added regularly if the present supply which is adequate in most cases, is to be maintained. Organic matter is necessary in some instances and farm manure will be particularly valuable on practically all of the types, even although there is no actual deficiency now. Materials supplying organic matter must be added at regular intervals if the stock in the soil is to be kept up.

The amount of lime in the lower soil layers has little influence on the reaction of the soil, as lime rarely moves upward in the soil. If the surface soil is acid, lime should be applied regardless of any lime in the subsoil. Thus the surface of the Webster silty clay loam should receive the lime shown to be necessary without regard to the fact that the subsurface soil and subsoil are basic. Even although basic, there is no supply of lime in these lower layers of this soil type. Furthermore the acidity of the subsoil need not be neutralized when applying lime, sufficient being added merely to remedy the acid conditions at the surface. The needs of lime as shown by the surface results are not changed, therefore, by these results. The conclusion should merely be emphasized that the soils of the county, except the Fargo and Lamoure types, should be tested regularly and the need of lime supplied.
Fig. 3. Greenhouse experiment with Carrington silt loam, showing relative effect of various treatments. The greatest increase on clover was obtained by applications of manure, lime and commercial fertilizer.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out with Clay county soils, one using the Carrington silt loam and the other the Webster silty clay loam, both important upland types.

In both experiments the same applications were made. Lime was added in sufficient amount to neutralize the acidity of the soils and supply two tons additional, manure was applied at the rate of eight tons per acre, rock phosphate at the rate of 2,000 lbs. per acre, acid phosphate at the rate of 200 lbs. per acre and a complete commercial fertilizer, a standard 2-8-2 brand at the rate of 300 lbs. per acre.

Wheat and clover were both grown in the tests, the latter crop being seeded when the wheat had been up about one month. The yields of wheat grain and of the clover crop were both secured and are given in grams.

Table VII gives the results secured on the Carrington silt loam. The manure brought about a distinct increase in the yield of wheat and an even greater gain in the clover. The lime had practically no effect on either crop and the rock phosphate in addition to the manure and lime had apparently no influence. The acid phosphate and commercial fertilizer had little effect on the wheat although slight gains were noted but on the clover there were decided increases with both materials, the commercial fertilizer having a somewhat greater effect.

TABLE VII. GREENHOUSE EXPERIMENTS. CARRINGTON SILT LOAM, CLAY COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>19.54</td>
<td>25.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>23.40</td>
<td>41.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>23.55</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock phosphate</td>
<td>23.16</td>
<td>40.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + acid phosphate</td>
<td>23.60</td>
<td>52.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + commercial fertilizer</td>
<td>24.27</td>
<td>56.5</td>
</tr>
</tbody>
</table>
### TABLE VIII. GREENHOUSE EXPERIMENT. WEBSTER Silty Clay Loam, Clay County

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover grain in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>26.24</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>29.56</td>
<td>51.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>30.44</td>
<td>44.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock phosphate</td>
<td>29.51</td>
<td>53.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + acid phosphate</td>
<td>28.97</td>
<td>53.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + commercial fertilizer</td>
<td>29.12</td>
<td>54.5</td>
</tr>
</tbody>
</table>

Manure is evidently the material of most value on this soil type and its use is certainly to be recommended. Rock phosphate did not give any influence but acid phosphate and the commercial fertilizer did give indications of proving profitable. Tests of these materials on this soil in the field are highly desirable to determine whether or not their use would prove profitable as these greenhouse experiments merely indicate what may occur in the field.

The results secured in the second experiment on the Webster silty clay loam are given in table VIII. The manure brought about a small increase on the wheat and a decided gain in the clover was shown by its use. The lime had no appreciable effect and the rock phosphate, acid phosphate, and commercial fertilizer showed no effect on the wheat and only a very slight influence on the clover, too slight indeed to be significant. It is apparent that on this type, manure is

![Fig. 4. Greenhouse experiment on Carrington silt loam, showing relative effect of various fertilizers on wheat. The use of manure showed a decided increase, the other fertilizers having little effect.](image-url)
the best fertilizing material to use and it is distinctly valuable in increasing crop
growth. Altho phosphorus is not abundant in the type, phosphate fertilizers
do not seem to give any increases in crop growth. Field tests are necessary, how­
ever, before definite conclusions should be drawn, and it is possible that these
materials might prove profitable in some cases in the field.

The results as a whole show very definitely that manure should be used on
these soils in as large amounts as practicable and its application will prove of
much value.

FIELD EXPERIMENTS

Until very recently it has not been possible to carry on field experiments in
Clay county. Some tests are now under way but they have not progressed far
enough to allow of the drawing of any definite conclusions. Results must cover
at least five years to be of any general value. Data obtained from these experi­
ments will be published at a later date as a supplement to this report.

The Carrington loam is one of the main soil types in Clay county and is found
extensively in other counties in the Wisconsin drift soil area. Some of the ex­
perimental plots at Ames are located on this soil and the results of the experi­
ments on these plots may be considered as directly applicable to conditions in
Clay county on the same soil type.

Fig. 5. Second greenhouse experiment with wheat, on Webster silty clay loam. Manure
was the only fertilizer which showed any appreciable effect in this experiment.
The results of a ten year test of various means of maintaining fertility in this Carrington loam have already been published and will be referred to here only briefly to indicate the general needs of this soil.

The experiment was carried out on five series of plots, two of which contained twelve plots, one-tenth of an acre in size, two series contained eleven plots of the same size and the fifth series contained twelve plots, three-twentieths of an acre in size. These plots were laid out in the usual way with division strips of $6\frac{1}{2}$ feet and a cropped border $6\frac{1}{2}$ feet wide around each series of plots.

The four series which were one-tenth of an acre in size were cropped to a four-year rotation consisting of corn, corn, oats, and clover. The fifth series was cropped continuously to corn. The treatment for each series was the same except that in the twelve plot series two were check pots. The treatments were:

1. Check
2. Legume
3. Manure
4. Manure and Legume
5. Manure and Legume and Phosphorus
6. Legume and Phosphorus
7. Manure and Phosphorus
8. Legume and Phosphorus and Potassium
9. Manure and Phosphorus and Potassium
10. Phosphorus and Potassium
11. Phosphorus
12. Check

Cowpeas were sown in the corn at the last cultivation, as the legume catch crop. In some seasons they were plowed under in the fall and in others disked down in the spring. Manure was applied at the rate of eight tons per acre once in the four year rotation to the clover sod in the fall just before plowing. This represents about the amount which would be applied if all the crops produced on the land were fed and the manure returned to the soil. Phosphorus was applied as steamed bone meal at the rate of 800 lbs. per acre, on the clover sod once in the four-year rotation. Potassium was applied either as muriate of potash or as potassium sulfate at the rate of 400 lbs. per acre, also on the clover sod once in the rotation.

In the case of continuous corn series the same fertilizing constituents were employed, the applications being made annually in the proper proportionate amounts.

The general plan of the experiment was to remove all the regular crops grown on the land except the corn stalks. These were usually plowed under but in seasons where the growth was heavy and the moisture conditions were not favorable they were removed. Two cuttings of clover were removed except in very dry years when the second crop was practically a failure and was plowed under.

The weight and value of each of the crops grown during the two separate four-year periods was determined and calculation made for the eight-year period.

In making the calculation, the corn was figured at 45 cents per bushel, the oats at 35 cents, and the clover at $8.00 per ton. The cost of fertilizers was as follows:

- Bone meal, $30 per ton
- Muriate of potash, $50 per ton
- Cowpeas, $2.50 per bushel
- Manure, $0.40 per ton

The figure for manure is based on the cost of handling and spreading and does not, of course, represent the actual value of the material. Manure is a waste product on the livestock farm and the actual expense involved in its utilization is very small.

The results for the three crops in the rotation and for the corn in the continuous cropping system are discussed in detail in the bulletin referred to and only summarized data for the eight-year period will be given here.

**THE ROTATION EXPERIMENTS**

Considering first the corn yields and the value of the treatments used, as shown in table IX, it is apparent that manure alone gave the largest net returns. This is undoubtedly partly due to the smaller cost of the treatment but with only two exceptions where the differences were very slight, actually larger yields of corn were secured with the manure alone.

**TABLE IX. CORN YIELDS—CARRINGTON LOAM**

<table>
<thead>
<tr>
<th>Soil treatment</th>
<th>Av. yield in bu. per acre</th>
<th>Inc. or dec. in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatment per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>60.2</td>
<td>-1</td>
<td>$-0.05</td>
<td>$1.25</td>
<td>$1.30</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>60.1</td>
<td>-1.1</td>
<td>$-0.15</td>
<td>$1.25</td>
<td>$1.10</td>
</tr>
<tr>
<td>Manure</td>
<td>72.4</td>
<td>12.2</td>
<td>5.49</td>
<td>8.00</td>
<td>4.69</td>
</tr>
<tr>
<td>Manure, cowpeas</td>
<td>68.3</td>
<td>8.1</td>
<td>3.65</td>
<td>2.05</td>
<td>1.60</td>
</tr>
<tr>
<td>Manure, cowpeas, phosphorus</td>
<td>73.1</td>
<td>12.9</td>
<td>5.81</td>
<td>5.05</td>
<td>0.76</td>
</tr>
<tr>
<td>Cowpeas, phosphorus</td>
<td>64.9</td>
<td>4.7</td>
<td>2.12</td>
<td>4.25</td>
<td>-2.13</td>
</tr>
<tr>
<td>Manure, phosphorus</td>
<td>72.1</td>
<td>11.9</td>
<td>5.36</td>
<td>3.80</td>
<td>1.56</td>
</tr>
<tr>
<td>Cowpeas, phosphorus, potassium</td>
<td>72.7</td>
<td>11.9</td>
<td>5.36</td>
<td>6.30</td>
<td>-0.67</td>
</tr>
<tr>
<td>Phosphorus, potassium</td>
<td>69.9</td>
<td>9.7</td>
<td>4.36</td>
<td>5.50</td>
<td>-1.14</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>59.2</td>
<td>-9.7</td>
<td>-5.36</td>
<td>5.00</td>
<td>-5.50</td>
</tr>
</tbody>
</table>

Average gain for manure ........................................... 8.8 Bu.
Average gain for phosphorus ..................................... 2.1 Bu.
Average gain for potassium ...................................... 6.2 Bu.

When phosphorus was added with the manure, almost the same yield was secured as with the manure alone but the cost of the phosphorus reduced the net returns considerably. Potassium applied with the manure and phosphorus
brought about no appreciable increase in the yield and the cost of the material lowered the value of the treatment to an actual loss. The phosphorus and potassium together increased the yield of corn but to a less extent than the manure alone and again the applications proved uneconomical.

The turning under of cowpeas alone did not increase the yield. Where they were added with other fertilizing constituents, some slight increases were secured, but in no case was the gain sufficient to warrant their use. This failure of cowpeas to prove of value as a green manure on the corn crop may probably be attributed to removal of plant food and moisture from the soil.

The average gains, 8.8 bushels per acre for the manure against 6.2 bushels for the potassium and 2.1 bushels for the phosphorus, show clearly the superior value of the manure.

Evidently, when manure is available it is the best fertilizing material for use on this soil and the application of other fertilizers with it cannot be considered profitable.

### TABLE X. OAT YIELDS—CARRINGTON LOAM

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Av. yield in bu. per acre</th>
<th>Inc. or dec in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatment per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>55.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>56.4</td>
<td>1.4</td>
<td>$.49</td>
<td>$1.25</td>
<td>$1.76</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>61.9</td>
<td>6.9</td>
<td>2.42</td>
<td>1.80</td>
<td>3.62</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>67.9</td>
<td>2.9</td>
<td>1.03</td>
<td>2.05</td>
<td>4.08</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>62.5</td>
<td>9.1</td>
<td>3.18</td>
<td>4.25</td>
<td>8.43</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>62.5</td>
<td>7.5</td>
<td>2.63</td>
<td>4.25</td>
<td>6.90</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>62.4</td>
<td>7.4</td>
<td>2.59</td>
<td>3.80</td>
<td>7.60</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>63.9</td>
<td>8.9</td>
<td>3.12</td>
<td>6.75</td>
<td>10.50</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>65.3</td>
<td>10.3</td>
<td>3.61</td>
<td>6.30</td>
<td>12.60</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>54.8</td>
<td>-.2</td>
<td>-.07</td>
<td>5.50</td>
<td>5.50</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>57.9</td>
<td>2.9</td>
<td>1.03</td>
<td>3.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Average gain for manure.............................................. 5.0 Bu.
Average gain for phosphorus........................................... 3.9 Bu.
Average gain for potassium............................................ 0.4 Bu.

The results of the experiment with oats as given in table X reveal the fact that with all the treatments except manure, the cost of the fertilizers considerably exceeded the value of the increases which they brought about in yields.

### TABLE XI. CLOVER YIELDS—CARRINGTON LOAM

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Av. yield in tons per acre</th>
<th>Inc. or dec. in tons per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatment per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>2.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>2.65</td>
<td>.40</td>
<td>$3.20</td>
<td>$1.25</td>
<td>$4.50</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>2.82</td>
<td>.57</td>
<td>4.56</td>
<td>.80</td>
<td>5.36</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>2.54</td>
<td>.29</td>
<td>2.32</td>
<td>2.05</td>
<td>.27</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>3.11</td>
<td>.86</td>
<td>6.88</td>
<td>5.05</td>
<td>1.83</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>2.71</td>
<td>.48</td>
<td>3.68</td>
<td>4.25</td>
<td>5.57</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>2.85</td>
<td>.60</td>
<td>4.80</td>
<td>3.80</td>
<td>8.60</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>3.35</td>
<td>1.10</td>
<td>8.80</td>
<td>6.75</td>
<td>15.55</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>3.06</td>
<td>.81</td>
<td>6.48</td>
<td>6.30</td>
<td>2.18</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>2.90</td>
<td>.65</td>
<td>5.20</td>
<td>5.50</td>
<td>-.30</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>2.45</td>
<td>.80</td>
<td>1.60</td>
<td>3.00</td>
<td>4.40</td>
</tr>
</tbody>
</table>

Average gain for manure.............................................. 0.284 Tons
Average gain for phosphorus........................................... 0.215 Tons
Average gain for potassium............................................ 0.433 Tons
CLAY COUNTY SOILS

Greater increases in yields were obtained in several cases, from the combined treatments than were obtained from the manure alone, but the cost of the other fertilizers made the treatments uneconomical.

The average gains for the manure, phosphorus, and potassium were 5.0 bushels per acre, 3.9 bushels per acre and 0.4 bushels per acre, respectively. Again the gains secured from the use of cowpeas were too small to be calculated. Not only were they of no value on the corn but they produced no effect on the oats in the succeeding year. As with the corn crop the manure had the greatest fertilizing value on the oats.

Table XI gives the results of the tests with clover for the eight-year period, and again the manure alone gave the largest net returns on the investment for the treatment and the other applications proved of less value. Gains in yield were shown for several other treatments and the average gains for the manure, phosphorus, and potassium were 0.284 tons, 0.215 tons, and 0.433 tons, respectively. The results for the clover crop were somewhat different from those secured with the corn and oats in that they showed a larger influence from the application of potassium. The greatest net returns were secured with the manure alone inasmuch as the cost of the potassium was very large. Cowpeas exerted some effect on the clover crop but their influence was less than that of the manure.

These tests on the four crops in the rotation show distinctly that manure is of the greatest value of any fertilizing constituent. In many cases it gives the largest yields and because of its low cost it shows in every case the greatest net returns. Phosphorus proved of little value on any of the crops and while potassium gave good effects on the clover, it failed to influence the other crops in the rotation. The value of cowpeas as a green manure in the rotation is very questionable, for only slight increases in crop yields were evidenced. The removal of available plant food and moisture from the use of the main crop may account for the lack of effect produced by the green manure on the corn and oats in the rotation.

THE CONTINUOUS CORN EXPERIMENT

TABLE XII. CONTINUOUS CORN YIELDS—CARRINGTON LOAM

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Av. yield in bu. per acre</th>
<th>Inc. or dec. in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatment per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>44.2</td>
<td>1.5</td>
<td>$.68</td>
<td>$.80</td>
<td>4.24</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>53.9</td>
<td>11.2</td>
<td>5.04</td>
<td>.80</td>
<td>4.24</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>56.4</td>
<td>13.7</td>
<td>6.17</td>
<td>5.05</td>
<td>1.12</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>56.4</td>
<td>13.7</td>
<td>6.17</td>
<td>5.05</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>46.5</td>
<td>3.8</td>
<td>1.71</td>
<td>4.25</td>
<td>2.54</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>54.9</td>
<td>12.2</td>
<td>5.49</td>
<td>3.80</td>
<td>1.69</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>55.5</td>
<td>12.8</td>
<td>5.76</td>
<td>6.75</td>
<td>-1.99</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>54.2</td>
<td>11.5</td>
<td>5.18</td>
<td>6.30</td>
<td>-1.12</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>49.2</td>
<td>6.5</td>
<td>2.93</td>
<td>5.50</td>
<td>-2.57</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>43.6</td>
<td>.9</td>
<td>.41</td>
<td>3.00</td>
<td>-2.59</td>
</tr>
</tbody>
</table>

Average gain for manure.................................................................9.3 Bu.
Average gain for phosphorus.........................................................1.8 Bu.
Average gain for potassium.........................................................4.6 Bu.

The results of the eight-year test with continuous corn are given in table XII. As in the rotation experiment the greatest net returns were secured by the treat-
Slightly greater yields were secured when phosphorus was used with the manure but the cost of the phosphorus reduced the net return below that secured with manure alone. Potassium showed some effect on the corn yield as did also cowpeas but the cost of the former was too great and the increases too small to make its use profitable while the increases from the cowpeas were too small to calculate. The average gains for the manure, phosphorus, and potassium were 9.3 bushels, 1.8 bushels, and 4.6 bushels respectively and these figures also show the superior value of the manure as a fertilizer for corn on this soil. Other fertilizing materials cannot be recommended for this soil type at the present time.

The yields of corn under continuous growing were very much smaller than those secured in the four-year rotation indicating that the continuous growth of corn is injurious to the soil. The plant food is used up too rapidly, the humus or organic matter content becomes depleted and the physical condition of the soil is injured. A longer period for the experiment would undoubtedly have shown a much greater decrease in yield than was apparent here but these results indicate clearly the superior value of a rotation of crops over a continuous growing of one crop.

The relative value on corn of the various treatments appeared to be practically the same whether the corn is grown continuously or in rotation. Manure was of the greatest value in both cases, potassium gave smaller gains, and phosphorus and cowpeas showed practically no effects. Furthermore none of the treatments except the manure yielded profitable net returns.

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

The field tests now under way in Clay county have not been carried on long enough to permit of definite conclusions from the results secured. These results will be published later in a supplementary report. The treatments recommended for the soils of the county are based at present on the laboratory and greenhouse tests and the one field experiment and also on the experience of farmers.

No suggestions are made regarding treatments which are not known to be of definite value in the field and are warranted by experience. Where uncertainty exists it is suggested that tests be carried out before any fertilizing materials are used as only in that way can the results be guaranteed. If a test on a small scale shows value from the use of a fertilizer then that material may safely be employed on a large area.

DRAINAGE

While much of the upland in Clay county has either been well-drained naturally or by the use of tile there are still some areas where drainage would be of value. Some areas in the Carrington loam and in the Carrington silt loam are level and poorly drained and the Webster silty clay loam is quite generally in
need of drainage. The Fargo silty clay loam, a terrace type is also generally poorly drained. All the bottomland types are in need of drainage as well as protection from overflow in order to make them productive. The Lamoure silty clay loam and the Lamoure loam are especially in need of better drainage.

A soil which is poorly drained will not be productive and no other treatment of such a soil will prove profitable until adequate drainage has been established. The first treatment needed by the soils mentioned above, therefore, is the installation of a proper drainage system. It is an easy matter to determine whether a soil is in need of drainage and while the expense involved in the installation of tile may be considerable, the returns secured will much more than warrant the outlay. Definite advice and suggestions regarding the drainage of special soils and the installation of tile will be given by the Soils Section upon request.

**MANURING**

Manure is undoubtedly a most profitable material for application to the soils of Clay county. The greenhouse and field experiments discussed above show distinct increases on some soil types by the use of manure. Furthermore, farm experience gives abundant confirmation of these results. Many others of the soil types which have not been the subject of special study will undoubtedly be benefitted materially by the use of manure. Even where other fertilizing materials are employed, manure should be used also if the best results are to be secured.

The value of manure is due to its content of plant food, to its effect on the organic matter in the soil and to the influence of the bacteria introduced with it. The plant food contained in the manure is that which was present in the crops which were used for feed and hence there is a return of much that was removed from the soil in the crops. The "life" of the soil is therefore considerably lengthened by the use of manure. The effect on the continued fertility of the soil of the return of as large a portion of the plant food as possible is so important that great care should be exercised in the storage and application of manure. When loosely stored and exposed to the weather, manure may lose from 75 to 90 percent of its plant food.

Such losses fall mainly on the nitrogen content and are due to the leaching and to the vigorous fermentations which occur. The value of the manure when applied to the soil is reduced in direct proportion to its loss of plant food. The losses from manure may be very largely prevented by proper care in storing and applying the material. It should be kept under cover, moist and compact or it should be applied to the soil as produced. The practice which should be followed will depend upon the particular farm conditions but if the manure is not applied as soon as produced it should be protected from the washing action of rain and kept from undergoing destructive fermentations.

With proper care in storing, manure may return as much as 85 percent of the plant food taken from the soil by the crops and hence the time when the addition of artificial fertilizers will become necessary will be put far in the future. The physical effect of the manure on the soil is very great. It opens up heavy soil and makes light soils more compact and more retentive of moisture. In both cases the
soil conditions are made better for the proper production of available plant food and for the best growth of crops. The organic matter content of soils must be kept up or crop growth will not be satisfactory and manure is the best material to be employed for this purpose. Manure contains large numbers of bacteria which are the producers of available plant food, hence by its use the decomposition processes are stimulated and the store of plant food in the soil is put into condition for supplying crop needs. It is undoubtedly the physical and bacterial effects of manure which make it of value on apparently rich soils such as the Webster silty clay loam.

The average application of manure for most soils is about eight to ten tons per acre. Smaller amounts than this may be used to advantage in some cases where the stimulative effect on available plant food production is the main reason for its value. Larger amounts are often used with profit on light open soils, poor in organic matter but it is not advisable to apply more than sixteen to twenty tons per acre for ordinary farm crops. The best results are ordinarily secured by the use of eight to ten tons per acre. Even this amount cannot be applied to all the soils on the average farm once in a four-year rotation, as the production of manure is insufficient.

On the grain farm, where the amount of manure is very small, green manures must be employed as substitutes. Legumes or non-legumes may be used as green manures but legumes should be chosen whenever feasible as they not only supply organic matter to the soil but when well inoculated as they always should be, they use nitrogen from the atmosphere and hence enrich the soil in that constituent. There are many legumes which may be chosen for use as green manures and hence some one may be selected which will be suitable for almost any condition. Green manuring is often desirable as a substitute for or supplement to the use of farm manure. The practice cannot be recommended for general use, however, and it should be followed carefully and intelligently. If this is not done it may not prove profitable and may even be injurious. Advice regarding the use of green manures on individual soils will be furnished by the Soils Section upon request. General information along this line may be secured from circular No. 10 of the Iowa Agricultural Experiment Station.

Under all systems of farming whether livestock, grain or any other, the crop residues such as straw and stover should all be returned to the soil as they are an important means of keeping up the organic matter in the soil. Such materials should never be burned or otherwise destroyed as they are too valuable on the soil. They may be used for feed or bedding on the livestock farm and returned to the soil with the manure, which is probably the best method of utilization as the straw is thus mixed with the manure and it will have the greatest effect. On the grain farm, the residues should be used even more carefully as they are the chief source of organic matter. They not only play an important part in keeping up the organic matter content in the soil but they also have a considerable influence on the "life" of the soil because of the plant food which they contain and which is returned to the soil.
The soils of Clay county do not contain an abundance of phosphorus, according to the analyses given earlier in this report and it seems reasonable to conclude therefore, that phosphorus fertilizers will be needed in the future and may possibly prove of value even now. The greenhouse tests on the Carrington silt loam showed some effect from the use of phosphorus but there was no definite influence evidenced in the case of the Webster silty clay loam. Other greenhouse tests on some of the soil types in this county have also given indications of value for phosphorus fertilizers. The results of greenhouse tests, however, should not be taken to show definitely what would occur in the field. Field tests should be carried out to confirm the greenhouse results before general conclusions are drawn. The one field experiment reported showed no profit from the application of phosphorus to the Carrington loam but other tests under the different conditions in Clay county might lead to different conclusions. There are several field experiments now under way in Clay county but the results of these will not be available for several years. For the present definite recommendations regarding the use of phosphorus fertilizers cannot be made. It can merely be said that phosphorus will certainly be needed in the future and it may be of value now in some instances. Farmers are urged to test the value of phosphorus fertilizers on their own farms under their particular soil conditions. Rock phosphate and acid phosphate are the two materials which may be used and tests should include both fertilizers. Rock phosphate is considerably cheaper but a much larger application must be made and it is an insoluble slowly available material while acid phosphate is a soluble, readily available material. It is necessary, therefore, to test the two materials to determine which will prove the most profitable. Farmers are urged to make simple tests on their own soils to solve their own problem. Directions for carrying out such tests are given in circular No. 51 of the Iowa Agricultural Experiment Station. Farmers who are interested may secure further advice and information along this line from the Soils Section. If one of the fertilizers proves to be profitable on a soil in a small test then that material may be employed on a large area of the same type with the assurance of economic returns.

Nitrogenous fertilizers are probably unnecessary on the soils of Clay county at the present time but nitrogen must be considered in systems of permanent soil fertility. Crop residues and farm manure return nitrogen to the soil but there is a gradual decrease in the amount present and eventually nitrogen will be needed in spite of the fact that a good supply is present now. Well inoculated legumes used as green manures are a cheap and effective means of adding nitrogen to the soil and they have an additional value in that they supply organic matter. Such materials if used at regular intervals will, therefore, serve to keep up the nitrogen in the soil. Except possibly in small amounts as top dressings to stimulate the early growth of certain crops, commercial nitrogenous fertilizers will probably not prove profitable on Clay county soils. If tests show them to be of value in special cases, however, they may be used.

Previous analyses of the soils of the state showed potassium to be present in such abundance that potassium fertilizers are not believed to be necessary at the...
SOIL SURVEY OF IOWA

present time. The soils of Clay county are well supplied with this plant food and if the soils are kept in the proper physical condition and reaction for the best crop growth, there should be a sufficient production of available potassium from the stock in the soil to keep crops supplied. The use of potassium fertilizers in this county except possibly as top dressings cannot be recommended.

The field tests now under way in Clay county include the use of a 2-8-2 complete commercial fertilizer and a comparison of the value of this material with rock phosphate and acid phosphate will, therefore, be secured. Such complete brands cannot be recommended at the present time and farmers are urged to test them along with phosphate materials on their own soils. If they prove of value, they may be employed without fear of injury to the soil. It is advisable always to test the use of such materials against phosphate fertilizers for their value, if any is shown, might be due to the phosphorus content. Potassium is present in abundance and nitrogen may be added by leguminous green manures and hence it is doubtful if complete brands of fertilizers containing phosphorus, potassium and nitrogen would prove as profitable as the incomplete phosphorus carriers.

LIMING

The need of lime is not so pronounced in the soils of Clay county as in some other sections of the state but most of the types are acid and in need of lime. The Webster silty clay loam, the steep phase Carrington loam, the Fargo silty clay loam, the Lamoure silty clay loam, and the Lamoure loam are the types which are not acid at present. In the case of the Webster silty clay loam, however, there is no supply of lime present and hence that type will be in need of lime in the future. The other soils mentioned are apparently well supplied for some time to come. The remaining types in the county should all be tested for acidity and if acid lime should be applied. Small grain crops and corn are rarely influenced to any appreciable extent by acid conditions, unless they are extreme and hence the beneficial effects of lime will be evidenced mainly on the legume in the rotation. The effect on this crop is, however, sufficient to warrant the use of lime. There may be an additional beneficial influence of lime on acid soils because of its effect in improving the physical conditions both of heavy, impervious soils and of light, open types.

Lime should be considered in all systems of permanent fertility as all soils tend to become acid and with better drainage and more intensive cultivation and crop production, even those types in Clay county which are not acid now, will eventually become so. Hence, the soils in the county should be tested from time to time and lime applied at regular intervals when necessary.

Soils vary widely in extent of acidity and the amount of lime needed by a particular soil can be determined only by a test of that soil. Average analyses even of a large number of samples will not show accurately the needs of a soil type. Farmers may test their own soils for acidity but it will be much more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way it may be ascertained how much lime to apply and an excess or an insufficient application will be avoided, both of which are undesirable economically.
Further information regarding the application of lime, the kind of lime to use, sources from which it may be secured and other points connected with the use of lime may be found in Bulletin No. 151 of the Iowa Agricultural Experiment Station.

CROP ROTATIONS

Many experiments and much farm experience have shown very definitely that the rotation of crops is of more value than the continuous growing of any one crop, even if that were a "money" crop. In fact for permanent fertility it has been shown very clearly that some rotation of crops is absolutely essential.

There are various rotations in use throughout the state which are quite satisfactory. Those given below are the most common. Other rotations may be chosen for special conditions and in general it may be said that any rotation may be employed provided it contains a legume.

1. Four or Five-Year Rotation

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Corn</td>
</tr>
<tr>
<td>Second</td>
<td>Corn</td>
</tr>
<tr>
<td>Third</td>
<td>Oats (with clover or with clover and timothy)</td>
</tr>
<tr>
<td>Fourth</td>
<td>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)</td>
</tr>
</tbody>
</table>

2. Four-Year Rotation with Alfalfa

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Corn</td>
</tr>
<tr>
<td>Second</td>
<td>Oats</td>
</tr>
<tr>
<td>Third</td>
<td>Clover</td>
</tr>
<tr>
<td>Fourth</td>
<td>Wheat</td>
</tr>
<tr>
<td>Fifth</td>
<td>Alfalfa (The crop may remain on the land five years. This field should then be used for the four year rotation outlined above)</td>
</tr>
</tbody>
</table>

3. Three-Year Rotation

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Corn</td>
</tr>
<tr>
<td>Second</td>
<td>Oats or wheat (with clover seeded in the grain).</td>
</tr>
<tr>
<td>Third</td>
<td>Clover (Only the grain and clover seed should be sold; in grain farming 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).</td>
</tr>
</tbody>
</table>

THE PREVENTION OF EROSION

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

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroughly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner to the detriment of the land.
Light, open soils which absorb water readily are not apt to be subject to ero-

sion while heavy soils such as loams, silt loams, and clays may suffer much from

heavy or long-continued rains. Loess soils are apt to be injured by erosion when

the topography is hilly or rough and it is this group of soils which is affected
to the greatest extent in Iowa. Flat land is, of course, little influenced by ero-
sion. Cultivated fields or bare bluffs and hillsides are especially suited for ero-
sion while land in sod is not affected. The character of the cropping of the
soil may therefore determine the occurrence of the injurious action. The care-
less management of land is quite generally the cause of the erosion in Iowa. In
the first place, the direction of plowing should be such that the dead furrows
run at right angles to the slope; or if that is impracticable, the dead furrows
should be “plowed in” or across in such a manner as to block them. Fall plow-
ing is to be recommended whenever possible as a means of preventing erosion.
Only when the soil is clayey and absorption of water is very slow will spring
plowing be advisable. The organic matter content of soils should be kept up by
the addition of farm manures, green manures and crop residues if soil subject
to erosion is to be properly protected. By the use of such materials the absorb-
ing power of the soil is increased and they also bind the soil particles together
and prevent their washing away as rapidly as might otherwise be the case. By
all these treatments the danger of erosion is considerably reduced and expen-
sive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may
occur over a rather large area and the surface soil may be removed to such a
large extent that the subsoil will be exposed and crop growth prevented. Sheet
washing often occurs so slowly that the farmer is not aware of the gradual re-
moval of fertility from his soil until it has actually resulted in lower crop yields.
Gullying is more striking in appearance but it is less harmful and it is usually
more easily controlled. If, however, a rapidly widening gully is allowed to
grow unchecked an entire field may soon be made useless for farming purposes.
Fields may be cut up into several portions and the farming of such tracts is
more costly and inconvenient.

In Clay county erosion does not occur to a very large extent but some of the
soil types in certain areas are subject to the destructive action. The Carrington
fine sandy loam, steep phase Carrington loam, Carrington silt loam and Shelby
fine sandy loam are all subject to erosion in some localities.

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

EROSION DUE TO DEAD FURROWS

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

“Plowing In”—It is quite customary to “plow in” the small gullies that
result from these dead furrows and in level areas where the soil is deep, this
“plowing in” process may be quite effective. In the more rolling areas, how-
ever, where the soil is rather shallow, the gullies formed from dead furrows
CLAY COUNTY SOILS  

may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

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

Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. They are somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it not practicable to fill them by dumping soil into them, for an immense amount of labor is involved and the effect will not be permanent.

"Staking In."—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water flowing upon it. A series of these brush-piles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets
smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving in time, labor and inspection.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a “Christopher” or “Dickey” dam.

The “Christopher” or “Dickey” Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a “T” being inserted in the tile just above the dam. This “T,” called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass. Considering the cost, maintenance, permanence, and efficiency, the Christopher or Dickey dam, especially when arranged in series of two or more, may be regarded as the best method of filling ditches and gullies and as especially adapted to the larger gullies.

The stone or rubble dam.—Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when tile openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The rubbish dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The woven wire dam.—The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for preventing erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the “staking in” system. It can
only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

*Sod strips.*—The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

*The concrete dam.*—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

*Drainage.*—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

**LARGE GULLIES**

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher dam, already described, may also serve in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

**BOTTOMLANDS**

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

*Straightening and tiling.*—The straightening of the larger streams in bottom land areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottom land and it often proves very efficient.
Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

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

Use of organic matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw, corn stalks, etc., may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing of crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also quite desirable for use in such locations. The root system of such crops as these hold the soil together and the washing action of rainfall is reduced to a marked extent.

Contour discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven very satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Deep plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.
INDIVIDUAL SOIL TYPES IN CLAY COUNTY

DRIFT SOILS

There are six soil types in Clay county which are classed as drift soils. Together they cover 73.4 percent of the total area of the county. The soils are classed in the Carrington, Webster, and Shelby series.

CARRINGTON LOAM (1)

This is the most extensive soil type in the county, covering 102,272 acres or 28.3 percent of the total area of the county. It covers most of the prairie region in the eastern and northern three-fourths of the county, including the territory north and east of the Ocheyedan and Little Sioux rivers. A narrow strip also occurs along the river in the southwestern part of the county.

The surface soil is a dark-grayish brown to dark-brown, mellow loam and extends to a depth of 8 to 10 inches. From this point down to 30 inches, the soil is a light-brown to yellowish-brown, rather compact, heavy loam to light silty clay loam or sandy silt loam. The subsoil to 36 inches is a yellowish-brown rather loose sandy loam or sandy clay. The subsoil frequently contains lime concretions and some glacial pebbles. Numerous reddish-brown iron stains also occur. Considerable fine sand is found in this type both in the surface soil and subsoil. There are some variations in the character of this soil in different localities which should be mentioned. In the flatter areas as, for example, north of Everly the surface soil is a heavy loam and the light-brown compact heavy loam subsoil continues to a depth of 3 feet. Glacial pebbles and bowlders occur on the surface and throughout the soil, in some of the more rolling areas. In the northeastern part of the county, gravel and sand practically free from clay often underlie the soil at a depth of 24 to 27 inches. There are some small knolls of the Shelby fine sandy loam, too small to map, which occur in the eastern and northeastern parts of the county. In general the more compact surface soil and subsoil occur in the flatter areas while the lighter textured surface soil and loose subsoil are found in the more rolling areas and on the steep slopes.

The topography of the type varies from undulating to gently rolling with some rather steep areas and some almost level, low lying areas. The type is usually fairly well drained but tile drainage is of value on many of the flatter areas.

About 85 percent of this soil is under cultivation, the remaining area which is more rolling and occurs along the bottomlands, is in pasture. Corn is the chief crop grown and average yields of 30 to 35 bushels per acre are secured. Oats is second in importance, yielding on the average, 32 to 37 bushels per acre. Barley, spring and winter wheat, alfalfa and clover and timothy are also grown. Barley yields 20 to 25 bushels, spring wheat, 15 to 20 bushels and winter wheat 17 to 25 bushels per acre. Alfalfa is grown more on this type than on any other soil in the county, yields of 2½ to 3½ tons of hay per acre being secured. Clover yields 1½ to 2 tons and timothy 1 to 1½ tons per acre. Potatoes are grown to some extent and yields of 85 to 100 bushels per acre are secured.

1 The descriptions of soil types given in this section follow closely those reported in the Bureau of Soils bulletin.
The needs of the Carrington loam to make it more productive and to keep it so include drainage of the level areas, the application of lime when the soil is acid, the use of manure in liberal amounts, and eventually the addition of phosphorus fertilizers. The type is quite generally acid in the surface soil and lime should be applied whenever tests show acid conditions. The soil should be tested at regular intervals especially before growing legumes, such as alfalfa or clover. Manure has been found to bring about considerable increases in crop yields and that material should be used in as large amounts as practicable. The type is not low in organic matter but in spite of that fact the use of manure adding as it does, plant food and bacteria as well as organic matter, brings about greater crop production. Phosphorus is probably not necessary now on this type, altho there are indications of value from its use but it certainly will be needed in the future as the content in the soil is low. With these treatments and especially drainage, lime, and manure this soil may be made and kept highly productive.

CARRINGTON LOAM (STEEP PHASE) (57)

This is a minor type in the county covering 10,496 acres or 3 percent of the total area of the county. It occurs in narrow, irregular strips on the slopes to the Little Sioux river and its tributaries in the southern half of the county. A narrow strip also occurs on each side of Elk and Willow creeks.

The surface soil is quite variable, ranging from a very sandy loam in some places to almost a clay loam in others. In general it consists of a dark-brown loam, 8 inches in depth. On some of the steeper slopes, the surface soil has been completely washed away. The subsoil is usually a buff or pale-yellow silty clay loam to silty clay. Both soil and subsoil contain glacial pebbles and bowlders.

The topography of the type as shown in the name is steep in some areas being almost precipitous. Erosion is very active and the soil washes badly after every rain. It is not feasible to farm the type and it is used practically entirely for pasture. There is a good growth of prairie grass over most of the phase and some trees are found. These are basswood, prickly and white ash, soft maple, box elder, white elm and cottonwood with scrubby growths of smooth sumac, wild plum, hazelnut, choke cherry, crabapple and red haw. The soil should be protected from erosion and kept in pasture which is the only reasonable use for the land.

WEBSTER SILTY CLAY LOAM (107)

This is the second largest soil type in the county, covering 72,788 acres or 20.2 percent of the total area of the county. It occurs mainly in a large continuous area in the southwestern third of the county, being interrupted only by a narrow strip of other types along Willow creek. It extends from Greenville west and south to the county lines. A few small areas of the type occur in other parts of the county chiefly associated with the Carrington loam, occurring on the broad level areas where erosion has not taken place and the drainage has been inadequate.

The surface soil is a very dark-brown or nearly black moderately heavy silty clay loam, about 15 inches in depth resting upon a dark yellowish-brown rather compact, crumbly silty clay loam. The subsoil at 24 inches is a brownish-yellow
crumbly silty clay loam. The subsoil usually has a grayish cast especially in the lower part of the 3-foot section. Glacial boulders and pebbles are sometimes found on the surface but they are not numerous.

In topography this soil is undulating to nearly flat but near the Carrington silt loam areas it becomes very gently rolling or sloping. The drainage is generally rather poor and tile drains are often used to advantage.

Practically all of the type is under cultivation, the principal crops being corn, oats, hay, barley, and wheat. Corn averages 40 bushels per acre, but in favorable seasons 65 bushel yields are common. Oats average 35 to 45 bushels; barley about 25 bushels and spring wheat 18 to 23 bushels per acre. Winter wheat has been grown recently to some extent and yields 25 to 27 bushels per acre. Clover and timothy mixed yield about 2 tons of hay per acre; red clover alone, \( \frac{3}{4} \) to 2 tons and timothy, \( \frac{1}{4} \) to \( \frac{3}{4} \) tons. Good results have been secured from growing alfalfa and average yields of 2 to \( \frac{3}{2} \) tons per acre are secured. The acreage in this crop is increasing as its value is becoming more generally recognized.

The Webster silty clay loam is naturally an extremely fertile soil but it is in need of certain treatments to increase crop production and to keep up its fertility. The chief need of the type is for drainage. Tile drains should be installed in most cases to carry away the excess water and to permit the soil to be properly aerated and to warm up earlier in the spring. It should be plowed and cultivated throroly so as to put it in a better physical condition and the addition of lime which is usually necessary to remedy the acidity of the soil will also aid in improving the physical condition of the soil.
The soil is not low in organic matter but additions of farm manure give large increases in crops and prove decidedly profitable. The use of farm manure regularly on this soil is advisable to keep up its content of organic matter. Leguminous green manures may be needed later to add nitrogen or at the present time, if farm manure is not available.

Phosphorus is low in the type and applications of phosphorus fertilizers may prove profitable now. They certainly will be needed in the future and farmers should test these materials on their own soils. With proper drainage and cultivation, the addition of lime, farm manure or green manures and phosphorus fertilizers, if not now, at least in the future, this soil may be made and kept highly productive.

**CARRINGTON SILT LOAM (83)**

The Carrington silt loam is the third soil type in area in the county, covering 54,144 acres or 15.0 percent of the total area of the county. It occurs in the largest bodies east and northeast of Greenville, along Willow creek and on the highland northeast of Gillett Grove. Smaller areas are found scattered over the rest of the county.

The surface soil to a depth of 12 inches is a dark brown moderately heavy silt loam. The subsoil is a dark yellowish-brown, compact, heavy silt loam grading at about 22 inches into a brownish-yellow to yellowish-brown less compact, light silty clay loam. The intermediate layer is often absent and the subsoil in such cases is a yellowish-brown to brownish-yellow rather friable, light, silty clay loam. Glacial bowlders and pebbles are occasionally found in this type but rarely in the surface soil. The type is generally quite uniform but in places the surface soil may be quite thin, especially on the more sloping areas.

The topography of the type is generally undulating to gently rolling. Along Willow creek, however, it is more strongly rolling. Drainage is generally good but on the flatter areas, tile drainage has proven quite beneficial.

Practically all of this soil is in cultivation, the chief crops grown being corn, oats and hay with considerable barley and some wheat. Alfalfa is also grown to some extent. Corn yields 30 to 40 bushels per acre and the other crops about the same as on the Webster silty clay loam.

The Carrington silt loam is a fertile, productive soil but with proper treatment it can be made more productive and its continued fertility can be insured. First of all, it should be thoroughly drained by the use of tile drains wherever necessary. It is quite acid in reaction and tests should therefore be made and the amount of lime shown to be necessary should be applied. Farm manure gives large increases in yields on this soil and this material should be used in as large amounts as practicable. Green manures may prove profitable in many cases and should be used as a supplement to or substitute for farm manure. Legumes used as green manures will be needed in the future to keep up the nitrogen supply. Phosphorus is low and phosphorus fertilizers will be required in the future if indeed they do not prove profitable now. Tests with these materials are highly desirable. Protection from washing is often necessary on this type.
CLAY COUNTY SOILS

CARRINGTON FINE SANDY LOAM (4)

This is a minor upland type in the county, covering 20,416 acres or 5.7 percent of the total area of the county. It occurs in small scattered areas practically entirely in the section north and east of the Ocheyedan and Little Sioux rivers. None of the areas cover more than 4 square miles.

The surface soil to a depth of 8 to 10 inches is a dark-brown to dark grayish brown fine sandy loam. The subsoil is a grayish-brown, rather compact fine sandy loam to light loam, grading at about 24 inches into a brown to light-brown or yellowish-brown fine sand. The texture of the surface soil may vary from a light loam to a sandy loam and in some places it is lower in organic matter and grayish-brown in color. Glacial bowlders occur in the soil and in places on the surface.

In topography the type is gently rolling, occurring on low ridges and small hills. It is sloping in some areas along the streams. The type is well drained and on the steeper slope it is subject to considerable erosion.

About 80 percent of the soil is cultivated, the remainder being in native grasses and used for pasture. The crops grown are the same as on the Carrington loam but there is a larger acreage in clover and timothy than on the heavier soil and less corn is produced. Corn yields 25 to 35 bushels per acre, oats 25 to 35 bushels, barley 18 to 25 bushels and spring wheat 14 to 18 bushels per acre. Clover and timothy yield 11/4 to 1 1/2 tons of hay per acre, red clover alone 1 1/4 to 2 tons, timothy 1 ton and alfalfa 2 to 3 tons.

The needs of this soil to make it more productive are the liberal use of farm manure and of green manures as a supplement to or substitute for farm manure, the application of lime in amounts shown to be necessary by acidity tests and the application of phosphorus fertilizers either now or in the near future. Leguminous green manures will also be necessary from time to time to keep up the nitrogen supply of the soil. This type is frequently in need of protection from erosion and care should be taken to prevent this injurious action.

SHELBY FINE SANDY LOAM (92)

The Shelby fine sandy loam is a very minor type in the county, covering only 4,160 acres or 1.2 percent of the total area of the county. It occurs mainly in the eastern fourth of the county on the hills, knolls and ridges which occur in the areas of Carrington fine sandy loam and Carrington loam. One area is mapped in the northwestern corner of the county. There are four comparatively large areas but the majority are quite small.

The surface soil is a brown to grayish-brown fine sandy loam to a depth of 10 to 12 inches. The subsoil is a rather compact, light brown, fine sandy loam to loamy fine sand, grading at 27 inches into a light brown clayey fine sand. Glacial pebbles and bowlders are found frequently throughout the surface soil and the subsoil.

The surface soil is quite variable in the different areas and even within individual areas it may vary from a fine sand to a light loam. In a few places small knobs of bowlder clay occur. Sometimes the surface soil is underlain directly by a fine sand which rests upon a layer of bowlders and gravel at 30 inches. In some areas the subsoil of fine sandy loam is underlain at 16 or 18 inches by a layer of bowlders, gravel and sand.
The type is hilly or rolling in topography on the larger areas while the smaller areas are knolly and ridgy. Drainage is good throughout the type, and in places it is excessive, owing to the open character of the subsoil. Erosion frequently occurs on the steeper slopes and the soil may be badly washed.

Less than one-third of this type is under cultivation, the major portion being used for grazing purposes. On the cultivated areas, corn, oats, hay, barley and wheat are grown and the yields of these crops are about the same as on the Carrington fine sandy loam.

The needs of this soil are for the application of farm manure in as large amounts as practicable and for the use of leguminous green manures to supplement the farm manure and also to keep up the supply of nitrogen. Lime is necessary as the soil is generally acid and this acidity must be corrected to secure the best growth of crops especially legumes. Phosphorus will be needed in the future if it does not prove profitable now which is quite probable. The soil must be protected from erosion in order to permit of the growth of satisfactory crops.

TERRACE SOILS

There are four terrace soils in the county covering 33,856 acres or 9.4 percent of the total area of the county. They are classed in the O’Neill, the Fargo and the Waukesha series.

O’NEILL LOAM (108)

This is the most extensive terrace type, covering 29,184 acres or 8.1 percent of the total area of the county. It is developed mainly along the Little Sioux and Ocheyedan rivers from Dickens to Everly and from Spencer north to the county line. This area is between 40 and 45 miles square. Smaller areas occur along some of the other streams of the county and near old lakes.

The surface soil is a dark-brown to dark-grayish brown, mellow-loam, about 8 inches in depth. The subsoil to a depth of 27 inches is a light-brown to brown rather compact loam to light silty clay loam. Below that point there is a bed of sand and gravel which is usually 25 to 30 feet in thickness. It may be mostly gravel with pockets of sand or it may be chiefly sand with layers of gravel. Below this bed of sand there is a layer of blue clay.

In some areas back from the streams or adjoining the uplands, the bed of gravel may be deeper and the surface soil quite silty. Near the streams or in other places where the surface soil has been partly washed away, the sand is nearer the surface and the surface soil is lighter in texture and color than the typical soil. Small areas of O’Neill fine sandy loam occur throughout the type. They are too small to map separately, however. Some areas near old lakes contain gravelly sandy loam mounds which are underlain by the typical subsoil.

In topography the soil is rather flat, occurring on benchlike areas usually 10 to 20 feet above overflow. One area occurs which is 15 to 20 feet above the terrace level. In general the larger areas are further above overflow than the smaller areas. The soil is well drained and where the sand and gravel are near the surface, the drainage is apt to be excessive. In dry seasons the crops on this type are apt to suffer from drought.
This type is a very important soil agriculturally. Probably 80 percent is in cultivation, the remainder being used for pasturage. The principal crops grown are corn, oats, hay, barley, and wheat. Corn yields 25 to 36 bushels per acre on the average, oats 25 to 35 bushels, barley 18 to 20 bushels, spring wheat 14 to 20 bushels and winter wheat 18 to 22 bushels. Clover, timothy and alfalfa grow well on the soil in favorable seasons particularly when the surface soil is deeper.

The needs of this soil to make it more productive are mainly for the application of large amounts of farm manure and the use of green manures to build up the content of organic matter and make the soil more retentive of water, richer in plant food, and put it generally in a better producing condition. Lime is necessary as the soil is acid and applications of this material should be made as shown to be necessary by tests. Phosphorus fertilizers may be of use now and certainly will be needed in the future. Nitrogen is low but the use of leguminous green manures will increase the amount of this constituent at the same time that the organic matter content is built up.

**FARGO SILTY CLAY LOAM (109)**

This is a minor terrace type, occurring over an area of 2,112 acres or 0.6 percent of the total area of the county. It is found mainly in the western part of Lake township. An area is also mapped in Logan township.

The surface soil is a very dark brown to nearly black, heavy silty clay loam, extending to a depth of about 18 inches. The subsoil is a dark-drab, heavy silty clay loam, becoming lighter in color with increasing depth. The surface soil and subsoil are high in lime content.

In topography the type is nearly flat or gently sloping from the uplands to the bottoms. Drainage is not good and the use of tile is quite essential for satisfactory crop production.

This is an important soil agriculturally. About 80 percent is drained and used for cultivated crops, corn, oats, hay, barley and wheat being grown. The remainder of the type is in native prairie and slough grasses and is used for hay or pasture.

The first treatment necessary to make this soil productive is proper drainage. When that is accomplished farm manure should be applied and eventually phosphorus fertilizers and leguminous green manures will be needed to keep the soil supplied with phosphorus and nitrogen.

**O’NEILL FINE SANDY LOAM (110)**

This is a minor terrace type, covering 2,048 acres or 0.6 percent of the total area of the county. It occurs on narrow, rather flat elevations, 10 to 15 feet above the O’Neill loam. None of the areas are large.

The surface soil is a dark-brown to dark grayish-brown fine sandy loam 8 to 10 inches deep. The subsoil is a light brown to brown, rather compact, fine sandy loam to loamy fine sand which at 16 inches grades into a light brown fine sand. In the areas near Trumbull and Mud lakes, there is considerable coarse sand and gravel throughout the soil. There is some coarse sand and gravel in some of the other areas, but usually a smaller amount.

In topography the type is flat but the drainage is excellent owing to the sand and gravel present throughout the surface soil and in considerable amounts in the subsoil.
It is not an important soil agriculturally, about 75 percent being under cultivation. The crops grown are the same as on the O'Nei1 loam. Small grains are often grown in preference to corn, and clover and alfalfa do well when well started. The crop yields are somewhat lower than on the O'Nei1 loam but in favorable seasons they may be quite satisfactory. Crops suffer, however, in dry weather. The soil needs mainly the addition of organic matter. The use of farm manure and of leguminous green manures is quite necessary. The soil is acid and needs lime and phosphorus fertilizers will be necessary in the future if indeed they are not of value now.

Waukesha Silt Loam (75)

This is a very minor type in the county, covering only 512 acres or 0.1 percent of the total area of the county. It occurs in a few small scattered areas in Lake and Meadow townships. The two largest areas lie south of Trumbull lake and one-half mile west of Langdon.

The surface soil is a dark-brown moderately heavy silt loam, about 15 inches in depth. The subsoil is a yellowish-brown to brownish-yellow compact, light, silty clay loam to a depth of 5 or 10 feet where there is a layer of sand and gravel. There may be considerable fine sand in the surface soil and gravel may occur throughout the 3-foot section.

The topography of the type is rather flat but the drainage is usually good. The soil is not droughty. The areas of the soil are usually 10 to 15 feet above the bottomlands and are practically entirely above overflow.

About 75 percent of the type is under cultivation, the remainder being in pasture. Practically all the smaller areas are in pasture. The same crops are grown as on the Carrington silt loam and the yields secured are very similar.

The soil may be increased in crop producing power by the use of farm manure in liberal amounts or by the application of leguminous green manures in case farm manure is not available in sufficient amount. Lime is necessary as the type is generally acid and that material should be added in amounts shown to be necessary by special tests. Phosphorus fertilizers will be needed in the future and might prove profitable now in some cases. Nitrogen will also be needed but may be added by the use of leguminous green manures.

SWAMP AND BOTTOMLAND SOILS

There are five swamp and bottomland soils together covering 62,208 acres or 17.2 percent of the total area of the county. The soils are grouped in the Lamoure and Wabash series and in addition there is a small acreage mapped as Muck and Peat.

Lamoure Silty Clay Loam (111)

This is the largest bottomland type, covering 42,944 acres or 11.9 percent of the total area of the county. It is the fourth soil type in area in the county. It occurs in narrow strips along sloughs and drainageways, in larger strips along the rivers and near stream heads in irregular patches which appear to be old lake-like marshes, recently drained. Much of the type occurs on the broad high terrace in the north-central part of the county.
The surface soil is a very dark-brown to nearly black silty clay loam, extending to a depth of about 20 inches. The subsoil is a dark-drab to brownish-drab silty clay loam, becoming lighter in color with increasing depth. The surface soil and subsoil are both usually high in lime content. Near areas of Muck and Peat the surface soil may contain much peaty material, to a depth of 3 or 5 inches. In the narrower areas adjoining the sandy upland types, the surface soil may contain considerable sand. In many of the areas on the terraces and near the lakes, the subsoil becomes yellow in color and grades below 30 inches into a yellowish-drab to drab sandy clay or clayey sand, with spots of greenish-colored material. In some places the subsoil has a yellow color but is not sandy. Throughout much of the type and especially in the center of the larger areas, the surface soil and subsoil are very similar in color and texture.

The surface of the Lamoure silty clay loam is nearly flat and drainage is naturally poor. Along the smaller streams, the soil is overflowed regularly. The greater part of the type along the Ocheyedan river, however, is overflowed only infrequently.

This type is very important agriculturally. When undrained, there is a luxuriant growth of slough grass which furnishes excellent pasturage and hay. Probably 85 percent of the type is still undrained. Of the total acreage in native grass, about 75 percent is used for pasturage. The value of tile drainage has been shown in many cases and more and more of the type is being thus prepared for the growth of cultivated crops. Corn is the chief crop grown and oats, clover, timothy, barley, wheat and flax are also produced to some extent. Corn yields 40 to 50 bushels per acre on well drained land, oats 35 to 45 bushels, barley about 25 bushels, spring wheat about 20 bushels and flax 8 to 10 bushels per acre.

The chief needs of this type to make it more productive are the installation of adequate drainage systems and the protection from overflow. When these are accomplished the yields of general farm crops are high. Applications of farm manure would also be of value and phosphorus fertilizers will be needed in the future. Leguminous green manures will also be needed in the future to keep up the supply of nitrogen in the soil.

There are some small areas within this type where it surrounds peat deposits, that are so-called alkali spots. These areas are rarely more than 80 feet wide and the total area affected in the county is small. To reclaim such areas a thorough drainage of the spots should be provided by the use of tile and farm manure or green manures applied in large amounts to hasten the removal of the alkali salts, which during a dry season often appear as a whitish deposit on the surface. Further information regarding alkali spots is given in bulletin 157 of the Iowa Agricultural Experiment Station.

WABASH SILT LOAM (26)

This is a minor bottom type, covering 10,688 acres or 2.9 percent of the total area of the county. It occurs mainly in narrow strips lying close to the channel of the Ocheyedan river and occupying nearly the entire first bottom along the Little Sioux river and its larger tributaries. In a few places along the Little Sioux river the strips are one-half mile wide.
The surface soil is a dark-brown to nearly black, heavy silt loam extending to a depth of 18 or 20 inches. The subsoil to 40 inches is a brownish-gray, rather compact, heavy silt loam to light silty clay loam. There is little change from the surface soil to the subsoil, the only difference being a slightly lighter color in the lower layer. In some areas along the Ocheyedan river, the surface soil is heavy, approaching a silty clay loam, and the subsoil is a very compact silty clay loam. Along the Little Sioux river, in places, the surface soil contains considerable sand and becomes a very mellow silt loam. Numerous areas of the Wabash loam, too small to map, are included in this type.

The surface of the type is nearly flat and drainage is usually rather poor. Practically all of the type is subject to overflow. In some areas along the Little Sioux river the type is somewhat higher and is less frequently overflowed. The drainage of these latter areas is somewhat better but even there it is not adequate. Probably less than 10 percent of the Wabash silt loam is under cultivation. The remainder is in native grasses and is used for pasture and hay. Only the higher lying and better drained areas are cultivated. Corn is the principal crop and clover and timothy are also grown. Small grains are grown only infrequently. Corn yields 40 to 45 bushels per acre, clover and timothy about 2½ tons and wild grasses 1 to 1¾ tons of hay per acre.

This soil needs primarily to be thoroly drained and protected from overflow. Without these treatments crop production is very apt to be poor. When the soil is well drained, however, and is not overflowed it is very productive. Farm manure would be of value on it and lime should be used in amounts shown to be necessary by acidity tests. Phosphorus fertilizers will be needed in the future and leguminous green manures will also be needed to supply nitrogen.
This is a minor type in the county, covering 4,032 acres or 1.1 percent of the total area of the county. It is found mainly along Willow creek and along the Little Sioux river near Peterson. Smaller areas are found along the smaller tributary streams. In the larger areas the soil occurs in narrow strips occupying all or nearly all the bottomland. In the other areas it is found in the bends of streams.

The surface soil is a dark-brown to dark grayish-brown rather mellow loam extending to a depth of 20 inches. The subsoil is a brownish-gray, compact heavy loam to sandy silt loam. In poorly drained areas the subsoil is often a silty clay loam, lighter in color in the lower depths. There are many variations in the surface soil. In the lower-lying areas it is frequently quite sandy while near the uplands it is often silty in character. When near the O'Neill loam, the type may contain considerable gravel.

Most of the type is quite flat in topography. Along the Little Sioux river there may be a slight slope to the uplands. These sloping areas are not usually overflowed but the remainder of the type is subject to overflow quite regularly. Drainage as a rule is rather poor and tile drains would be quite profitable.

Less than 15 percent of this type is under cultivation, the same crops being grown as on the Wabash silt loam and approximately the same yields being secured. Most of the type is used for hay and pasture. Some areas support a considerable forest growth of basswood, cottonwood, willow, ash and box elder.

This soil needs primarily drainage and protection from overflow. When these are provided, it will prove very productive. Farm manure and lime are needed and eventually leguminous green manures and phosphorus fertilizers will be required.

MUCK AND PEAT (21)

There is a small area of so-called Muck and Peat in the county, amounting to 3,520 acres or 1.0 percent of the total area of the county. This material is found in old slough or lakelike depressions where there has been no drainage. The four largest areas occur southwest of Lost Island lake, southwest of Webb along Montgomery creek, in the west-central part of Lake township and in the bed of Mud lake. Small areas of Muck and Peat also occur in the eastern part of the county. Areas too small to map are included in the Lamoure silt loam clay.

The surface material consists of 6 to 24 inches of dark-brown to black partly decomposed plant remains with a mixture of silt, clay or very fine sand. It averages 12 inches in depth. The underlying material is a nearly impervious drab silty clay to clay. The subsoil is high in lime content. Muck and Peat differ only in the extent of decomposition. Muck is composed of finely decomposed vegetable matter and is black in color while Peat is brown in color and the plant forms remain only slightly changed.

The chief need of Muck and Peat, to make it suitable for crop production, is to provide thorough drainage. When this is accomplished and the material is opened up by fall plowing and deep plowing and is thoroughly cultivated, a productive soil is formed. The best crop to grow on newly reclaimed peat land is
timothy and alsike clover used for hay or pasture. Corn and small grains should not be grown until the peat has been rather completely decomposed. Further information regarding peat soils is given in bulletin 157 of the Iowa Agricultural Experiment Station.

LAMOURE LOAM (112)

This is a very minor type covering only 1,024 acres or 0.3 percent of the total area of the county. It occurs mainly in small areas scattered over the northeastern fourth of the county, principally to the north of Spencer.

The surface soil to a depth of 12 or 15 inches is a nearly black loam. It is underlain by a dark-brownish drab to dark yellowish-drab silty clay loam which grades at 30 inches into a yellowish-drab to drab sandy clay to clayey sand.

Considerable coarse sand is usually present in the subsoil. Both soil and subsoil are high in lime content.

The type has a flat surface and is poorly drained. It is subject to overflow and very little of it is under cultivation. There is a growth of native slough grass which is used for hay or pasture. When cultivated, the same crops are grown as on the Lamoure silty clay loam and about the same yields are secured.

It must be drained and protected from overflow before it can be used for general farm crops. When this is accomplished the soil may become highly productive and may be kept so by the use of farm manure, leguminous green manures and phosphorus fertilizers.
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 Iowa 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 cooperation 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 soil 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. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers, or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins, as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

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, although 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.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green
Manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced," as in market gardening, some nitrogenous fertilizer may be of value.

**THE "SOIL DERIVED" ELEMENTS**

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true in 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 in this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proven of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if phosphorus is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

**AVAILABLE AND UNAVAILABLE PLANT FOOD**

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.
The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be unavailable. Plants cannot take up food unless it is in solution; hence available plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an 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. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished care should always be taken that the soil be in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

It is evident from the table that the continuous growing 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 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
TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (NaNO₃)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl)).

<table>
<thead>
<tr>
<th>Crop</th>
<th>YIELD</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Food Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn crop</td>
<td>......</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>......</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats crop</td>
<td>......</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Barley grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley crop</td>
<td>......</td>
<td>33.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>......</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of the nutrients which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is 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 the loss of plant food.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms. This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed. This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

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,

* Bulletin 150 Iowa Agricultural Experiment Station.
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 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 those other elements which are 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 to 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 a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought by thorough 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.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drought may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

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

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amount of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop, if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotations. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be
SOIL SURVEY OF IOWA

hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under they not only supply organic matter to the soil, but they also increase the nitrogen content.

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 a 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 nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

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

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

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated, and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.
CLAY COUNTY SOILS

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

THE USE OF PHOSPHORUS

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

Phosphorus may be applied to soils in three commercial forms, bone meal, 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 all 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 given in bulletin 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 to 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 accompanying map.

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 or "nigger-heads." Two of these drift areas occur in Iowa to-day, 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 soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching action 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 their 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 stones. 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 soil 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 divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thorough and complete study of them in place in small areas. The climatic conditions,
topography, depth and character of the soil, chemical and mechanical composition, and in short all the factors which may affect 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 soil 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 type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the 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 Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or eumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or 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.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows: according to the Bureau of Soils:

Organic Matter

- All partially destroyed or undecomposed vegetable and animal material.
- 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.

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 different general groups of soils by types are indicated thus by the Bureau of Soils:

- Peats—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.
- Peaty Loams—15 to 35 per cent of organic matter mixed with much sand and silt and a little clay.
- Mucks—25 to 35 per cent of partly decomposed organic matter mixed with much clay and some silt.
- Clays—Soils with more than 20 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.
- Silty Clay Loams—20 to 30 per cent clay and more than 50 per cent silt.
- Clay Loams—20 to 30 per cent clay and less than 50 per cent silt and some sand.
- Silt Loams—20 per cent clay and more than 50 per cent silt mixed with some sand.
- Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

* 25 mm. equals 1 in.
1 Bur. of Soils Field Book.
2 I C.
Sandy Clays—20 per cent silt and small amounts of clay up to 30 per cent.

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

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

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

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

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

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

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

Gravels—More than 50 per cent very coarse sand.

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

**METHOD USED IN THE SOIL SURVEY**

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

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all the 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 it is the first duty of the field party to 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 by and 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 or 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 road map of the county.