12-1918

Soil Survey of Iowa, Report No. 8—Clinton County

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Iowa State College

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SOIL SURVEY OF IOWA
CLINTON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 8
December, 1918
Ames, Iowa
# IOWA AGRICULTURAL EXPERIMENT STATION

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SOIL SURVEY OF IOWA

Report No. 8—CLINTON COUNTY

By W. H. Stevenson and P. E. Brown with the assistance of G. E. Corson and F. B. Howe

One of Clinton county's soil types — Clinton silt loam

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

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson and F. B. Howe

Clinton county is located in central eastern Iowa along the Mississippi river, partly within the Mississippi loess and partly in the Iowan drift soil areas. Most of the soils are of loessial origin but there are several drift soils whose total acreage is considerable.

The county includes an area of 691 square miles, or 442,240 acres, of which 389,515 acres or 88 percent is in farmland. The total number of farms is 2,516 and their average size is 154.4 acres.

The utilization of the farmland of the county is shown in the following figures taken from the Iowa Yearbook of Agriculture for 1916.

| Acreage in general farm crops | 238,570 |
| Acreage in pasture | 138,654 |
| Acreage in orchards | 355 |
| Acreage in farm buildings, feed lots and public highways | 1,633 |
| Acreage in crops not otherwise listed | 38 |
| Acreage in waste land | 1,272 |

The agriculture of Clinton county is of two kinds, hog and cattle raising and grain. Livestock farming is followed mainly in the northern part of the county where the soils are largely of loessial origin while on the drift soils in the southern part grain farming is practiced to a considerable extent and the raising of hogs and cattle is of secondary importance. Thus there seems to be a rough relationship between the origin of the soils and the system of farming altho it is probably due more to the topography of the areas involved than to the character of the soils. The loessial area is rolling in character while the glacial or drift area is gently rolling to nearly flat. The rougher character of the loess soils makes them less desirable for intensive general farming but particularly valuable for pasture. The drift soils are more commonly utilized for grain production but the livestock industry is increasing in importance and it is doubtful if the relation between the type of farming and the topography will continue far into the future.

There is a rather large area of waste land in the county and methods should be adopted for the reclamation of such unproductive land. No general recommendations along this line are possible as the reasons for unproductiveness are variable. Each individual area of waste land must be handled and treated according to its particular needs. The description of individual soil types given later in this report includes statements of the needs of each type and further specific information for special soil conditions may be secured from the Soils Section of the Iowa Agricultural Experiment Station.

The acreage in orchards and gardens is very small, fruit and vegetables being grown mainly for home consumption. On the sandy soils near Camanche some sweet potatoes, strawberries, cantaloupes and watermelons are produced to a small extent and sold on the local markets. Apples, cherries, grapes, plums and

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1 Soil Survey of Clinton County, Iowa by H. W. Hawker of the U. S. Dept. of Agriculture and F. B. Howe of the Iowa Agricultural Experiment Station.
peaches are grown in the county but not on a commercial scale except near Dewitt.

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

Corn is by far the most important crop in the county. Its acreage and value is greater than that of all the other crops combined. The average yields secured are 35 bushels per acre but much larger yields than this are obtained under favorable conditions. In general the northern portion of the county does not produce enough corn for its needs while the reverse is true in the southern part. Estimates indicate that more corn is brought into the northern part of the county for feeding purposes than is shipped out of the southern part.

The second crop of importance in the county is hay. Very little wild hay is produced. Most of the tame hay consists of timothy and clover mixed but timothy is also grown alone to a considerable extent. Clover is grown alone only on a small percentage of the total hay acreage. Practically all the hay produced in the county is utilized for forage purposes on the farms and only small amounts are shipped out of the county.

Oats is the next crop of importance and the average yields secured are 39 bushels per acre. Only about 10 percent of the oats produced in the county is shipped out. The crop is largely used for feeding purposes and its importance in the county is increasing.

Barley is grown on a rather large area, its acreage having increased considerably in the last few years. The average yields of this crop amount to 29 bushels per acre.

The next crop of importance in the county is wheat. Spring wheat is grown only on a small area, the winter varieties being used much more extensively. Average yields of 23 bushels per acre of winter wheat are secured while the spring varieties show only 18 bushels per acre. Wheat was formerly grown much more extensively than at present and the production is now quite insufficient to meet local demands. Much wheat is shipped into the county every year.

Potatoes are grown to a small extent, largely for home consumption. Rye is raised only on a small area and alfalfa is likewise produced only to a minor

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**TABLE I. THE ACREAGE, YIELDS, AND VALUE OF CROPS GROWN IN CLINTON 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 bu. or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>123,000</td>
<td>31.6</td>
<td>35</td>
<td>4,355,000</td>
<td>$0.81</td>
<td>$3,487,050</td>
</tr>
<tr>
<td>Oats</td>
<td>44,000</td>
<td>11.3</td>
<td>39</td>
<td>1,716,000</td>
<td>0.49</td>
<td>840,840</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>860</td>
<td>0.2</td>
<td>18</td>
<td>15,500</td>
<td>1.54</td>
<td>23,870</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>2,900</td>
<td>0.8</td>
<td>25</td>
<td>66,700</td>
<td>1.58</td>
<td>165,386</td>
</tr>
<tr>
<td>Barley</td>
<td>5,100</td>
<td>1.3</td>
<td>29</td>
<td>147,900</td>
<td>0.90</td>
<td>133,110</td>
</tr>
<tr>
<td>Rye</td>
<td>1,300</td>
<td>0.3</td>
<td>19</td>
<td>24,700</td>
<td>1.15</td>
<td>28,405</td>
</tr>
<tr>
<td>Potatoes</td>
<td>900</td>
<td>0.2</td>
<td>28</td>
<td>23,200</td>
<td>1.75</td>
<td>40,600</td>
</tr>
<tr>
<td>Tame Hay</td>
<td>58,000</td>
<td>14.9</td>
<td>1.7</td>
<td>98,600</td>
<td>9.00</td>
<td>887,400</td>
</tr>
<tr>
<td>Wild Hay</td>
<td>1,900</td>
<td>0.5</td>
<td>1.1</td>
<td>2,100</td>
<td>7.89</td>
<td>16,569</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>600</td>
<td>0.1</td>
<td>3.0</td>
<td>1,800</td>
<td>11.71</td>
<td>21,078</td>
</tr>
<tr>
<td>Pasture</td>
<td>138,654</td>
<td>35.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
extent. The acreage devoted to the latter crop is increasing rapidly, however, and the yields secured are very satisfactory.

The livestock industry in Clinton county is exceedingly important. The following figures taken from the Iowa Yearbook of Agriculture for 1916 indicate the extent and character of the industry.

<table>
<thead>
<tr>
<th>Animal Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses (all ages)</td>
<td>17,411</td>
</tr>
<tr>
<td>Mules (all ages)</td>
<td>218</td>
</tr>
<tr>
<td>Swine (on farms, July 1, 1916)</td>
<td>145,010</td>
</tr>
<tr>
<td>Swine (all ages)</td>
<td>218</td>
</tr>
<tr>
<td>Swine (on farms)</td>
<td>145,010</td>
</tr>
<tr>
<td>Cattle (cows and heifers kept for milk)</td>
<td>16,802</td>
</tr>
<tr>
<td>Cattle (other cattle not kept for milk)</td>
<td>42,165</td>
</tr>
<tr>
<td>Cattle (total, all ages)</td>
<td>63,876</td>
</tr>
<tr>
<td>Sheep (all ages on farms)</td>
<td>2,149</td>
</tr>
<tr>
<td>Sheep (shipped in for feeding)</td>
<td>420</td>
</tr>
<tr>
<td>Sheep (total pounds wool clipped)</td>
<td>13,037</td>
</tr>
</tbody>
</table>

According to these figures hog raising and cattle raising are the most important of the livestock industries. Dairying and sheep raising are relatively unimportant. Horses and mules are raised only to a small extent.

Land values vary in Clinton county, depending upon the character of the soil, its topography, location with respect to markets and other factors. In the northern part of the country the upland ranges from $133 to $250 per acre. The bottomlands which are subject to overflow sell for $50 to $100 per acre and those which are only rarely overflowed for $100 to $175 per acre.

In the southern part of the county the drift soils range in value from $150 to $225 per acre. Sandy areas are usually less valuable and such soils are valued at $40 to $100 per acre, although some sandy areas such as the strawberry soils near Camanche are held at a high figure.

The yields of general farm crops are not as large as they should be. The soils evidently need special treatments to make them more productive. Practically all the soils are acid in reaction and in need of lime and should be tested.

Fig. 1. Railway cut east of Lost Nation showing a distinct line of demarcation between the loess and underlying Kansan drift, the loess layer following the contour of the ridge.
and the amount of lime, indicated by the tests, applied. This is particularly necessary in order to secure the best crops of clover and alfalfa.

Many of the soils are low in organic matter and applications of farm manure bring about large increases in crop yields and also aid in keeping the soils permanently fertile. Green manuring would also be of value on some of the soils as a substitute for or supplement to farm manure. Crop residues should be utilized in all cases to aid in keeping up the organic matter content in the soils.

Phosphorus fertilizers have not yet shown profitable returns but phosphorus is low in the soils of the county and some fertilizing material containing that element will have to be applied in the future. Field tests now under way will show the need for phosphorus on the main soil types and also the kind of phosphorus fertilizer which should be used. The results of these tests will be published later. Crop rotations are necessary to maintain the fertility of these soils and drainage must be improved in the case of several soil types to permit of satisfactory crop growth.

THE GEOLOGY OF CLINTON COUNTY

The rock formations underlying the soils of Clinton county are so deeply buried under drift and loess deposits that their influence on soil conditions is negligible. Twice during the glacial age Clinton county was passed over, in whole or in part by great glaciers and there are certain evidences that a third and possibly a fourth glacier covered parts of the county. The Kansas and Iowan, however, have left unmistakable evidences of their presence in the so-called "drift" which remained on the surface of the land upon the retreat of the glaciers.

The Kansan drift was deposited first and covered the entire county. In the time which elapsed between its deposition and the coming of the next ice sheet and the laying down of the loess it was subjected to much weathering and leaching. It consists of a yellow or gray till or bowlder clay filled with pebbles and bowlders of various kinds, the majority of which are characteristic of the Kansan drift.

Long after the Kansan glaciation, a glacier known as the Iowan entered Clinton county from the west along the lowlands of the Wapsipinicon and left a drift deposit extending across most of the southern part of the county. This Iowan drift material is more recent in origin than the Kansan and has been less weathered and leached. The soils which were formed from it are therefore not strikingly deficient in fertility altho in many cases they need treatment to make them more productive.

The latest upland deposit is the loess. This is a yellow or gray, porous material, of a uniformly fine texture, presumably deposited from the atmosphere by the wind at some time when climatic conditions were very different than at present. This loess extends over the entire Kansan drift plain in the northern part of the county and in small areas throughout the remainder of the county. The area which it covers amounts to about 55 percent of the total area of the county, and occurs in the northern portion of the county in a large wedge-shaped area. It averages 15 to 20 feet in thickness but in some places is very

\[1\] Udden-Geology of Clinton County, In. Geol. Rep't, Vol. XV.
much thicker than this. Small areas of loess are also found in the southern part of the county overlying the Iowan drift, but in such locations the loess is thin. These small areas have been termed "paha," a term which has come to mean loess-covered knolls in the midst of surrounding drift areas. The loess also occurs in a small area in the southwestern corner of the county where it is underlain as in the north by the Kansan drift.

Just south of the large area of loess, the Iowan drift appears in a wide belt-like area extending across the county. The boundary line between the loess area in the north and this drift area is usually very sharply defined by a distinct drop in elevation. The belt of drift merges gradually, however, into the alluvial bottoms of the Wapsipinicon and Mississippi rivers on the south and east and the boundary between these two areas in many places is not very distinct. The alluvial material making up the bottomlands is somewhat variable, representing both the drift and loess materials carried by the streams. Sand and gravel are common in the bottoms and even occur in ridges in the Iowan drift. In the latter case they are of uncertain origin but probably represent glacial deposits rather than stream formations.

PHYSIOGRAPHY AND DRAINAGE

The surface of Clinton county may be divided roughly into three areas of distinctly different physiography and topography. The Kansan drift plain with its loess covering is the most elevated, having a relief of 700 to 900 feet above the sea level. It has a gentle slope toward the south and southeast from the northwestern corner of the county. The greater part of the plain has been considerably eroded since its formation and consists mainly of slopes and ridges with drainage ways between. These slopes are sometimes steep and high along the Mississippi in Elk River and Spring Valley townships but away from the larger stream valleys they are more gentle. The smoothest areas of this upland plain occur in a belt from Delmar westward for several miles, southeasterly to Petersville and from there southward to Welton. There is also another level area near Elvira. In these areas the topography is very gently rolling.

The Iowan drift plain which extends across the county to the south of the loessial-covered Kansan drift plain ranges from 620 to 780 feet in elevation. The surface of this plain is generally smooth to almost level and there has been little action of erosion altho in some localities there are ridges of glacial material rising above the surrounding plain. Ridges and rounded hills of sandy material also occur north and east of the Wapsipinicon lowlands in the western part of the county. Near Bledorn and Wheatland the plain is somewhat higher and is more cut up by erosion.

The bottomlands along the Mississippi river vary from one to three miles in width. At two points the upland extends up to the river, appearing as bluffs along its banks, and in those places there are no bottomlands. In several localities the bottomlands are separated from the uplands by well marked terraces but ordinarily the boundary lines are rather indistinct, the uplands grading gradually into the lowlands. The surface of these lowlands is that of a level, alluvial plain with a gentle slope to the south. In general it is about 25 to 30 feet above the level of the river.

The Wapsipinicon bottoms vary from one-quarter of a mile to three miles in
Fig. 2. Natural drainage system of Clinton county
width but in some places they are very narrow, the uplands extending out to the river. The surface of these bottoms is level ranging from 15 to 25 feet in elevation above the low water mark of the river.

There is a third area of bottomland which has been called Goose Lake Channel. It extends thru Deer Creek township and Center township and joins the Wapsipinicon bottoms in Edon township. These bottomlands were formed by pre-glacial drainage and they surround Deer creek and Brophys creek which are of more recent formation. Well-marked bluffs separate this bottomland from the adjoining upland.

Very little of the drainage of Clinton county is thru the Mississippi river. Only a strip of land about nine miles wide along the Mississippi river drains directly into the river or thru small tributary streams. A small area in the northwestern part of the county is drained thru Pine creek, Sugar creek, Deep creek and Deer creek, northward into the Maquoketa river. With the exception of this small area and the strip along the Mississippi the drainage of the county takes place thru the Wapsipinicon river and its tributaries. Yankee Run, Rock creek, Barber creek, Silver creek, Ames creek, Cherry creek and Brophys creek are the main drainage channels. There is also an extensive system of drainage ditches south and southeast of Lost Nation and near Calamus which helps to drain the central portion of the county. The streams flow thru deeply cut channels in the loessial upland and the current is rapid. When they reach the Iowan drift area they flow thru broad, winding valleys at a more leisurely rate.

In general the drainage of the county is well established as is indicated on the accompanying map. On the drift plain, however, artificial drainage is sometimes necessary and low-lying ponded areas surrounded by uplands are occasionally found. Tile drainage is necessary in the case of several soil types and ditching is also required in some instances.

THE SOILS OF CLINTON COUNTY

The soils of Clinton county may be grouped in five classes according to their origin and location. These groups are drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are those which are formed from the material left behind by a retreating glacier and they are characterized by the occurrence of pebbles from various sources and sometimes by more or less sizeable boulders. They are made up of material accumulated by the glacier during its forward movement and consequently they usually bear no relation to the underlying rock material. Loess soils are deposits of fine dust-like material made by the wind at some time when climatic conditions were very different than at present. Terrace soils are former bottomlands which were raised above overflow by the 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 the streams and subject to more or less frequent overflow. Residual soils are produced by the weathering of the underlying rock material and remain in the location where they were formed.

The areas of these different groups of soils in Clinton county are shown in table II. The loess soils cover the largest area in the county, over 50 percent. The drift soils are more than half as extensive in area, covering 29.6 percent of
TABLE II. AREA OF DIFFERENT GROUPS OF SOILS IN CLINTON COUNTY

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift Soils</td>
<td>131,072</td>
<td>29.6</td>
</tr>
<tr>
<td>Loess Soils</td>
<td>232,384</td>
<td>52.5</td>
</tr>
<tr>
<td>Terrace Soils</td>
<td>19,068</td>
<td>4.6</td>
</tr>
<tr>
<td>Swamp and Bottomland Soils</td>
<td>58,240</td>
<td>13.2</td>
</tr>
<tr>
<td>Residual Soils</td>
<td>576</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>442,240</td>
<td></td>
</tr>
</tbody>
</table>

the total area of the county. The swamp and bottomland soils are much smaller in extent and cover only 13.2 percent of the area of the county. The terrace soils are very minor in extent covering 4.6 percent of the county and one residual soil is found which occupies only 576 acres or 0.1 percent of the area of the county.

In topography the upland soils of the county are usually rolling to gently undulating, altho some areas of various types are rather level. The bottomland soils are generally level while the terrace soils are usually level to rolling.

Twenty-seven types of soils are found in the county, six of which are drift soils; four, loessial in origin; six, terrace soils; ten, swamp and bottomland soils and one, a residual soil. These various types are distinguished according to the characteristics which are described in the appendix to this report and the names which are given them are based on certain group characteristics. The areas of the various soil types are shown in table III.

The drift soils belong in the Clyde and Carrington series; the loess soils in the Clinton, Musesatin, Lindley and Memphis series; the terrace soils in the Bremer, Buckner and Calhoun series; the bottomland soils in the Wabash and Sarpy series with two unclassified materials, muck and riverwash; and the residual soil is the Union stony loam.

The Carrington silt loam is the most extensive drift soil and it is the third type in area in the county. The Carrington loam and the Clyde silt loam are the next drift soils in order of importance and they rank fifth and sixth, respectively, in the county. The other three drift soils are of lesser importance.

The Clinton silt loam is the most extensive loess soil and has the largest area of any type in the county covering 29.2 percent of the total area of the county. The Musesatine silt loam is the second loess soil in area and it also stands second among all the soils of the county. The two remaining loess types are of minor importance.

Only one terrace soil is at all extensive in area. The Bremer silt loam covers 3.5 percent of the county and is an important soil. The other terrace types are small in area, three of them covering only 0.1 percent of the area of the county.

The Wabash silt loam is the most extensive bottomland soil and it stands fourth among all the soil types in the county. Together with the colluvial phase which is mapped separately, it covers 7.8 percent of the county. The other bottomland soils are of less importance, the Wabash silty clay loam and the Sarpy silt loam being the only ones which are at all extensive in area. The one residual soil, the Union stony loam is very small in area and of no importance agriculturally.
TABLE III. AREAS OF DIFFERENT SOIL TYPES IN CLINTON COUNTY

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Soil Types</th>
<th>Acres</th>
<th>Percent total area of County</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>75,456</td>
<td>17.1</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>22,912</td>
<td>5.2</td>
</tr>
<tr>
<td>84</td>
<td>Clyde silt loam</td>
<td>15,616</td>
<td>3.5</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>8,448</td>
<td>1.9</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>6,400</td>
<td>1.4</td>
</tr>
<tr>
<td>86</td>
<td>Carrington fine sand</td>
<td>2,240</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>129,088</td>
<td>29.2</td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>98,176</td>
<td>22.2</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>4,544</td>
<td>1.0</td>
</tr>
<tr>
<td>87</td>
<td>Memphis very fine sandy loam</td>
<td>576</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>15,424</td>
<td>3.5</td>
</tr>
<tr>
<td>46</td>
<td>Buckner fine sand</td>
<td>1,984</td>
<td>0.5</td>
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<tr>
<td>40</td>
<td>Buckner sandy loam</td>
<td>1,472</td>
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<tr>
<td>38</td>
<td>Buckner loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>256</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26A</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>3,008</td>
<td>7.8</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>31,680</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>8,640</td>
<td>2.0</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>5,504</td>
<td>1.2</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>2,432</td>
<td>0.6</td>
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<tr>
<td>21A</td>
<td>Muck</td>
<td>2,304</td>
<td>0.5</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,738</td>
<td>0.4</td>
</tr>
<tr>
<td>90</td>
<td>Sarpy sandy loam</td>
<td>1,664</td>
<td>0.4</td>
</tr>
<tr>
<td>91</td>
<td>Sarpy loam</td>
<td>832</td>
<td>0.2</td>
</tr>
<tr>
<td>53</td>
<td>Riverwash</td>
<td>448</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td><strong>RESIDUAL SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>Union stony loam</td>
<td>576</td>
<td>0.1</td>
</tr>
</tbody>
</table>

THE FERTILITY IN CLINTON COUNTY SOILS

Samples were drawn from all the soils in the county except the Union stony loam and the riverwash and analyses made for the essential plant food constituents. All the samples were secured with care that they should represent accurately the typical soils and that variations due to local conditions or special treatments be eliminated. Three samples were drawn from the more extensive types and one sample from each of the minor types. The samples were taken at three depths; 0-6 2/3 inches, representing the surface soil; 6 2/3-20 inches, representing the subsurface soil; and 20-40 inches, representing the subsoil.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were used for the nitrogen, phosphorus and carbon determinations and the Veitch method for the limestone requirements.

The results given in the tables are the averages of duplicate determinations on all the samples of every type. Thus if three samples of a type were drawn, the results for that type are the average of six determinations. The results are all calculated on the basis of pounds per acre.

THE SURFACE SOILS

The results for the surface soils are given in table IV. They are calculated on the basis of two million pounds of surface soil. (0-6 2/3"
In the first place it is apparent from the table that there is not a large amount of phosphorus present in any of the soils of the county altho the bottomland soils are somewhat better supplied than the upland types and the loess soils average slightly more phosphorus than the drift types. In all cases, however, there are greater variations in phosphorus content among the individual types within the large groups than there are between various groups.

There seems to be some relation between the character of the soil and the content of phosphorus. Thus the sandy soils are always lower in phosphorus than the other types and the silty clay loams, or heavier types are better supplied than the loams or silt loams. This is probably due in most cases to the lower crop production on the heavy types and the consequent smaller removal of phosphorus. There is usually also some relation between the phosphorus content of the soils and their color. The darker-colored types, richer in organic matter, are generally richer in phosphorus than the light-colored soils. It seems possible that there may be an appreciable amount of phosphorus in the organic form in some soils and that amount undoubtedly has some importance from the fertility standpoint. At the present time, however, no distinction can be made between inorganic phosphorus and that occurring in the organic form and all conclusions must be based on the total content.

The results as a whole show that the soils of the county are so low in phosphorus that they might in some cases respond profitably to the application of
phosphorus fertilizers if not now, at least in the future. The field tests which are now under way on the main soil types in the county will give some definite evidence of their value but the results from these tests will not be available for several years and for the present it can only be recommended that local tests be made as the most satisfactory means of determining the needs of the soils. Farmers who are interested in such tests are urged to correspond with the Soils Section of the Iowa Agricultural Experiment Station for suggestions and assistance in carrying them out.

The nitrogen content of the soils of the county, like the phosphorus, is extremely variable, some of the types being well supplied while others are rather low. No relation can be established between the different groups of soils, on the basis of nitrogen content except that the bottomland soils average somewhat higher than the upland types. There is, however, apparently some relation among the different types between nitrogen content and the character of the soil. The heavier types of soil, such as the silty clay loams, are better supplied than the sandy types as these less completely aerated and poorly drained soils lose less nitrogen and the smaller crop growth on such soils results in a smaller removal by crops. Nitrogen is probably not a limiting factor of growth on many soils in the county but nevertheless care should be taken to maintain the nitrogen supply in all the soils if they are to be kept permanently fertile. The return of manure and crop residues to soils aids materially in maintaining their nitrogen supply but if nitrogen is to be increased in the soil the best method to follow is to use well-inoculated green manures and fix in the soil some of the inexhaustible supply of nitrogen from the atmosphere, thus making commercial nitrogenous fertilizers unnecessary.

The organic carbon content of soils is a measure of their supply of organic matter. As most of the nitrogen in soils is in the organic matter, there is always a close relation between organic carbon and nitrogen. Thus in the Clinton county soils, those which are high in nitrogen are high in organic carbon and vice versa. Again in the case of the organic carbon there is apparently no relation among the groups of soils but the differences are greater among the different types of soil. The heavier types are richer in organic carbon and the darker colored soils are higher than the light-colored types, so that the need of organic matter is greater on the sandy soils just as is the case with nitrogen. Organic matter must be supplied from time to time on all types if the soils are to be kept permanently fertile. Manure is the best fertilizing material to use on these soils and it gives large increases in yields.

The relation between the nitrogen and carbon in some of the soil types is additional evidence of the need and value of manure. Apparently in some cases the decomposition processes are not proceeding sufficiently rapidly to keep the supply of available plant food at the proper point for the best crop production. The Muscatine silt loam, the Carrington fine sandy loam and the Carrington fine sand are the most striking examples of the need of manure indicated by a poor relation between nitrogen and carbon. Several other types are also in need of the increased decomposition processes which result from the action of manure and of the consequent increased production of available plant food.

Only two of the types in the county show any content of inorganic carbon
and in one case the amount present is very small. This shows definitely the need of lime on the soils. The limestone requirement determinations also show a very decided acidity in the soils. With the exception of the colluvial phase of the Wabash silt loam all the soils of the county should be limed to secure the best crop growth especially for such crops as clover and alfalfa. In three instances no limestone requirement is shown but in those cases there is no content of lime in the soils and they will soon be in need of this material. All the soils of the county should be tested for acidity and the amount of lime indicated as necessary by the tests should be applied. The figures given in the table should be considered merely as indicative of the needs of the soil types and applications should not be based on them. Soils vary widely in their need of lime and even soils of the same type may show quite different acidity. Hence every soil should be tested before lime is applied in order that an excessive or insufficient application may be avoided.

**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 pounds per acre of four million pounds of subsurface soil and six million pounds of subsoil respectively.

The plant food content of the underlying soil layers has little effect on the “life” of the surface soil unless there are considerable amounts of some con-

### TABLE V. PLANT FOOD IN CLINTON COUNTY, IOWA, SOILS. POUNDS PER ACRE OF FOUR MILLION POUNDS OF SUBSURFACE SOILS (6%-$20'$)

<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 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1840</td>
<td>4980</td>
<td>68,750</td>
<td>0</td>
<td>6000</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1510</td>
<td>2580</td>
<td>37,820</td>
<td>0</td>
<td>2800</td>
</tr>
<tr>
<td>84</td>
<td>Clyde silt loam</td>
<td>1840</td>
<td>4920</td>
<td>51,920</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>1880</td>
<td>7280</td>
<td>98,428</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1540</td>
<td>1900</td>
<td>30,460</td>
<td>0</td>
<td>3600</td>
</tr>
<tr>
<td>86</td>
<td>Carrington fine sand</td>
<td>1300</td>
<td>1660</td>
<td>20,350</td>
<td>0</td>
<td>4400</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>2013</td>
<td>2200</td>
<td>25,053</td>
<td>0</td>
<td>3333</td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>3787</td>
<td>7213</td>
<td>74,680</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>1760</td>
<td>3240</td>
<td>25,400</td>
<td>0</td>
<td>2400</td>
</tr>
<tr>
<td>87</td>
<td>Memphis very fine sandy loam</td>
<td>1740</td>
<td>3300</td>
<td>26,400</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2660</td>
<td>7900</td>
<td>103,560</td>
<td>0</td>
<td>6400</td>
</tr>
<tr>
<td>46</td>
<td>Buckner fine sand</td>
<td>1620</td>
<td>1400</td>
<td>16,325</td>
<td>0</td>
<td>4800</td>
</tr>
<tr>
<td>40</td>
<td>Buckner sandy loam</td>
<td>2020</td>
<td>2520</td>
<td>27,360</td>
<td>0</td>
<td>3600</td>
</tr>
<tr>
<td>38</td>
<td>Buckner loam</td>
<td>2020</td>
<td>2300</td>
<td>45,320</td>
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<td>4400</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>2100</td>
<td>4880</td>
<td>49,560</td>
<td>Trace</td>
<td>4000</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>2720</td>
<td>7520</td>
<td>30,980</td>
<td>0</td>
<td>1600</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3260</td>
<td>5040</td>
<td>64,590</td>
<td>Trace</td>
<td>4000</td>
</tr>
<tr>
<td>26A</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>4160</td>
<td>4480</td>
<td>56,240</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>43</td>
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<td>2000</td>
</tr>
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<td>5720</td>
<td>66,600</td>
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<td>7200</td>
</tr>
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<td>Wabash silty clay</td>
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<td>7960</td>
<td>111,400</td>
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<td>4000</td>
</tr>
<tr>
<td>21A</td>
<td>Muck</td>
<td>2720</td>
<td>25680</td>
<td>397,510</td>
<td>Trace</td>
<td>2400</td>
</tr>
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<td>49</td>
<td>Wabash loam</td>
<td>2080</td>
<td>7200</td>
<td>71,740</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>90</td>
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<td>7200</td>
<td>18,940</td>
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<td>3200</td>
</tr>
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<td>91</td>
<td>Sarpy loam</td>
<td>2140</td>
<td>3140</td>
<td>39,210</td>
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<td>3200</td>
</tr>
</tbody>
</table>
TABLE VI. PLANT FOOD IN CLINTON COUNTY, IOWA, SOILS. POUNDS PER ACRE OF SIX MILLION POUNDS OF SUBSOIL (20”-40”)

<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 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>2010</td>
<td>3420</td>
<td>46,020</td>
<td>0</td>
<td>5200</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>2180</td>
<td>3450</td>
<td>47,500</td>
<td>0</td>
<td>2800</td>
</tr>
<tr>
<td>54</td>
<td>Clyde silt loam</td>
<td>2540</td>
<td>3180</td>
<td>32,160</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>2550</td>
<td>6560</td>
<td>65,640</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1680</td>
<td>2010</td>
<td>28,740</td>
<td>0</td>
<td>3200</td>
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<td>2430</td>
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<td>3600</td>
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</table>

DRIFT 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 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Clinton silt loam</td>
<td>3380</td>
<td>2280</td>
<td>51,263</td>
<td>0</td>
<td>3200</td>
</tr>
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<td>32</td>
<td>Lindley silt loam</td>
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<td>2160</td>
<td>21,120</td>
<td>0</td>
<td>3200</td>
</tr>
<tr>
<td>87</td>
<td>Memphis very fine sandy loam</td>
<td>2130</td>
<td>2280</td>
<td>25,860</td>
<td>0</td>
<td>4000</td>
</tr>
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</table>

LOESS 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 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Buckner silt loam</td>
<td>2550</td>
<td>4710</td>
<td>26,550</td>
<td>0</td>
<td>4400</td>
</tr>
<tr>
<td>49</td>
<td>Buckner sandy loam</td>
<td>2340</td>
<td>2610</td>
<td>24,825</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>38</td>
<td>Buckner loam</td>
<td>2370</td>
<td>2340</td>
<td>44,520</td>
<td>0</td>
<td>3200</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>2670</td>
<td>4110</td>
<td>39,495</td>
<td>Trace</td>
<td>6000</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silt loam</td>
<td>2400</td>
<td>4200</td>
<td>14,670</td>
<td>0</td>
<td>800</td>
</tr>
</tbody>
</table>

TERRACE 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 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>4110</td>
<td>5550</td>
<td>77,280</td>
<td>0</td>
<td>3900</td>
</tr>
<tr>
<td>26A</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>3360</td>
<td>6540</td>
<td>63,540</td>
<td>13860</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>3960</td>
<td>6540</td>
<td>106,470</td>
<td>0</td>
<td>1600</td>
</tr>
<tr>
<td>59</td>
<td>Sarpy silt loam</td>
<td>2520</td>
<td>1320</td>
<td>65,850</td>
<td>0</td>
<td>4800</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>3750</td>
<td>9600</td>
<td>120,300</td>
<td>0</td>
<td>3200</td>
</tr>
<tr>
<td>21A</td>
<td>Muck</td>
<td>4360</td>
<td>26880</td>
<td>359,538</td>
<td>24612</td>
<td>0</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2820</td>
<td>3720</td>
<td>58,680</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>90</td>
<td>Sarpy sandy loam</td>
<td>2190</td>
<td>1020</td>
<td>53,910</td>
<td>0</td>
<td>2400</td>
</tr>
<tr>
<td>91</td>
<td>Sarpy loam</td>
<td>2100</td>
<td>1750</td>
<td>47,130</td>
<td>0</td>
<td>2400</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND 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 Requirements</th>
</tr>
</thead>
</table>

stituent present. In the present instance the plant food content actually decreases rapidly in the lower soil layers. The needs of the soils as shown by the analyses of the surface samples may therefore be considered as practically uninfluenced by the results given in the analyses of the lower soil layers.

The need of phosphorus now or in the future is confirmed by these results, the need of lime is proven and the need for nitrogen and organic matter is likewise emphasized. All the soils with two exceptions show a lime requirement in the subsoil. These exceptions are the colluvial phase of the Wabash silt loam, the same soil which was basic in the surface soil, and the Muck. It is not advisable, however, to apply enough lime to any soil to neutralize the acidity of the subsoil. Sufficient should be used to remedy the acidity in the surface soil and the soil tested from year to year and lime applied to keep it from becoming acid. Lime rarely moves upward in the soil but generally down and out in the drainage water and applications of lime are especially essential on soils which like those in Clinton county are acid in the subsoil.

GREENHOUSE EXPERIMENTS

Greenhouse experiments were carried out on four soil types found in Clinton county; the Carrington silt loam, Carrington loam and Muscatine silt loam obtained from Clinton county; and the Clinton silt loam from Scott county. This latter experiment is included here because the soil type is the same as that found
in Clinton county and the results secured in the test are directly applicable to
the same type in that county.

The first experiment was on the Carrington silt loam and the treatments con­sisted in the use of lime, rock phosphate, acid phosphate and manure. Lime
was applied in the amount necessary to neutralize the acidity of the soil and,
two tons additional used to put the soil in the best reaction for crop growth.
Manure was applied at the rate of 10 tons per acre, rock phosphate at the rate
of 1000 pounds per acre and acid phosphate at the rate of 200 pounds per acre.
The pots were seeded to Marquis spring wheat and kept under optimum condi­tions of moisture and temperature in the greenhouse. The crop was harvested
when mature and the yield of grain obtained. The results of this test are given
in table VII.

The application of lime exerted no appreciable influence on the yield of wheat.
However, wheat does not respond to applications of lime except when the soil
is strongly acid but if a legume such as clover or alfalfa had been grown, in­
creases in crop yields would undoubtedly have been secured as the soil is gen­
erally acid in reaction. Such crops, however, do not grow as well in the green­
house as wheat and the latter crop was chosen as best suited to show the effect
of other fertilizing materials. General farm experience has proven that lime
should be used on this soil to secure the best growth of legume crops.

The application of rock phosphate or acid phosphate with the lime resulted in
small gains in crop yields. Manure brought about a decided increase in yields
and one much larger than that given by the phosphatic materials. Rock phos­
phate or acid phosphate applied with the manure both brought about definite
gains in crop growth. The rock phosphate showed a slightly larger increase
than the acid phosphate.

These results indicate that manure is the most valuable fertilizing material to
use on this soil and rock phosphate or acid phosphate used without manure do
not prove profitable. When applied with manure, however, decided gains are
noted indicating that phosphorus fertilizers may be of value on this soil now
if used with manure altho field tests are necessary before definite recommenda­tions can be made. It is not possible from these results to choose between the
rock phosphate and the acid phosphate as the differences were not large enough
to be distinctive. Further tests are desirable and farmers are urged to test
the use of both materials on their own soils.

The second experiment was on the Carrington loam. Manure was applied at
the rate of eight tons per acre, lime in sufficient amount to neutralize the acidity
of the soil and supply two tons additional, rock phosphate at the rate of 2000
pounds per acre, acid phosphate at the rate of 200 pounds per acre and a com-

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wt. Grain Gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>12.25</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>12.25</td>
</tr>
<tr>
<td>3</td>
<td>Lime, Rock Phosphate</td>
<td>14.50</td>
</tr>
<tr>
<td>4</td>
<td>Lime, Acid Phosphate</td>
<td>14.50</td>
</tr>
<tr>
<td>5</td>
<td>Lime, Manure</td>
<td>16.00</td>
</tr>
<tr>
<td>6</td>
<td>Lime, Manure, Rock Phosphate</td>
<td>24.50</td>
</tr>
<tr>
<td>7</td>
<td>Lime, Manure, Acid Phosphate</td>
<td>21.50</td>
</tr>
</tbody>
</table>
Fig. 3. A greenhouse pot experiment on Carrington silt loam. Immature wheat.

Fig. 4. The mature wheat growing in these pots shows the relative effects of various treatments of Carrington silt loam.

Fig. 5. A greenhouse pot experiment showing the beneficial effect of a combination of manure and lime on Carrington loam.
TABLE VIII. GREENHOUSE EXPERIMENT. CARRINGTON LOAM, CLINTON CO.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wheat Grain in grams</th>
<th>Clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>7.27</td>
<td>6.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>7.50</td>
<td>35.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>8.75</td>
<td>57.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock Phosphate</td>
<td>9.17</td>
<td>58.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid Phosphate</td>
<td>7.77</td>
<td>63.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Commercial Fertilizer</td>
<td>9.32</td>
<td>56.5</td>
</tr>
</tbody>
</table>

Commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat was seeded and clover put in about one month after the wheat was up. The results of this experiment are given in table VIII.

The manure brought about little effect on the wheat but the clover crop was considerably increased. Lime had a beneficial effect on both the wheat and the clover, especially the latter. Rock phosphate and the commercial fertilizer showed a small effect on the wheat but acid phosphate had no influence. Acid phosphate gave a slight increase on the clover but the rock and commercial fertilizer had no effect at all. Manure and lime are evidently the most necessary fertilizing materials on this soil and are essential to bring about the best crop growth both of small grains and legumes.

The third experiment was on the Muscatine silt loam. The soil was treated as in the preceding test and the same crops grown. The results are given in table IX.

Fig. 6. Lime and manure proved the most valuable fertilizers in this greenhouse experiment with mature wheat grown on Muscatine silt loam. Phosphates and commercial fertilizer showed no effect.
Fig. 7. Lime showed a marked effect on the clover in this greenhouse experiment with Mus­
catine silt loam and phosphates and commercial fertilizers proved of value

TABLE IX. GREENHOUSE EXPERIMENT. MUSCATINE SILT LOAM, CLINTON
COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wheat Grain in grams</th>
<th>Clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>22.75</td>
<td>35.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>25.97</td>
<td>35.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>30.42</td>
<td>45.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock Phosphate</td>
<td>28.55</td>
<td>51.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid Phosphate</td>
<td>31.42</td>
<td>63.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Commercial Fertilizer</td>
<td>29.02</td>
<td>58.5</td>
</tr>
</tbody>
</table>

The application of manure resulted in some beneficial influence and the lime
showed a marked effect on the wheat and especially on the clover. The phos-

Fig. 8. A greenhouse pot experiment on Clinton silt loam. Manure and lime brought about
slight increases in the growth of wheat
TABLE X. GREENHOUSE EXPERIMENT. CLINTON Silt Loam

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wheat Grain in grams</th>
<th>Clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>8.34</td>
<td>25.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>8.55</td>
<td>49.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>9.30</td>
<td>47.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock Phosphate</td>
<td>8.49</td>
<td>58.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid Phosphate</td>
<td>9.97</td>
<td>46.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Commercial Fertilizer</td>
<td>9.27</td>
<td>49.5</td>
</tr>
</tbody>
</table>

Phosphates and commercial fertilizer had no effect on the wheat but they all exerted a beneficial influence on the clover. The acid phosphate in particular gave a distinct increase in the clover crop and so also did the commercial fertilizer, the rock phosphate having a much less effect. Evidently manure and lime are of value on this soil and there are indications that phosphates and commercial fertilizers may also prove valuable.

The fourth experiment was on the Clinton silt loam from Scott county, a soil type which occurs extensively in Clinton county and is the same in both counties. The treatments of the soil were the same as in the preceding test and the same crops were grown. The results appear in table X.

The manure gave a small increase in wheat but the effect on the clover was very pronounced, almost twice as large a crop being secured. The lime increased the wheat slightly but did not affect the clover. The rock phosphate, acid phosphate and commercial fertilizer had practically no influence on the wheat crop and only in the case of the rock was there even a small effect on the clover. The fertilizing materials most needed on this soil are manure and lime. Phosphorus fertilizers and commercial fertilizers do not seem to be necessary now but they will be needed in the future and tests of their use in the field are highly desirable.

FIELD EXPERIMENTS WITH GUMBO

Within the state there are areas of soil popularly called "gumbo" which have received special attention for several years because of the difficulty in farming them and because of their need for special treatment.

The term "gumbo" is not a recognized name for a particular class of soils,
according to any accepted scheme of soil classification. It is a popular name for a group of soils which possess characteristics well known and dreaded by farmers. It is very different from the gumbo referred to in geological reports which includes almost impervious gray or yellow clay subsurface soils.

The soil that Iowa farmers call "gumbo" is a heavy, "greasy" black clay soil, occurring in flat areas, either river bottoms or level uplands. It is usually inky black and is stickier and bakes more easily than any other type of soil in the state. If such soil is plowed when too wet it balls up before the plow point in such a way that the implement cannot be made to stay in the ground. On the other hand, if it becomes too dry it will turn up in clods which cannot be worked down during the whole season. Where such clods are formed, freezing and thawing is the only process which will restore the loose, mealy structure. This soil can, however, be put in excellent tilth, with a fine, mealy appearance and kept so during the entire season provided it is not cultivated when too wet.

The total area of "gumbo" in Iowa is probably about one percent of the entire state, occurring in small patches in various localities. The principal areas are in southeastern Iowa and along the Missouri river in western Iowa. The counties in which "gumbo" has been found are Muscatine, Washington, Louisa, Henry, Des Moines, Van Buren, Lee, Woodbury, Monona, Harrison and Pottawattamie.

There are three soil types in Clinton county which are locally known as "gumbo," the Clyde silty clay loam, an upland soil and the Wabash silty clay loam and the Wabash silty clay both of which are bottomland soils. These three types together cover 4.5 percent of the total area of the county.

The management of "gumbo" may be profitably considered at this point, therefore, and the results of a field experiment presented. While this experiment was not carried on in this county, it yielded results applicable to "gumbo" soils everywhere in the state.

This experiment was located on a typical area of "gumbo" bottomland near Wapello, Louisa county. Two series of plots were laid out in 1908, one consisting of six plots which were undrained and one of ten which were as well drained as conditions would permit. The treatment and yields of corn in 1909 are given in table XI.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. corn per acre 1909</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>Rape (too wet)</td>
<td>24</td>
</tr>
<tr>
<td>102</td>
<td>Buckwheat</td>
<td>62</td>
</tr>
<tr>
<td>103</td>
<td>Clover</td>
<td>94</td>
</tr>
<tr>
<td>104</td>
<td>Check</td>
<td>77</td>
</tr>
<tr>
<td>105</td>
<td>Lime — 10 T per acre</td>
<td>68</td>
</tr>
<tr>
<td>106</td>
<td>Straw — 4 T per acre</td>
<td>47</td>
</tr>
<tr>
<td>107</td>
<td>Check</td>
<td>40</td>
</tr>
<tr>
<td>108</td>
<td>Manure — 12 T per acre (too wet)</td>
<td>23</td>
</tr>
<tr>
<td>109</td>
<td>Manure — 6 T per acre (too wet)</td>
<td>14</td>
</tr>
<tr>
<td>Undrained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>Clover and timothy sod</td>
<td>7</td>
</tr>
<tr>
<td>202</td>
<td>Clover and timothy sod</td>
<td>10</td>
</tr>
<tr>
<td>203</td>
<td>Manure — 12 T per acre</td>
<td>15</td>
</tr>
<tr>
<td>204</td>
<td>Check</td>
<td>27</td>
</tr>
<tr>
<td>205</td>
<td>Manure — spring plowed</td>
<td>20</td>
</tr>
<tr>
<td>206</td>
<td>Check — spring plowed</td>
<td>20</td>
</tr>
</tbody>
</table>
Plots 101, 102, 103, 201 and 202 were green manured in 1908 with rape, buckwheat, clover and clover and timothy, respectively. The clover and timothy on plots 201 and 202 had been a meadow for several years and produced a crop of hay in 1908 which made a yield of 2½ tons per acre. The aftermath was plowed under for green manure. All, except plots 205 and 206, were fall plowed in 1908, the treatments indicated being made prior to plowing.

In the fall plowing it was noticed that the clover and buckwheat plots worked much more easily than the others. The following season the plots which received manure dried out more slowly after a wet spell than the others. Further observations on the effects of treatment could not be made.

Great differences in yield occurred but these should undoubtedly be attributed to differences in drainage rather than to the effects of treatment. It was impossible to get a satisfactory outlet for the tile drain and on each side of the experiment field there was a swampy place in which the water stood nearly all summer and this surely affected the results from the outside plots. (101, 108, 109).

Where the soil was fall plowed, a fine mealy seed bed was obtained for the corn which was planted on May 13. Surrounding undrained land which was not fall plowed could not be planted until about June 10. The undrained plots were too wet nearly all summer and the outside plots in the drained series were also too wet. In the latter part of the summer all of the plots dried out well at the surface and the undrained ones cracked open, leaving wide fissures to a depth of more than a foot. On the best drained plots, the fine crumbly surface soil prevented this cracking. On the hard, cracked ground the corn turned yellow and "fired" about the middle of August, but on the other plots it remained green at least three weeks longer.

The fall plowed plots were fairly clean of weeds and grass while the others were very foul. The lime treatment of plot 105 seemed to have no effect on the "gumbo."

This experiment shows very definitely the possibilities of "gumbo" soils when properly drained and fall plowed. The drainage of "gumbo" is more readily accomplished than would be supposed. On the upland the tile should be laid 8 rods apart to secure good drainage, altho reports have been made of successfully drained "gumbo" when the tile was 10 to 12 rods apart. On the lowland "gumbo" the tile should be somewhat closer together, but the securing of a satisfactory outlet is the chief necessity for thorough drainage and in some cases it may be necessary to run an open ditch thru to the river, in which case a drainage district must be organized. When properly tiled out such "gumbo" soil is equal to any other soil in the state in producing power for general farm crops. Fall plowing improves the soil very decidedly and the use of clover or some other green manure is also of value.

The occurrence of "gumbo" on a farm need not be a cause of lower value of the farm. It may be made and kept productive thru the treatments mentioned above and is then equal in value to the best farm land.
THE NEEDS OF CLINTON COUNTY SOILS AS INDICATED BY LABORATORY AND GREENHOUSE TESTS

Field tests are now under way on the main soil types in Clinton county to ascertain the needs of the soils for lime, manure, phosphorus fertilizers and complete commercial fertilizers. These tests have been begun only recently and it will be several years before the results secured will be available for publication. They will be published at a later date in a supplementary report. For the present the recommendations for treatment of the soils of the county can be based only on the greenhouse and laboratory tests reported in this bulletin and on general farm experience. The suggestions made herein are only those which have been found to be of value by the experiences of farmers, and while, therefore, field experimental data cannot be given, the needs of the soils are definite and the treatments advised are of proven value.

LIMING

 Practically all the soils of Clinton county are acid in reaction and therefore in need of lime. The greenhouse experiments reported here did not show large returns from the use of lime on wheat but wheat is not particularly sensitive to acid conditions and unless they are extreme no great increases in that crop will be secured by the application of lime. Legumes, particularly clover and alfalfa, are very sensitive to acidity in the soil and, in general, will not grow properly in the absence of lime. Lime should be used on acid soils, therefore, primarily

Fig. 10. Limed and unlimed land in alfalfa. Notice the difference in the growth of the crop on the two portions of the field
Fig. 11. Alfalfa on limed land. Lime was applied at the rate of two tons per acre for the purpose of securing the best growth of the legume in the rotation. Large increases in the yields of corn, oats and other grains should not be expected. Lime aids also in keeping soils in the best physical condition not only for crop growth but also for the best production of available plant food which in turn influences crop production. This is particularly the case on very heavy or light soils.

There is great variation in the lime requirement of soils, even among those of the same type and all soils should be tested to determine their need of lime. Average analyses even for a considerable number of samples should not be taken to show the amount of lime needed by a soil. Tests should be made of each individual soil thus avoiding insufficient or excessive applications both of which are undesirable economically. Farmers may test their own soils but it will be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it can be tested more accurately free of charge.

Further information regarding the application of lime to acid soils, the effect on different crops, the kind to use, time and method of application is given in Bulletin 151 of the Iowa Agricultural Experiment Station.

**MANURING**

Many of the soils of Clinton county are low in organic matter and the application of manure is particularly desirable. The experiments reported in this bulletin and general farm experiences show that farm manure gives large increases in crop growth on practically all the soils of the county. Other fertilizing materials have little effect in the absence of manure and no other material gives as large returns for the expense involved.

All the manure produced on the farm should be carefully stored and applied
to the soil. It should never be allowed to accumulate in a loose pile exposed to
the weather so that the valuable liquid portion is permitted to wash out and
away from the farm. Losses fall mainly on the nitrogen and the economic loss
is therefore considerable.

When manure that has been properly stored is applied to the soil, the return
of plant food removed from the soil by the crops grown may be very large. Thus
the use of manure is an important factor in keeping up the ‘‘life’’ of the soil
from the plant food standpoint. It will put off the time when commercial fer­
tilizing materials will be needed, far into the future. The chief effect of manure,
however, is probably due to its physical action in promoting decomposition pro­
cesses in the soil. Unless these processes are properly maintained crops may
suffer for food even when there is plenty present which merely needs to be put
into a soluble and available form.

Manure has a third effect due to the introduction of large numbers of bacteria
into the soil. These are the agents which bring about available plant food
production and hence by the mere increase in bacteria in the soil, manure may
influence crop production to a considerable extent.

There is little danger of applying too much manure to a soil as the amount
produced on the average farm is rarely great enough to be used on all the soils
of the farm. It should be distributed systematically over the soils of the farm
and one soil should not be neglected that a larger application may be made to
another. It is not desirable to apply more than 16 to 20 tons of manure per
acre, as those amounts bring about maximum effects. Even smaller applications
than those are used with large effects on crop growth.

In some cases on livestock farms and commonly on grain farms the manure
produced is insufficient to keep the soil supplied with organic matter and must
be supplemented by green manuring. A large variety of crops are available for
this purpose, but legumes are the most desirable because when well-inoculated,
as should always be the case, they utilize the nitrogen of the atmosphere and
thus increase both the nitrogen and the organic matter content of the soil.
Even where farm manure is available and added to soils in small amounts it is
often advisable to use green manure to supplement it particularly on light, open
soils where the organic matter content is low and disappears rapidly after
application. Like many other farm practices, however, green manuring should be
followed with care and understanding. Further information regarding green
manuring may be found in Circular 10 of the Iowa Agricultural Experiment
Station and advice and suggestions for special cases will be given by the Soils
Section upon request.

The return of crop residues such as straw and stover to the soil is a third
means of keeping up the content of organic matter. Such materials should never
be burned, or otherwise destroyed, as they are very valuable when used on the
soil. They not only add organic matter which is so necessary for permanent
fertility but they also return some of the plant food removed by the crop and
thus prolong the ‘‘life’’ of the soil. The return of crop residues, particularly
straw, along with manure as is commonly practiced on the livestock farm is
especially valuable as the decomposition of the straw is increased considerably
by being introduced with the manure. Such materials are particularly neces-
sary on the grain farm in order to make up in part at least for the lack of farm manure.

COMMERCIAL FERTILIZERS

The phosphorus content of most of the Clinton county soils was so low that it seems reasonable to assume that phosphorus fertilizers might be of value in some cases now and they must certainly be considered in any system of permanent fertility adopted for these soils.

The greenhouse experiments showed that some soil types might respond profitably to the application of such materials while others showed hardly any effects whatever. The field tests now under way on the main soil types in the county will show not only what soils will be benefited by the use of phosphorus fertilizers but also whether rock or acid phosphate should be employed. Tests on individual farms are highly desirable and farmers are urged to test the needs of their own soils and also to test the use of the two phosphate materials. Rock phosphate is an insoluble material while acid phosphate is soluble but costs much more than the rock and it is necessary to ascertain which is the cheaper material. Farmers who are interested in making such tests of phosphate fertilizers may secure suggestions from Circular 51 of the Iowa Agricultural Experiment Station or from the Soils Section upon request.

The use of nitrogenous fertilizers has not been tested on Clinton county soils, but since they are not particularly low in that element it seems unlikely that commercial nitrogenous materials would be profitable. The use of farm manure returns much nitrogen to the soil and where there is any deficiency as is the case in some of the lighter types, the turning under of leguminous green manure crops would prove a much cheaper and quite as satisfactory means of increasing the nitrogen content of the soil. For permanent fertility the use of legumes as green manures will serve to keep up the nitrogen content of the soil and commercial nitrogenous materials need not be applied. In general it may be said that it is not believed that such materials should be applied to Clinton county soils for general farm crops except perhaps in small amounts as top dressings to encourage the early growth of crops. If they are found profitable, however, there is no objection to their use.

Potassium is present in all the soils of the state in such large amounts that it is not considered the limiting factor of growth in many cases. No analyses were made for potassium in this work but previous tests have shown that Clinton county soils are abundantly supplied with potassium. If the soil is kept in the proper physical condition, there will be a sufficient production of available potassium to keep the crop supplied and there would be no value from the use of potassium fertilizers. Such materials are not recommended, therefore, and should be used only as top dressing for encouraging the early growth of some crops.

Complete commercial fertilizers are not expected to show profitable returns on Clinton county soils, inasmuch as potassium is probably unnecessary and nitrogen might be added more economically by legumes. The field tests now under way include the use of a complete commercial fertilizer, as well as phosphate materials and will yield comparative results. Farmers may include such materials in their tests and if complete commercial fertilizers are found to be
Fig. 12. This view shows the typical Muscatine silt loam topography

profitable then there is no objection to their use. They do not "wear out" the soil, as is commonly supposed and if they are used with lime and organic matter, the soil may be kept permanently fertile as in other cases. For the present such materials cannot be recommended for general farm crops but tests of their use are desirable. For truck crops complete commercial fertilizers may be used with profit. In such cases brands should be chosen which are prepared for the particular crop.

DRAINAGE

All soils which are not properly drained fail to produce satisfactory crops. The first step necessary in making wet soils productive is to install an adequate drainage system either by the use of tile or drainage ditches, or both. No other treatment of wet soils will prove profitable until they have been drained.

In Clinton county there are several soils which would be benefited by drainage. Some areas of the Muscatine silt loam, the Carrington loam and the Carrington silt loam are in need of tiling. The Clyde silt loam, Clyde silty clay loam, Bremer silt loam, Bremer silty clay loam, Calhoun silt loam and Wabash silty clay loam are all in need of drainage over considerable portions of the areas which they cover. It is easy to ascertain the need for drainage and the results will more than repay the expense involved. Suggestions and advice regarding the installation of tile drains and drainage ditches may be secured from the Soils Section upon request.

CROP ROTATION

It is a well-known fact that the continuous growing of one crop very quickly decreases the yields on any soil. A rotation should be practiced in order that the yields may be kept up and in many experiments rotations have proven more profitable than the continuous growing of even the "money" crops. All sys-
tems of farming should, therefore, follow a definite rotation of crops and, furthermore, every rotation should contain a legume. No specific experiments were carried out in Clinton county to show the best rotations, but the following may be suggested as applicable to the county and as having proven quite satisfactory.

1. FOUR OR FIVE-YEAR ROTATION

**First year:** Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).

**Second year:** Corn.

**Third year:** Oats (with clover or with clover and timothy).

**Fourth year:** Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2. FOUR-YEAR ROTATION WITH ALFALFA

**First year:** Corn.

**Second year:** Oats.

**Third year:** Clover.

**Fourth year:** Wheat.

**Fifth year:** Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above).

3. THREE-YEAR ROTATION

**First year:** Corn.

**Second year:** Oats or wheat (with clover seeded in the grain).

**Third year:** 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).

**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 thoroly 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 erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very 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 erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion 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 careless 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 plowing 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 absorbing 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 expensive 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 may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal 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 Clinton county erosion occurs to some extent in the Memphis very fine sandy loam, the Clinton silt loam, the Lindley silt loam and in isolated cases on some other soil types.

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.

**EROSSION DUE TO DEAD FURROWS**

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

"Plowing In."—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this

![Fig. 13. Wash due to rains in cultivated areas of the Clinton silt loam](image-url)
"plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows 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 made 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 is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

"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. A series of these brushpiles 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
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 a 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

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, is especially applicable 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 and corn stalks 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 red top are also quite desirable for use in such locations. The root system of such crops as these holds 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 quite 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 CLINTON COUNTY

DRIFT SOILS

There are six drift soils in Clinton county belonging to the Carrington and Clyde series and together they cover 29.6 percent of the total area of the county.

CARRINGTON SILT LOAM (83)

This soil covers 75,456 acres, or 17.1 percent of the total area of the county. It occurs in extensive areas on the Iowan drift plain associated mainly with the

1The description of individual soil types given in the Bureau of Soils report have been rather closely followed in this section.
Carrington loam and the Clyde silt loam and usually occupying a topographic position between the two. Near Bliedorn and Wheatland, however, the type is higher than the remainder of the drift plain.

The surface soil to a depth of 8 to 12 inches is a dark grayish-brown to black or dark-brown, friable and generally mellow silt loam to fine loam. Sometimes very fine to fine sand, with small quantities of medium sand, is found. The subsoil is a dark-brown, heavy, silt loam in most cases grading into a slightly compact silty clay loam of the same color. The layer of heavy silt loam is occasionally absent. In the poorly drained areas of the type the subsoil material is marked with some gray mottlings in the lower portion. Typically, however, there is a gradation, at 15 to 24 inches, from the dark-brown, silty clay loam into a brown, compact, silty clay loam which sometimes changes to a light-brown or yellowish-brown material at 30 inches. Where the type occurs on the tops of ridges there has been more erosion and a light-brown, clayey loam or loam occurs at 30 inches, grading generally into a sandy loam or loamy sand of a light-brown, yellowish-brown or even reddish-brown color.

This type was originally a prairie soil, but small forested areas are included, which are somewhat lighter in color. In these areas the subsoil is sometimes a brown to yellowish-brown heavy silt loam below 8 to 12 inches grading into a yellowish-brown silty clay loam. Gravel is found underlying much of the type and gravel pits occur in several places. Sometimes this gravel appears within 3 feet of the surface and in some cases the soil approaches a gravelly loam. Pebbles and gravel are frequently found in the surface soil and huge boulders are sometimes encountered.

In topography the soil is generally undulating to gently rolling, except on the high ridges which have rather sharp slopes. Drainage is usually adequate but ditching and tiling are necessary on some of the small, flat areas.

Most of the type is under cultivation and it is quite satisfactorily productive. Corn is the main crop and average yields of 40 to 50 bushels per acre are secured. Oats yield 30 to 35 bushels; wheat, 18 to 25 bushels; barley, 18 to 20 bushels; and rye, 15 to 20 bushels per acre. Yields of 1 to 1 1/4 tons of clover and timothy hay are secured and alfalfa averages 3 to 4 tons per acre.

The needs of this soil to make it more productive are manure, lime and probably phosphorus fertilizers. Applications of farm manure bring about large increases in yields, altho the soil is not low in organic matter and manure should be used on this type in normal amounts. The soil is acid in reaction and lime should be applied if the best growth of legumes is to be secured. The soil should be tested at regular intervals and the amount of lime shown to be necessary according to the tests, should be applied. Phosphorus is low and there are indications that phosphorus fertilizers could be used with profit. Tests of these materials, using both acid phosphate and rock phosphate are highly desirable in order to determine the value from the use of these materials for individual conditions. In any case phosphorus must be applied in the future, even if it is not of use now. Drainage is necessary in some cases. These treatments will not only make the soil more productive at the present time but will keep it permanently fertile.
CLINTON COUNTY SOILS

CARRINGTON LOAM (1)

The Carrington loam covers 22,912 acres or 5.2 percent of the total area of the county. It occurs in connection with the Carrington silt loam on the Iowan drift plain and is usually found on low mounds and ridges. The largest areas are near Low Moor and Malone and smaller areas are scattered through the drift plain.

The surface soil to a depth of 7 to 12 inches consists of a dark-brown or nearly black to grayish-brown loam, containing some sand. The subsoil is a dark-brown, compact clay loam which grades into a brown clay loam or a brown, compact silt loam at depths of 15 to 20 inches. Sometimes a layer of a dark-brown heavy loam about 8 inches in thickness separates the surface soil and subsoil. At a depth of 28 inches or more there frequently occurs a brown clayey loam, grading into a light-brown sandy loam and this in turn into a yellowish-brown loamy sand to clayey sand. Gravel and pebbles occur at the surface and throughout the soil and boulders are also found, but not in large numbers. Small areas of a loam, generally brownish-gray in color, overlying a light-brown clay loam to silty clay loam are included in this soil type.

In topography this soil is generally rolling to slightly undulating. The drainage is usually good but in some of the more level areas tiling and ditching are of value.

Most of this type is under cultivation, only a small part being forested. On the wooded portion, the chief tree growth is oak with some hickory and elm. General farm crops are grown on the cultivated portion and fairly satisfactory yields are secured. Corn yields on the average 40 to 50 bushels per acre; wheat, from 18 to 25 bushels; and rye and barley, from 18 to 22 bushels per acre. Clover and timothy yield 1 to 1 1/4 tons of hay per acre and alfalfa, 3 to 4 tons per acre.

The needs of this soil are for organic matter, lime and phosphorus. It is not high in organic matter and farm manure would be of great value in increasing crop production. Crop residues should be thoroughly utilized and if sufficient farm manure is not produced, leguminous green manures should be employed as a substitute for or supplement to farm manure. The surface soil is generally acid and tests should be made at regular intervals and the amount of lime shown to be necessary, should be applied. Phosphorus is low in this soil and phosphorus fertilizers will undoubtedly be necessary in the future and the indications are that they could be used with profit in many cases at the present time. Tests on individual farms are urged.

CLYDE SILT LOAM (84)

This soil occupies 15,616 acres or 3.5 percent of the total area. It occurs throughout the Iowan drift plain and is usually associated with the Carrington silt loam.

The surface soil to a depth of 6 to 12 inches is a black to dark grayish-brown, friable silt loam ranging to a heavy, compact silt loam in the flat or depressed areas. The subsoil is rather variable. Typically it is a dark-brown to nearly black, compact silt loam which at 18 inches grades into a brown or dark-gray, heavy impervious silt loam. At 24 to 30 inches a mottled brown and gray or light-brown and gray, stiff, compact silt loam occurs. The subsoil varies
in minor areas from a heavy loam to clay loam or silt loam and from brown thru gray and drab to black with mottlings of gray, drab, rusty-brown and yellow. Gravel and pebbles are frequently found and small areas of sandy material are sometimes encountered. A variation of this type occurs in some small areas. In such cases the soil is a dark-brown to grayish-brown loam with some sand to a depth of 8 to 10 inches and grades into a rusty-brown to dark-brown heavy loam to light clay loam. It is mottled with brown, rusty-brown, drab or yellow. At about 24 inches it passes into a drab or mottled light-drab and rusty-brown compact clay loam.

In topography the soil is level to almost flat. Areas of depressed land are common. The drainage is generally poor and tiling and ditching are necessary, especially in the depressed areas.

A large part of the soil is in pasture and general farm crops are grown on the cultivated portion. Corn yields 35 to 40 bushels per acre on the average; oats, 25 to 30 bushels; and wheat, 18 to 20 bushels. Little rye and barley are grown. Clover and timothy yield 1 ton of hay per acre on the average. Bluegrass pasture does very well on this type.

The main need of this soil is for drainage. The removal of excess water particularly in wet seasons is absolutely necessary for satisfactory crop production. Farm manure would be of value on the soil as would also lime. Phosphorus fertilizers will be necessary in the future and might prove profitable at the present time.

Within this soil type there occur small areas of so-called "alkali" spots. These areas have been described in a previous bulletin and the treatment necessary for the reclamation has been given.

**CLYDE SILTY CLAY LOAM (85)**

This is a minor soil in the county covering only 8,448 acres or 1.9 percent of the total area of the county. It occurs throughout the Iowan drift plain mainly at the heads of and along the drainage ways and in slightly depressed areas without drainage outlets.

The surface soil is a black to nearly black silty clay loam of a heavy, compact, tough, impervious character and extending to a depth of 10 to 16 inches. The subsoil is a dark-drab to drab, heavy, compact silty clay loam to silt loam which below 18 to 24 inches becomes dark-gray or gray. Mottlings with rusty-brown or yellow are common. Small areas of a silt loam or clay loam are included as they are too small to be shown separately. Gravel and pebbles are found in the soil and bowlders also occur in places throughout the type. In topography this soil is level to flat. The drainage is poor and tiling and ditching are usually necessary.

The soil, when properly drained, is productive and gives good yields of corn. Forty to 45 bushels per acre are the average yields of this crop. Small grains are little grown owing to their tendency to lodge. Much of the type is devoted to pasture and it supports a good growth of bluegrass.

This soil is locally known as "gumbo" and a description of the treatment needed to make it productive is given in the section on "gumbo" earlier in this report. Adequate drainage and fall plowing are the most essential treatments.

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CARRINGTON FINE SANDY LOAM (4)

This is a minor type in the county, covering 6,440 acres or 1.4 percent of the total area of the county. It occurs mainly associated with the Carrington loam. There is an area, 4 miles or more in length along the edge of the Wapsipinicon lowlands near Calamus, and several smaller areas occur throughout the drift plain. The type is generally higher than the remainder of the drift soils, the large area, referred to above, being 10 to 20 feet above the plain.

The surface soil to a depth of 15 to 24 inches is a dark-brown, dark grayish-brown or brown, loose, friable fine sandy loam. The subsoil is a brown to dark-brown loamy fine sand which grades into a light-brown to brown loamy fine sand and in some cases to a yellowish-brown fine sand. Small areas have a layer of brown to yellowish-brown silty clay loam to clay loam below the surface soil. Pebbles and gravel are found throughout the surface and subsoil.

In topography, the soil is flat to gently sloping. The ridges and mounds have sharp to medium slopes and the larger areas on the tops of the ridges are gently undulating to rolling. The drainage of the type is good to excessive.

Most of the soil along the lowlands of the Wapsipinicon is forested with a growth of oak, hickory and elm and an undergrowth of blackberry, sumac, and other shrubs.

The cultivated portion of the soil is utilized for general farm crops, meadow or pasture. The soil has a tendency to "blow" and its cultivation may result in the removal of much of the surface soil, especially from the ridges. The type is best left in meadow or pasture. Corn, oats and wheat give only poor yields.

The needs of this soil are for treatment which will increase its water-holding power and remove the danger of blowing. Farm manure, crop residues and leguminous green manures should be used in large quantities to increase the organic matter in the soils. With these additions, the application of lime as necessary and probably phosphorus fertilizers this soil could be made more productive.

CARRINGTON FINE SAND (86)

This soil is a very minor type which covers only 2,240 acres or 0.5 percent of the total area of the county. It occurs mainly as mounds and ridges and is associated with the other Carrington soils. The largest areas adjoin the bottoms of the Wapsipinicon river. Small, scattered areas are found throughout the drift plain.

The surface soil is a dark-brown to grayish-brown, slightly loamy, loose and friable fine sand to a depth of 18 to 24 inches. The subsoil is lighter in color than the surface soil, ranging from a light-brown to yellowish-brown or brownish-yellow fine sand. Pebbles and gravel are common throughout the soil. A variation of the type occurs in two areas several miles west and north of Dewitt and in one area near Clinton. In those areas the surface soil is of a grayish-brown to brown slightly loamy fine sand, grading into a material of the same texture but lighter in color, varying from light-brown to yellowish-brown. This variation occurs mainly as low knolls and ridges which are especially subject to "blowing."

In topography this soil is hilly to rolling on the slopes and varies from slightly rolling to undulating on the tops of the ridges. Drainage is excessive and the type is drouthy.
Most of the type is in pasture or meadow, only a small part being cultivated or forested. The timbered areas are found along the Wapsipineon bottoms. The soil as a rule is subject to wind action and is therefore best suited for meadow or pasture. Corn and small grains give low yields and the chief crop, on the cultivated portion is rye, which yields 10 to 15 bushels on the average. On the variation of the type mentioned above, truck crops such as watermelons and cantaloupes are grown profitably.

The principal need of this soil is for the use of organic matter. Farm manure and green manures along with the crop residues should be used in large amounts. Lime is necessary and phosphorus fertilizers will be of value in the future, if not now. For truck crops special brands of commercial fertilizers might be used with profit. This type occurs in such small areas that it is probably better to have them in pasture or meadow, but if cultivated crops are to be grown, the treatments mentioned are necessary to prevent the blowing of the soil.

LOESS SOILS

The loess soils cover more than half the acreage of Clinton county. They are found on 232,384 acres, or 52.5 percent of the total area of the county. Four types are included here, belonging to the Clinton, Muscatine, Lindley and Memphis series.

CLINTON SILTY LOAM (80)

This is the largest soil type in the county, covering 129,088 acres or 29.2 percent of the total area of the county. It occurs in large areas back from the Mississippi bluffs and along the larger streams coming from the uplands.

The surface soil to a depth of 6 to 10 inches is a light brownish-gray to light grayish-brown or yellowish-brown, mellow silt loam. In places along the Missis-
sippi river, fine sand is found in fairly large amounts. In some areas the surface soil is light-gray to almost white in color.

The subsoil is a light-brown or yellowish-brown silty clay loam, rather stiff and compact. In some small areas the subsoil is a yellowish-brown, heavy, compact silt loam. Grayish mottlings are frequently present and the lower material sometimes approaches a silty clay texture. Where erosion has been active, the surface soil has been largely removed and the underlying Kansan drift is very close to the surface. In such places the subsoil is a yellowish-brown to slightly reddish-brown clay-loam to silty clay loam. This soil is closely associated with the Muscatine silt loam and often it is difficult to draw definite boundary lines between the two.

A variation from the true type occurs along Ames and Silver creeks near Dewitt and in small areas along the bottoms of the Wapsipinicon river. This variation has all the characteristics of the true Clinton, except for the presence of glacial gravel and boulders. It is not separated on the map and its needs are very similar, so it may be considered a part of the true type.

In topography the Clinton silt loam ranges from hilly to gently rolling, the latter areas occurring on the divides between the streams. Toward the east the type becomes hilly to broken, the streams have worn deep channels and erosion is active. Drainage is good to excessive.

Most of the soil is under cultivation, only about 25 to 35 percent being in timber. The main forest growth is oak, white, red, scarlet, black and bur with some post oak and pin oak. Walnut, hickory, elm, locust, hard and soft maple, basswood and other trees are also commonly found. Corn is the chief crop grown and yields of 35 to 45 bushels are secured on the average. Oats yield 30 to 35 bushels per acre; rye, 15 to 20 bushels; and barley, 20 to 25 bushels per acre. Spring wheat and winter wheat are both grown on small areas. Clover and timothy yield 1 to 1 \( \frac{1}{2} \) tons of hay per acre, and alfalfa gives from 3 to 4 tons per acre. Some trucking is done on the type near Clinton and Lyons.

The rougher part of the type is kept in forest or in pasture to prevent erosion and the raising of livestock, chiefly beef, cattle and hogs which is practiced on such areas is probably the best use to which they can be put. The more level portions of the type may be used for general farm crops and with proper treatment satisfactory yields are secured. The soil is low in organic matter, nitrogen and phosphorus and lime. It should receive applications of farm manure in as large amounts as practicable and of leguminous green manure as a supplement or a substitute. Lime should be applied as shown necessary by special tests and phosphorus fertilizers must be used in the future if not now.

All of these treatments should of course be preceded by precautionary measures to prevent erosion. Some one of the methods suggested in the section on erosion should be selected and with proper installation and maintenance the soil may be kept from washing and may yield profitable crop returns.

**MUSCATINE Silt Loam (30)**

This is the second largest soil type in the county covering 98,176 acres or 22.2 percent of the total area of the county. It occurs in large areas in the uplands being associated mainly with the Clinton silt loam. It is found on the divides between the main streams and is generally distinctly higher than the drift plain.
The largest area extends from a point northeast of Dewitt northward beyond the county line. It is usually found on the edge of the Iowan drift plain and seldom adjoins the larger drainage ways.

The surface soil to a depth of 12 to 16 inches is a mellow, friable silt loam of a dark-brown to nearly black color. In the eastern part of the county small quantities of fine sand and very fine sand are found. On the tops of the ridges the soil is shallower than the typical phase and hence lighter in color. The subsoil is a yellowish-brown or light-brown silty clay loam, generally stiff and compact in structure. In places it is mottled with light-gray. There is a layer 4 to 6 inches in depth of dark-brown to nearly black heavy silt loam to silty clay loam between the surface and subsoil. In flat areas, near the heads of streams and on the flat-topped divides, the surface soil grades into a dark-brown to black silty clay loam to a depth of 20 to 24 inches, below which the material is a yellowish-brown silty clay loam mottled with gray and in places brown or brownish-drab mottled with gray. In a few instances the lower subsoil is a brown and gray mottled silty clay. In the north-central part of the county where the loess is thinnest, the underlying drift is sometimes in evidence in the 3-foot section. In such cases the subsoil is a yellowish-brown to slightly reddish-brown clay

Fig. 15. Surface, subsurface and subsoils of four of the individual soil types in Clinton county

1. Sarpy loam
2. Wabash silt loam
3. Clinton silt loam
4. Bremer silty clay loam
loam or silty clay loam of compact structure. In small areas near drainageways and at the heads of streams the soil is a black heavy silt loam to silty clay loam to a depth of 8 inches, beyond which it passes thru a dark-brown silty clay loam into a brown to light-brown or yellowish-brown silty clay loam.

The topography of the Muscatine silt loam varies from rolling in some areas to undulating in others. At the heads of streams and on the divides it is almost level. Near well-developed drainageways the type is sometimes strongly rolling to hilly and at the edge of the Iowan drift plain it is somewhat cut up. Drainage is generally adequate but in the flatter areas tiling and ditching have proven of value.

Most of the soil is under cultivation, only a small area being too rough for the growth of general farm crops. In such places the land is used for grazing purposes. Corn is the main crop on the type and yields 45 to 50 bushels per acre on the average. Oats yield 30 to 40 bushels per acre and wheat, 20 to 25 bushels per acre. Some barley and rye are grown. Hay consisting mainly of clover and timothy yields 1 to 1½ tons per acre. Alfalfa yields 3 to 4 tons per acre but it is produced only on small areas. Some sweet clover is being grown also. Bluegrass does well on this soil and it is used to a considerable extent for grazing purposes.

The needs of this soil for treatment are for farm manure which brings about large increases in crop yields, for lime and for phosphorus. The soil is generally acid in reaction and should be tested at regular intervals and lime applied if the best growth of crops, particularly clover and alfalfa are to be secured. Phosphorus is low in the soil and the use of phosphorus fertilizers will be necessary in the future, if not now. There are indications that they may be valuable on this soil and tests are desirable, both of acid phosphate and rock phosphate. Farmers may determine the needs of their own soils under local conditions by simple tests in the field and thus also aid in the general solution of the phosphorus problem.

LINDLEY SILT LOAM (32)

This is a minor soil type in the county, covering 4,544 acres or 1.0 percent of the total area of the county. It occurs on the sharp slopes from the loessial uplands to the streams. On many slopes the loessial covering has been removed and the slope is exposed. Sometimes rock outcrops appear on the steepest slopes. North of Clinton, limestone is exposed in a sheer bluff 100 feet or more in height.

The surface soil is a light-brown to grayish-brown silt loam of varying depth. Sand is occasionally present and, in some areas, in sufficient amounts to make the soil a sandy loam rather than a silt loam. The subsoil is a brown to yellowish-brown, or slightly reddish-brown clay loam to silty clay loam. It is rather stiff, compact and impervious and contains pebbles, gravel and sometimes large boulders.

The type is mainly forested and it is suitable only for trees or pasture. It is too rough for farming operations.

MEMPHIS VERY FINE SANDY LOAM (87)

This is a very minor type in the county, covering only 576 acres or 0.1 percent of the total area of the county. The largest area is found northwest of Camanche
where it occurs on the top of a ridge at the edge of the upland. Smaller areas are mapped in the eastern and southern parts of the county, mainly on the tops of ridges.

The surface brown to light soil to a depth of 4 to 10 inches is a light grayish-brownish very fine sandy loam, loose and friable and in places rather silty. The subsoil is a brown to light-brown or yellowish-brown silty clay loam containing more or less very fine sand to fine sand.

The subsoil is generally stiff and compact. In topography the soil is sharply rolling to gently undulating.

Fig. 16. Surface, subsurface and subsoils of five of the main soil types in Clinton county.


Drainage is good to excessive and erosion occurs to a considerable extent. A variation of this type is found on small ridges in the Clinton silt loam. It is similar to the Memphis very fine sandy loam except for the presence of gravel and pebbles in the surface soil.

Crop yields are not very satisfactory on this soil and proper methods of soil treatment are necessary to make it produce as well as the surrounding silt loam. In the first place erosion must be controlled or prevented after which manure should be applied in as large amounts as practicable and lime and phosphorus fertilizers added if profitable. With these treatments the soil can be made and kept productive.

TERRACE SOILS

There are six terrace soils in Clinton county belonging to the Bremer, Buckner and Calhoun series. Together they cover only a small part of the county, 19,968 acres or 4.6 percent of the total area of the county.
This is the main terrace soil and it covers 15,424 acres or 3.5 percent of the total area of the county. It occurs on terraces along the Mississippi and Wapsipinicon rivers and in a terrace position in Goose Lake Channel where it separates the Wabash silt loam from the uplands. A small area occurs at the east end of Big Beaver island. All the areas of the type are small in extent and it is sometimes difficult to draw definite boundary lines between the type and the bottomland on the one hand and the upland on the other.

The surface soil to a depth of 6 to 12 inches is a dark-gray to black silt loam, generally friable but in places heavy and compact. The subsoil is a black, rather stiff and compact silty clay loam which sometimes grades into a drab to dark-drab silty clay loam to silty clay and is occasionally mottled with rusty brown and yellow. In small areas the subsoil below 10 or 12 inches is a brown, or brown mottled with gray, heavy silt loam becoming mottled gray and brown or gray or drab mottled with brown in the lower depths. These areas are poorly drained. Where drainage is well developed, some areas consist of 8 to 12 inches of a mellow, friable silt loam underlain by a brown, compact silty clay loam.

The topography of this soil is generally flat. The natural drainage is poor and tiling and ditching are necessary in many areas for proper crop production. Much of the land is used for grazing purposes and bluegrass pastures do well. Cultivated crops are largely grown, however, and corn is the chief crop. It yields 40 to 45 bushels per acre on the average. Oats yield 25 to 30 bushels and wheat, 15 to 20 bushels per acre. The small grains tend to lodge and hence are not grown very extensively. Clover and timothy give average yields of 1 to 1½ tons of hay per acre.

The prime need of this soil is for adequate drainage and then the use of lime and possibly also of phosphorus. Applications of manure would also prove profitable altho this soil is not so deficient in organic matter as some of the other types. Phosphorus fertilizers will undoubtedly be needed in the future, if not now. The soil should be tested for acidity at regular intervals and lime applied as necessary.

This is a minor type covering only 1,984 acres or 0.5 percent of the county. The greater part occurs near Camanche on a terrace along the Mississippi. Another area occurs just west of Camanche, adjoining the drift plain.

The surface soil is a dark-brown loamy fine sand about 12 to 20 inches deep. It is underlain by a brown fine sand which is less loamy than the surface material and grades into a light-brown or yellowish-brown fine sand. Gravel is frequently found throughout the type.

There are some small areas along the Wapsipinicon river which are included in this type in which the soil is a sand rather than a fine sand. In these areas which are not separated because of their small extent, the surface soil to 14 to 18 inches is a brown to dark-brown loamy sand. The subsoil is a brown to slightly grayish-brown medium sand, grading at 28 inches into a light-brown or yellowish-brown medium sand. In topography the Buckner fine sand is flat but drainage is good. Crops are sometimes subject to drought.

The soil is well adapted for the growth of watermelons, cantaloupes, straw-
berries and other truck crops. Small areas are used for corn and small grains, chiefly rye. Corn yields 20 to 25 bushels per acre and rye, 12 to 15 bushels per acre.

The needs of this soil are mainly for organic matter, lime and phosphorus. Farm manure should be applied in as large amounts as practicable, leguminous green manures used as a substitute for or supplement to farm manure and all crop residues should be utilized. In this way the soil will be built up in organic matter. It is acid and lime should be applied in amounts shown to be necessary by special tests. Phosphorus fertilizers may be of value now and will certainly be needed in the future. In the case of truck crops, complete commercial fertilizers specially designed for certain crops may often be used with much profit. These should not be employed in large amounts until tests have proven their value.

BUCKNER SANDY LOAM (40)

This is a minor type, occupying only 1,472 acres or 0.3 percent of the total area of the county. It occurs mainly on the terraces southwest of DeWitt along the Wapsipinicon river.

The surface soil is a dark-brown to almost black sandy loam which extends to a depth of 12 to 18 inches. The subsoil is a brown loamy sand which becomes less loamy and a lighter brown in color with increasing depth. It sometimes grades into a yellowish-brown sand at a depth of three feet. A variation of the type occurs on the terraces along the Mississippi and Wapsipinicon rivers. It is a dark-brown, friable sandy loam underlain by a dark-brown loamy fine sand. Areas of this fine sand variation of the main type occur southwest of Elk River Junction and at Folletts. Small areas also occur on Big Beaver Island and near Camanche. The type is flat in topography but the drainage is good and crops do not suffer for moisture except in very dry seasons.

Corn is the chief crop grown, yielding 25 to 30 bushels per acre. Oats yield 25 to 30 bushels and wheat 18 to 20 bushels per acre. On the fine sand variation of the type near Camanche, watermelons, cantaloupes, strawberries and other truck crops are grown. These crops would do well also on the main soil type.

The chief needs of this soil are for organic matter, lime and phosphorus. Farm manure should be used in as large amounts as practicable and supplemented with leguminous green manures. The soil should be tested for acidity and lime applied as necessary. Phosphorus is low and applications of phosphorus fertilizers would probably prove valuable in many cases now and will certainly be necessary in the future. For truck crops complete commercial fertilizers may often be used with profit. Tests should be made with such materials, however, before they are used extensively.

BUCKNER LOAM (38)

This is a very minor type in the county, covering only 512 acres or 0.1 percent of the county. It occurs along the Wapsipinicon and Mississippi rivers in a terrace position. The largest area is west of Camanche.

The surface soil to a depth of 7 to 12 inches is a dark-brown to black loam. It grades generally into a brown to dark-brown heavy loam to clayey loam which at 18 to 20 inches passes into a brown to dark-brown or mottled brown
Fig. 17. Surface, subsurface and subsols of five of the individual soil types of Clinton county.
11. Wabash silty clay loam
12. Calhoun silt loam
13. Muck
14. Carrington fine sand
15. Sarpy silt loam
and gray clay loam, generally quite stiff and compact in structure. Sometimes
this clay loam is absent and the heavy loam continues to a depth of 24 to 28
inches below which the material becomes lighter in texture consisting of brown
sandy loam to loamy sand grading into a yellowish-brown loamy sand at 3 feet.
Gravel is sometimes found throughout the soil. The topography is flat and drainage
is often poor. Tilling and ditching are necessary in several cases.

Corn is the chief crop yielding 30 to 40 bushels per acre on the average. Oats
yield 25 to 30 bushels; wheat, 18 to 20 bushels; and rye, 12 to 16 bushels per
acre. Clover and timothy yield about 1 ton of hay per acre.

The needs of this soil include first drainage, then organic matter as farm
manure or green manures or both, lime and phosphorus. These materials will
increase crop growth and keep the soil permanently fertile.

CALHOUN SILT LOAM (42)

This is another extremely minor soil type in the county covering less than 0.1
percent of the total area of the county. One area occurs along the old channel of
the Wapsipinicon west of Toronto, one, where Mill creek emerges from the up­
land; one, along Elk river; and one north of Lyons.

The surface soil is a dark-brown, dark-grayish brown or gray friable silt loam
from 6 to 10 inches in depth. This is underlain by a compact layer of silt vary­
ing in color from ashy gray to gray or buff, slightly mottled with brown and ex­
tending from 8 to 12 inches in depth. The subsoil is a dark-gray, heavy, comp­
act, stiff silty clay which becomes slightly lighter in the lower part of the 3-foot
section. The areas along Elk river and near Lyons differ somewhat from the
typical. The soil in those places is a dark-gray stiff, heavy, compact silty clay
to silty clay loam. The subsoil is a gray stiff silty clay. Mottlings of red, brown,
yellow and pink occur in the subsoil. The topography of the soil is flat and
drainage is poor.

In the eastern part of the county the soil is forested, the timber consisting
mainly of oak, elm and hickory. West of Toronto, it is being brought under
cultivation. Corn is the chief crop grown, yielding 40 bushels per acre on the
average. The small grains lodge badly.

The needs of this soil are for drainage, organic matter and lime. Phosphorus
fertilizers will also be necessary either now or in the near future.

BREMER SILTY CLAY LOAM (43)

This is a very small type covering only 256 acres or less than 0.1 percent of
the total area of the county. It occurs mainly in two small areas in Goose Lake
channel.

The surface soil is a black, compact, heavy, silty clay loam to a depth of 6 to
10 inches. The subsoil is a black or dark-drab sticky, compact impervious silty
clay loam slightly mottled with rusty brown and grading at 20 inches either
into a drab or gray stiff, compact silty clay loam mottled with brown or yellow
or into a silty clay of the same color. The topography is flat and the type is
poorly drained.

Corn is the main crop grown and yields 45 to 50 bushels per acre. The small
grains lodge badly. Bluegrass does well and the uncultivated areas are used
for pasture.
This soil needs primarily proper tiling and ditching after which good crop yields could be secured. Small applications of farm manure would prove valuable, and lime is necessary to remedy the generally acid condition of the soil. Phosphorus fertilizers will be necessary in the future.

**SWAMP AND BOTTOMLAND SOILS**

There are ten swamp and bottomland soils in Clinton county, together covering 58,240 acres or 13.2 percent of the total area of the county. They belong in the Wabash and Sarpy groups, except for two areas which are classed as Muck and Riverwash respectively.

**WABASH SILT LOAM (26)**

This is the most extensive bottomland soil covering 31,680 acres and together with the colluvial phase occupying 7.8 percent of the total area of the county. Large areas of this soil occur along the Wapsipinicon river in the western part of the county. Large areas are also found along Yankee Run, Brophys and Deer creeks and at the junction of Cherry and Brophys creeks. Smaller areas occur along the Wapsipinicon and Mississippi rivers and other streams.
The surface soil is a dark-brown to dark-grayish brown or almost black silt loam to heavy silt loam, 6 to 12 inches in depth. The subsoil consists of a dark-drab or dark-gray, heavy, compact silt loam, sometimes with a brownish hue and mottled with rusty-brown. At about 16 inches the heavy silt loam grades into a drab to dark-drab silty clay of heavy and compact structure and mottled with rusty-brown. In places at about 28 to 30 inches a mottled silty clay of a gray and brown or gray and yellow color is encountered. In other places a clay loam of a drab color occurs which passes into a loamy sand or sand of a grayish-brown or brownish-gray color and coarse texture. Sand occurs both in the surface soil and subsoil either in pockets or layers. In the higher areas where the drainage is better, the subsoil differs somewhat from the typical. In such places it is a brown, compact silty clay loam, mottled with rusty brown and gray and grades, at 28 inches, into a gray to dark-gray compact silty clay loam. On islands in the Mississippi river and in some areas along that river and along the Wapsipinicon, the soil is really a light phase of the Wabash silt loam. It consists of a gray to light grayish-brown, loose, friable silt loam underlain at 6 to 12 inches by a drab to slightly brownish-gray, heavy silt loam, mottled with
brown and rusty brown, or a gray silty clay loam or silty clay, compact and stiff.

In topography this soil is practically flat. Along the larger streams it is somewhat cut up by old stream channels and depressions. Much of the soil is subject to overflow and the sloughs and depressions retain water for a long period. The drainage is poor and tiling and ditching are sometimes of value. As a rule, however, the type is not high enough above the stream to permit of successful drainage.

A large part of the Wabash silt loam is still forested with elm, sycamore, hard and soft maple, box elder, cottonwood, hickory, oak, blackberry, hawthorn, birch and willow. In such areas the soil is devoted to grazing. Areas above overflow are under cultivation and yield satisfactory crops. Corn is the principal crop grown and average yields of 40 and 50 bushels per acre are secured. Small grains are also grown, but they have a tendency to lodge. Oats yield about 30 bushels per acre on the average; wheat, 20 to 25 bushels; rye, from 15 to 20 bushels per acre; and timothy and clover hay, 1 to 1 1/4 tons per acre. Bluegrass pasture does well on this soil.

The first need of this soil for the best growth of cultivated crops is drainage and protection from overflow. When this is accomplished, good crop yields may be obtained. Small amounts of manure would prove of value in keeping up the organic matter content of the soil. Lime is necessary to remedy the acidity of the soil, and phosphorus fertilizers, while probably unnecessary now, will be needed in the future.

WABASH SILT LOAM (COLLUVIAL PHASE) (26A)

This is a minor soil type in the county covering only 3,008 acres or less than one percent of the total area of the county. It occurs at the heads and along the courses of streams in the loessial upland where the slopes are rather steep. Small areas of it are included in the typical Wabash silt loam.

The surface soil of this type is a light-brown or light-grayish-brown loose, friable silt loam, containing some fine sand. It extends from 8 to 36 inches in depth. The subsoil is a black silt loam, generally heavy and compact in structure or a stiff, compact silty clay loam. There may be a layer of black silt loam, 6 to 12 inches in thickness between the surface soil and the silty clay loam subsoil.

The topography of the soil is flat and like the typical Wabash it is subject to overflow. The drainage is poor. The areas of the phase are small and scattered and it is largely used for grazing purposes.

The needs of this soil when cultivated crops are produced are the same as of the Wabash silt loam with especial emphasis on drainage and protection from overflow.

WABASH SILTY CLAY LOAM (48)

This is the second most extensive bottomland soil, occupying 8,640 acres or 2.0 percent of the total area of the county. The largest areas of this type are mapped along the Mississippi river, as islands in that river and in the Goose Lake channel. Small areas occur in the bottoms of the Wapsipinicon river and along the larger creeks. Several rather extensive areas are found south of Lost Nation.

The surface soil, from 6 to 15 inches in depth, is a black to dark-grayish-brown silty clay loam, usually compact and heavy in structure tho sometimes friable.
In the former condition it is locally known as "gumbo." The subsoil is a dark-drab to almost black silty clay loam, becoming drab or gray in color at 24 inches. In some small areas, at 28 inches there is a layer of mottled gray and yellow tough, compact, impervious silty clay. At other places the subsoil consists of alternate layers of mottled gray and rusty brown fine sandy clay to clay loam and of the typical subsoil material. Below 28 inches, the heavy subsoil sometimes grades into a loam or sandy loam. Pockets and layers of sand are common both in the surface soil and subsoil. A light variation of the type occurs along the Mississippi river and on islands in that river. In such places the surface soil is a dark-gray, plastic, silty clay loam to a depth of 7 or 10 inches. The subsoil is a dark-gray to gray silty clay loam to silty clay, more or less mottled with brown.

The topography of this soil is flat and the drainage is poor. Along the larger streams it is somewhat cut up by sloughs and old drainage channels. It is subject to overflow and is very difficult to drain owing to the heavy character of the soil. Ditching and tiling have been successfully accomplished in some cases but ordinarily the soil is so close to the stream level that little drainage takes place.

The greater part of the type is forested and used for pasturage. The timber growth consists mainly of oak, elm, sycamore, soft maple, birch, cottonwood and willow with some hard maple, hickory, box elder, scarlet hawthorn, and hackberry. Areas above overflow and those in the Goose Lake channel are used for cultivated crops. Corn averages 40 bushels per acre; wheat, 20 to 24 bushels; and oats about 30 bushels per acre. Hay yields 1 to 1 1/4 tons per acre. Bluegrass does well on this type and makes good pasturage.

The needs of this soil for the best growth of cultivated crops are for drainage and protection from overflow. The soil is difficult to cultivate, like all "gumbo." The treatments recommended in the previous section of this report for "gumbo" soils apply to this type especially drainage and fall plowing. Lime and manure would prove of value and phosphorus fertilizers will be necessary in the future for permanent fertility.

**SARPY SILT LOAM (89)**

This is a minor soil type in the county covering only 5,504 acres or 1.2 percent of the total area of the county. It occurs in areas of considerable extent in the bottoms of the Wapsipinicon river.

The surface soil of this type is variable. In general it is a dark-brown to black and ranges from a silt loam to a heavy silt loam. It is 8 to 10 inches in depth, grading into a brown to dark-brown heavy silt loam, or a silty clay loam of the same color, mottled with rusty brown. At about 15 inches this passes into a brown heavy loam, or clay loam which grades into a sandy loam or loamy sand, of a distinctly brown or tan color. Generally the sandy material grades into a rusty-brown or grayish-brown to brownish-gray sand. A coarse sand sometimes occurs at about three feet. In some areas at 10 inches, the surface soil grades into a sandy loam of a dark-brown or brown color. This in turn changes to a rusty brown or grayish-brown loamy sand which becomes a brownish-gray sand to coarse sand at 3 feet. In a few instances the soil grades directly into a medium or coarse sand of a brownish-gray color.
Fig. 20. Surface, subsurface and subsoils of four of the individual soil types in Clinton county

26. Muscatine silt loam 27. Sarpy sandy loam
28. Memphis very fine sandy loam 29. Buckner fine sand

The topography of this soil is flat with a gentle slope toward the streams. It is subject to overflow and the character of the soil changes with each overflow. Sand patches are scattered along the streams. Where the sandy subsoil is close to the surface, drainage is apt to be excessive and in other areas where the subsoil is heavy, drainage is poor.

A large part of the type is still timbered and used for grazing. Corn, wheat, rye, oats and hay are grown on the small portion which is cultivated. Corn yields 30 to 40 bushels per acre on the average; wheat, 18 to 22 bushels; oats, 25 to 30 bushels; rye, 15 to 18 bushels; and hay, 3/4 to 11/4 tons per acre.

The needs of the soil when it can be used for cropping purposes are for protection from overflow and, in some cases, for drainage. Manure would be of value, lime is necessary and phosphorus fertilizers will be needed in the future altho they are probably unnecessary now.

**WABASH SILTY CLAY (27)**

This is a minor type in the county covering only 2,432 acres, or 0.6 percent of the total area of the county. It occurs in depressions in the first bottoms of the Wapsipinicon and Mississippi rivers, on the islands in the Mississippi, and in
Goose Lake channel adjoining the former bed of Goose Lake. The largest area occurs on Big Beaver Island.

The surface soil is a gray to dark-gray heavy, tough, impervious silty clay from 6 to 10 inches in depth, sometimes of a brownish tinge or mottled with brown. The subsoil, to a depth of 36 inches or more, is a gray to drab silty clay similar to the surface soil. It is mottled with brown and yellow. When wet the soil is sticky and plastic but on drying it becomes hard and cracks. It is locally known as “gumbo.” In a part of the area near the Wapsipinicon south of Shaffton the soil is almost black, grading through dark-drab into the typical subsoil, which passes into a silty clay loam or clay loam.

The type is subject to overflow and it is not utilized for agriculture. It has no value except for pasture. In forested areas, the growth is mainly swamp, white oak, birch, soft and hard maple, willow, box elder and elm.

MUCK (21A)

Muck occurs to a small extent in Clinton county covering 2,304 acres or 0.5 percent of the county. It is found in depressions and along drainage ways in the drift area and also in the bottoms of old lakes, which existed in the Goose Lake channel west of Goose Lake. The largest areas are near Calamus and Lost Nation. Smaller areas occur at the heads of and adjacent to the minor drainageways of the county. Two kinds of muck are distinguished, the shallow and the deep but they are not mapped separately. A large area of the deep material is in the bed of the larger lake west of the village of Goose Lake.

The shallow deposit consists of 6 to 18 inches of a black, finely divided muck which grades into a subsoil of black or dark-drab to drab silty clay loam or silty clay. The subsoil is stiff, compact and impervious and is sometimes mottled with rusty brown. In places a layer of black peat occurs between the surface soil and the subsoil. The deep muck consists of 8 to 15 inches of black well decomposed organic matter grading into peat which may continue thru the three-foot section. The deep areas are usually found in the center of the shallow areas. Some very small areas of typical peat are found but they are not mapped separately.

This soil is generally wet and boggy and is poorly drained. When tiled and drained, corn is grown successfully on it. The treatments necessary to make this material productive have been discussed in another bulletin¹ and if the recommendations made there are followed, good crop yields may be secured on muck even sooner than on typical peat.

WABASH LOAM (49)

This is a minor type in the county covering 1,728 acres or 0.4 percent of the total area of the county. The greater part of the type occurs in the bottoms of the Wapsipinicon river south of Lost Nation. Only one area occurring just north of Camanche is mapped in the Mississippi river bottoms.

The surface soil to a depth of 8 to 12 inches is a dark-brown to black loam. The subsoil is a dark-drab to dark-gray silty clay loam or clay loam, mottled with rusty brown. It is usually compact but occasionally quite plastic. At about 26 inches, this grades into a gray compact silty clay loam or clay loam also mottled with rusty brown. Pockets and layers of sand are common. The higher-

lying areas have a typical surface soil but the subsoil below 8 to 10 inches is a brown silty clay loam to clay loam, stiff and compact and mottled with gray and rusty brown. This grades at 28 to 30 inches into a gray to dark-gray silty clay loam. In the soil near Camanche, there is some variation from the typical. Below 8 inches the material is a dark-brown clay loam which grades into a reddish-brown clay loam.

The topography of the soil is flat with only a slight slope toward the streams and the natural drainage is poor. Tiling and ditching are difficult as the soil is so nearly at the level of the streams.

The greater part of the type lies above ordinary overflow and is used for crop production. The remainder is forested and used for pastures. In the cultivated areas, corn is the chief crop and some wheat, oats and rye are grown. Corn yields 35 to 45 bushels; wheat, 20 to 25 bushels; oats, 25 to 30 bushels; and rye, 15 to 20 bushels. Clover and timothy hay yield \( \frac{3}{4} \) to \( \frac{11}{4} \) tons per acre.

The needs of the soil for the best crop production include the use of organic matter such as farm manure or leguminous green manures and the application of lime and of phosphorus fertilizers either now or in the near future. These treatments should follow proper drainage and protection from overflow.

SAPPY SANDY LOAM (90)

This is a minor type in the county covering 1,664 acres or 0.4 percent of the county. It occurs in small scattered areas in the first bottoms of the Wapsipinicon and Mississippi rivers.

The surface soil to a depth of 8 to 12 inches consists of a dark grayish-brown, dark-brown or brown, friable sandy loam. The subsoil consists of a brown loamy sand of medium or fine texture, which grades into a grayish-brown to brownish-gray sand or fine sand. In some cases the soil contains much coarse material and in others it grades directly into a grayish-brown to brownish-gray coarse sand. Sometimes the brown fine sand continues thru the three-foot section in which case, there is a gradation, at 30 to 40 inches, into a light-brown or yellowish-brown fine sand. A few areas of dark-grayish-brown coarse sandy loam with a subsoil of grayish-brown to brownish-gray coarse sand are included with this type, on account of their small extent. Southwest of Calamus there is a small-sized area where the soil material is a gray to dark-gray loamy fine sand 8 to 10 inches in depth. This grades into a dull-white loamy sand of medium texture, at about 18 inches. There are small areas of Sarpy sand included in this type. The surface soil of these areas is a brown to rather dark-brown sand which continues throughout the three-foot section. The soil is flat and subject to overflow. Drainage is good.

The type has little agricultural value but is mainly forested and used for grazing purposes. When cultivated it gives poor yields. The needs of the soil are for protection from overflow and for the application of manure in as large quantities as practicable, the use of lime and eventually the addition of phosphorus.

SARPY LOAM (91)

This soil is of minor importance in the county covering only 832 acres or 0.2 percent of the total area of the county. It occurs in small areas scattered along the Wapsipinicon river.
The surface soil is a dark-brown to nearly black loam containing some sand and extends to a depth of 6 to 12 inches. The subsoil is a loamy sand, brown to grayish-brown in color. With increasing depth the soil material becomes more of a gray in color and more sandy in texture. A heavy variation of the type occurs in areas too small to map. There it consists of black silty clay loam to clay loam in places mottled with rusty brown. The subsoil is a grayish-brown to brownish-gray sand to coarse sand. A layer sometimes occurs between the surface soil and subsoil in which the soil is a dark-brown clay loam which grades into a loam and sandy loam, brown in color. In depressed areas, old slough bottoms and small drainageways the soil is more nearly a silty clay or clay and is tough, compact and tenacious.

In topography the Sarpy loam and the variation described are both flat. In the Sarpy itself the drainage is good but in the heavy variation, drainage is necessary and tiling and ditching must be practiced if the soil is to be used for cultivated crops. At present it is forested and used principally for pasture. Its location is such that it is doubtful whether the growth of cultivated crops is worth attempting. Of the true Sarpy loam only a small part is under cultivation, the remainder being in forests and used for pasture. Corn and rye are the principal crops grown, corn yielding 20 to 25 bushels per acre and rye 10 to 15 bushels per acre. Crops are apt to suffer from drought.

The needs of this soil include first of all protection from overflow. It is low in organic matter and manure in large amounts would make the soil richer, more retentive of moisture and hence more productive. Lime is necessary and phosphorus fertilizers will be needed in the future if not now.

RIVERWASH (53)

This material includes the sand-bar islands, and sand banks of the Mississippi and Wapsipinicon rivers and areas along the old channels in the flood plains of those streams. It represents recently deposited alluvial material and is composed mainly of grayish-brown to brownish-gray loose sand. In some cases layers of black silty and clayey material occur between the sand layers. A growth of willows and weeds is supported by some of this material, the remainder being bare and changed constantly in character by the action of the streams.

RESIDUAL SOILS

There is one residual soil in Clinton county, the Union stony loam. It covers only 576 acres or 0.1 percent of the total area of the county.

UNION STONY LOAM (73)

This soil occurs mainly in the northern part of the county. The greater part adjoins streams or occurs on the bluffs where the uplands meet the bottoms. It is made up of areas where the drift and loess have been removed exposing the underlying limestone. Sometimes a layer of surface soil, composed of a brown to dark-brown sandy material from 2 to 4 inches in thickness occurs. Fragments of limestone are scattered throughout the soil. In topography it is level to sloping; in some places becoming sharply sloping. It has no agricultural value.
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 potassium 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
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>111</td>
<td>17.25</td>
<td>53</td>
<td>6.81</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>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td>5.28</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>48.5</td>
<td>8</td>
<td>34</td>
<td>3.68</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>32.5</td>
<td>6</td>
<td>18.5</td>
<td>4.70</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>41.4</td>
<td>9</td>
<td>28.8</td>
<td>10.08</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>7 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</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 constituents 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 amounts 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
hindered or stopped and crops may suffer. The use of legumes in rotations is of particular
desire since when they are well inoculated and turned under they not only supply organic mat-
ter 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 use of such crops to the soil. In no other way can
the humus and nitrogen content of soils be ekpt 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 satis-
factory 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 nitro-
gen 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 phos-
phorus 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, there­
fore, 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 resi-
dues. 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 pecu-
liarity 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 atmos-
pheric 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.
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, although 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 cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical 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.
- **Inorganic Matter**
  - 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 silt.
- **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 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.
- **Silt 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.