Soil Survey of Iowa, Report No. 3—Muscatine County

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SOIL SURVEY OF IOWA

Report No. 3—MUSCATINE COUNTY

By W. H. Stevenson, P. E. Brown and H. W. Johnson

One of Muscatine county's soil types—Wabash silty clay
CONTENTS

Introduction .................................................................................................................. 3
General farm crops of Muscatine county............................................................... 4
Truck crops in Muscatine county......................................................................... 5
Live stock industry.................................................................................................. 6
Geology of Muscatine county............................................................................... 7
Physiography and drainage.................................................................................... 8
Soils of Muscatine county...................................................................................... 11
Fertility of Muscatine county soils...................................................................... 12
  The surface soils ............................................................................................... 12
  The subsurface soils and subsoils .................................................................. 17
Greenhouse experiments...................................................................................... 18
Field experiments with gumbo............................................................................ 20
Needs of Muscatine county soils indicated by laboratory and greenhouse tests 22
  Lime .................................................................................................................. 22
  Manuring .......................................................................................................... 23
  Use of commercial fertilizers ......................................................................... 25
  Drainage ........................................................................................................... 26
  Crop rotations .................................................................................................. 27
Prevention of erosion............................................................................................ 28
  Dead furrows ................................................................................................... 29
  Small gullies ...................................................................................................... 29
  Large gullies ...................................................................................................... 31
  Bottomlands...................................................................................................... 31
  Hillside erosion ............................................................................................... 32
Individual soil types in Muscatine county............................................................. 33
  Loess soils ......................................................................................................... 33
  Terrace soils ...................................................................................................... 42
  Swamp and bottomland soils ......................................................................... 51
Appendix: The soil survey of Iowa .................................................................... 55
MUSCATINE COUNTY SOILS

By W. H. Stevenson, P. E. Brown and H. W. Johnson

Muscataine county is situated in the southeastern part of Iowa along the Mississippi river and includes an area of 432 square miles or 276,480 acres. The county is almost rectangular in shape, with the exception of the irregular boundary on the southeast made by the Mississippi river. To the influence of this river is due the great variety in soil types and the wide range of soil conditions which make the study of the soils of the county of much importance.

The county is located within the large soil area known as the Mississippi loess and its principal types are of loessial origin. There are also numerous terrace and swamp and bottomland soils which are largely composites from various sources.

Of the total area of Muscataine county, 239,791 acres, or 86.7 per cent, is in farms. This total farm acreage is divided among 1,500 farms averaging 154 acres.

The following figures from the report of the state department of agriculture in 1915 show roughly the utilization of the farm land of the county:

<table>
<thead>
<tr>
<th>Description</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in pasture</td>
<td>90,500</td>
</tr>
<tr>
<td>Acreage in farm buildings, feed lots and public highways</td>
<td>8,412</td>
</tr>
<tr>
<td>Acreage in orchards</td>
<td>861</td>
</tr>
<tr>
<td>Acreage in gardens</td>
<td>3,510</td>
</tr>
<tr>
<td>Acreage in waste land</td>
<td>2,033</td>
</tr>
<tr>
<td>Acreage in general farm crops</td>
<td>139,510</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>5,230</td>
</tr>
</tbody>
</table>

As the above figures indicate, the agriculture of Muscataine county is largely livestock farming. The raising and feeding of beef cattle and hogs are important industries.

Dairying is growing in importance while sheep raising has decreased. General farming is followed to some extent and truck farming has become very important on Muscataine island and in a small area north and east of Muscataine.

Methods of soil treatment and systems of permanent fertility suitable for livestock and general farming do not apply to truck farming and special studies of individual soil types adapted to truck crops are necessary. While specific experimental work dealing with truck crops has not been carried out in Muscataine county, general recommendations for the treatment of particular soils adapted to truck crops may be given. Information regarding truck crops may be secured from the Truck Crops section of the Iowa Agricultural Experiment Station.

Rather a large acreage in this county is in waste land and methods of reclaiming it should be considered. General recommendations for making waste land productive cannot be made on account of variable field conditions. Treatments must be suited to the particular conditions and suggestions can be given only for individual cases.

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1 See Soil Survey of Muscataine County, Iowa, by H. W. Hawker of the U. S. Dept. of Agriculture and H. W. Johnson of the Iowa Agricultural Experiment Station.
THE GENERAL FARM CROPS OF MUSCATINE COUNTY

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

Corn has always been the chief crop of the county and the yields are usually satisfactory. The value of this crop is more than that of all others combined. Comparatively little of the corn produced is shipped out of the county; it is largely used in the raising and fattening of beef cattle and hogs and much of it is put up in silos for winter feeding.

Hay is the second crop in acreage and in value. It is mostly tame hay, there being only a very small production of wild hay. Timothy alone is used on about one-half the total hay acreage and timothy and clover mixed are grown on the remaining area, except for a comparatively small acreage devoted to clover alone. Both corn and hay do well on practically all the soils of the county although they are better suited to the upland types. In many cases applications of lime are necessary to remedy acidity in the soil before clover can be grown successfully. Alfalfa, rape and millet are grown on small areas in the county while cowpeas are popular on light soils, and give very good yields on the average.

Oats stand next to hay in acreage and value. The yields are generally satisfactory except on the light soils of Muscatine island although difficulty is sometimes experienced by the lodging of the rank growth on the heavier soils. Very little oats is shipped out of the county, the crop being used for feeding purposes.

Barley is an important crop in Fulton and Wilton townships and it is grown to some extent in other parts of the county. The yields depend on the seasonal conditions and are not always satisfactory. It is very largely used for seed and feed; only a part of the crop is shipped out of the county.

Winter wheat shows uniformly satisfactory yields except on the very light soils while spring wheat is grown only to a very small extent.

Potatoes are the next crop in value although the acreage is smaller than that devoted to rye. They are grown commercially principally in Fulton and Sweetland townships and the yields are very satisfactory.

Rye is grown throughout the county but in most cases the yields are rather low. This crop is mainly used on sandy soils in rotation with melons.

### TABLE I. AVERAGE YIELDS AND VALUES OF THE GENERAL FARM CROPS GROWN IN MUSCATINE COUNTY*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>% of total farm land in county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons per acre</th>
<th>Average Price</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>75,700</td>
<td>31.5</td>
<td>35</td>
<td>2,649,000</td>
<td>$0.45</td>
<td>$1,192,050</td>
</tr>
<tr>
<td>Oats</td>
<td>21,000</td>
<td>8.7</td>
<td>39</td>
<td>819,000</td>
<td>$0.32</td>
<td>262,080</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>370</td>
<td>0.1</td>
<td>16</td>
<td>5,900</td>
<td>$0.83</td>
<td>4,897</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>3,700</td>
<td>1.5</td>
<td>21</td>
<td>77,700</td>
<td>$0.85</td>
<td>66,045</td>
</tr>
<tr>
<td>Barley</td>
<td>6,250</td>
<td>2.6</td>
<td>32</td>
<td>200,000</td>
<td>$0.51</td>
<td>102,000</td>
</tr>
<tr>
<td>Rye</td>
<td>2,800</td>
<td>1.1</td>
<td>18</td>
<td>50,400</td>
<td>$0.77</td>
<td>38,808</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,100</td>
<td>0.4</td>
<td>109</td>
<td>119,900</td>
<td>$0.55</td>
<td>63,547</td>
</tr>
<tr>
<td>Tame hay</td>
<td>27,500</td>
<td>11.4</td>
<td>1.5</td>
<td>41,300</td>
<td>$8.94</td>
<td>368,328</td>
</tr>
<tr>
<td>Wild hay</td>
<td>750</td>
<td>0.3</td>
<td>1.2</td>
<td>900</td>
<td>$7.41</td>
<td>6,669</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>340</td>
<td>0.1</td>
<td>3.3</td>
<td>1,100</td>
<td>$11.18</td>
<td>12,298</td>
</tr>
<tr>
<td>Pasture</td>
<td>90,500</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

* Iowa Year Book of Agriculture, 1915.
MUSCATINE COUNTY SOILS

TRUCK CROPS IN MUSCATINE COUNTY

The sandy soils of Muscatine island* and in the vicinity of Moscow and Conesville are especially adapted to the growth of truck crops. Trucking has always been the chief industry on these light soils, but the crops grown recently have been different from those which were formerly of chief importance. Tomatoes and cabbage were grown extensively up to 1905 but the losses thru drouth and fungus diseases brought about to a large extent the use of other crops in their stead. Watermelons, cantaloupes, sweet potatoes and asparagus are the chief crops grown at the present time. The average yield of watermelons is from one-fourth to one-half carload per acre and the yield of cantaloupes is about the same. The latter crop is grown mainly on Muscatine island while the watermelons are grown in the Conesville district as well. The larger yields of both these crops are obtained in seasons of well-distributed rainfall and where irrigation is practiced. The distribution of the moisture during the growing season governs very largely the quality and flavor of both cantaloupes and watermelons.

The total yield of melons can only be approximated as it includes not only the amounts shipped out of the county but also those sold at local markets, those used for seed and those remaining on the ground at the close of the season. In 1914 there were shipments of 956 carloads of melons, including both cantaloupes and watermelons. Of these, 752 carloads were shipped from Conesville, 198 from Muscatine island and 6 from Moscow. The yield in that season from Muscatine island was low, owing to drouthy conditions. In good seasons the shipments equal those from Conesville. It has been estimated that 60 to 75 per cent of the total output is shipped to outside markets where their superior quality has led to separate quotations for "Muscatine melons."

Sweet potatoes are grown in considerable amounts on Muscatine island where the soils seem to be especially suited to this crop, the sands being better than the sandy loams. The yields range from 75 to 125 bushels per acre, the best crops being secured in seasons when the moisture conditions are the most satisfactory or where irrigation is practiced. Over one thousand acres in Muscatine county are devoted to this crop and over 90 per cent of this acreage is on Muscatine island.

Asparagus is grown on between 200 and 300 acres on Muscatine island and on the average 20 5-inch cuttings are obtained during the season of six weeks, beginning about April 1. This asparagus is claimed to be less fibrous and of better quality than the California product and is mainly sold to local canneries.

Cabbage, tomatoes, onions and cucumbers are grown to a smaller extent than the crops just mentioned and are used chiefly in the local canning and pickling establishments. About 1200 acres are devoted to cabbage and the yields average 8 to 10 tons per acre. The continuous growth of this crop has led to diseased conditions which have cut down the yields considerably and brought about the use of other crops to some extent. The rotation of crops will prevent this difficulty. Tomatoes are grown on about 1,000 acres of the county and the yield is about 8 to 10 tons per acre. They are also subject to disease when grown continuously and should be rotated with some other crop. Onions yield about 400 bushels per acre and cucumbers average 200 to 250 bushels per acre.

* See Bureau of Soils Report on Muscatine County.
acre. These crops (cabbage, tomatoes, onions and cucumbers) are grown mainly on the area north and east of Muscatine although they all do well on heavier soils than the chief trucks crops.

Pumpkins are being grown to a larger extent in recent years and yield 18 to 25 tons per acre. They are used in local canneries. Sweet corn is also grown to a small extent for canning purposes.

Orcharding is of minor importance in Muscatine county altho there are several commercial orchards. Apples, cherries, pears, plums and peaches are grown on many farms, largely for home consumption and the yields are quite satisfactory. Strawberries are also of considerable importance commercially, the average yield being about 2,000 to 3,500 quarts per acre.

**THE LIVESTOCK INDUSTRY**

Cattle and hog raising are the chief livestock industries, altho in some sections sheep raising is also practiced. Dairying is still of minor importance altho interest in it is increasing and in some townships it bids fair to become the leading industry.

The present extent of the livestock industry is shown in the following figures compiled in 1915:-

<table>
<thead>
<tr>
<th>Livestock Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses (all ages)</td>
<td>10,726</td>
</tr>
<tr>
<td>Mules (all ages)</td>
<td>593</td>
</tr>
<tr>
<td>Swine (July 1, 1915)</td>
<td>81,202</td>
</tr>
<tr>
<td>Cattle (cows and heifers kept for milk)</td>
<td>7,777</td>
</tr>
<tr>
<td>Cattle (other cattle not kept for milk)</td>
<td>17,373</td>
</tr>
<tr>
<td>Cattle (total, all ages)</td>
<td>29,161</td>
</tr>
<tr>
<td>Sheep (all ages on farms)</td>
<td>1,193</td>
</tr>
<tr>
<td>Sheep (shipped in for feeding)</td>
<td>1,090</td>
</tr>
<tr>
<td>Sheep (total pounds of wool clipped)</td>
<td>9,342</td>
</tr>
</tbody>
</table>

The value of land in Muscatine county is extremely variable on account of the wide differences in the character of the soils and in the crop adaptations. The average value has been estimated at $92.45 per acre. Even the poorer sandy bottomland soils are valuable because of their adaptation to truck crops which are extremely profitable, while the upland soils are as valuable as any in the state and when properly handled can be made fully as productive.

The yields of most crops in the county are quite satisfactory but in many cases they can be increased by proper methods of soil treatment. Acid soils are common and the use of lime would prove of benefit, particularly for clover and other legumes. Drainage is necessary on many soils, while in the case of truck crops irrigation is often of value. Organic matter is lacking in many of the soils and the use of farm manure or the turning under of green manure crops would prove very profitable. Complete commercial fertilizers are not used to any extent in the county and cannot be recommended except for truck crops. On the heavier upland soils, used for general farming purposes, phosphorus fertilizers might prove profitable at the present time and will undoubtedly be necessary in the future. Special brands of commercial fertilizers may be used to advantage in truck crop growing, but they should be carefully selected and tested to show their value for each individual crop, before being used on large areas. Crop rotations should always be followed and especially is this true in the growing of truck crops as it will tend to eliminate plant diseases.
THE GEOLOGY OF MUSCATINE COUNTY *

In Muscatine county the bed-rock of preglacial formation is buried so deeply under the drift material deposited by the successive ice sheets which invaded the county that its effect on present soil conditions is practically negligible. Attention will, therefore, be directed primarily to the glacial drift material and its surface covering of loess, which together constitute the soils of the county.

At two different times during the glacial period, Muscatine county was covered by extensive ice invasions which upon their retreat left vast accumulations of drift material. This glacial drift or "till", as it is called, is exceedingly complex in character and variable in composition. The glaciers carried rocks and other materials from the areas over which they passed and later deposited them. Thus, limestones, sandstones, shales, and many other rocks occurring far to the north of Muscatine county are represented in the drift layer left by the glacier. It consists of a mass of clay, silt, sand and rock fragments of various sizes and is generally a loam or clay except in a few instances, where it is sandy in character. The color of this material usually varies from yellow-to reddish-yellow or red.

With exception of the bottomlands and some sandy areas on the West Liberty plain and on the west slope of the Illinoisan drift plain, the drift material is invariably covered with loess. Loess is generally considered to be of atmospheric origin, its fine dust-like material having been deposited from the atmosphere at some previous geological period when conditions were quite different than at present. It varies in thickness from a few feet on some terraces and on the West Liberty plain to 40 feet on the bluffs at Muscatine. The average

* J. A. Udden: Geology of Muscatine County, Iowa, Iowa Geological Report, Vol. IX.
depth on the uplands is about 10 feet, while along the bluffs of the Mississippi it varies from 15 to 25 feet.

The loess is of fine, smooth texture and includes six types in Muscatine county, three silt loams, a silty clay loam, a fine sandy loam, and a fine sand. These types together make up over 60 per cent of the area of the county, the remaining part being covered by terrace soils and swamp and bottomland soils. These latter have been formed in Muscatine county according to the usual method thru the agency of the streams, and are composed of drift, loess and alluvium in various mixtures. The drift proper is not exposed anywhere in the county to a sufficient extent to be mapped, and it becomes of interest only when the subsoil characteristics are considered in areas having thin loess coverings. In such cases the effect of the drift on the fertility of the soil may be important.

**PHYSIOGRAPHY AND DRAINAGE**

The main topographic features of Muscatine county are two upland and two lowland areas roughly forming four curving belts extending from the northeast to the southwest. The Mississippi bottoms, including a narrow strip of land along the Mississippi river east of Muscatine and Muscatine island, and the West Liberty plain are the two lowlands, and the two uplands have been called the Illinoisan and the Kansan drift plains. The map shows these four areas and their drainage.

The Mississippi bottom just above Muscatine range from one-quarter to one-half mile in width. They form a low slope, subject to overflow in places but rising rapidly toward the bluffs and bringing the soil above the high water level. Near Muscatine the bottomlands broaden considerably, forming Muscatine island. This is separated from the bluffs by Muscatine slough, which widens out to form Lake Keokuk. The elevation of the island is 546 feet.

The West Liberty plain is a broad valley, extending diagonally across the county from northeast to southwest. Its elevation on the northeast is 663 feet and at the south but 615 feet. The upland near Atalissa merges gradually into the plain. It is bounded on the east by the Cedar river, on the west by bluffs 80 to 100 feet in height and on the north by less abrupt bluffs. The chief topographic features of this plain are formed by the streams. The Cedar river has formed bottomland 25 to 30 feet below the level of the plain and the river valley on the east side partly coincides with the bluffs, while in places strips of the plain as much as a mile in width extend like terraces along the upland bluffs. On the west the encroachments of the river in past times have left curving areas of the plain facing the river. The Wapsinonoe river has formed a rather inconspicuous valley west of the Cedar. It is seldom more than 15 feet deep and generally flat and open.

The bottomlands of both these lowland areas are poorly drained and the ground water maintains a level rather near the surface.

The Illinoisan drift plain consists of a sheet of loess covering the Illinoisan drift. It comprises the entire east end of the county and has an average elevation of 725 feet. It has a flat central portion, sloping gently toward either margin. Toward the southeast the upland is largely marked by creeks and ravines, the latter in some places having a depth of 125 to 150 feet below
Fig. 2. Natural drainage system of Muscatine county; the broken lines indicate intermittent drainage.
Fig. 3. A typical Memphis silt loam topography, north of Muscatine and two miles east of Spangler Chapel, looking north
the level. Proceeding northward the streams become less deep and the ravines are less extensive and have comparatively narrow valleys. In the northwest slope of the plain the streams occupy wide, shallow depressions in the upland, the valleys rarely reaching a depth of more than 60 to 70 feet. South of Musketo creek these depressions become the chief feature of the landscape and near the bluffs of the Cedar river they unite with a marginal ridge which follows the bluffs and rises in places 20 to 30 feet above the upland. There are also some dune-like hills and some isolated ridges.

The Kansan drift plain is a sheet of sand and loess covering the Kansan drift. It is divided by the Wapsinonoc creek into an eastern part, sloping to the south, and a western part, sloping to the southeast. The average elevation is 700 feet. With the exception of one small area the plain is cut by streams with wide, open valleys and along the Big Slough and near West Liberty there are indications of terraces at 30 to 60 feet elevations above the lowland. This drift plain is everywhere well drained by streams from the north and west thru valleys which extend out thru the West Liberty plain. The Big Slough has a wide bottomland and a very gradual fall.

The West Liberty plain is very poorly drained as there are many shallow depressions which retain the water. In the western part some extensive peat bogs have been drained by ditches but the slope is generally so slight that the water is removed very slowly and natural channels have not been produced.

The Cedar bottoms are poorly drained and are characterized by frequent lagoons and swamps. Nearly all the drainage of the Illinoisan drift plain belongs to the basin of the Cedar river. Just inside the Cedar bluffs, small undrained ponds are common, but further away from the river the drainage is good. The land nearest the streams is low and flat, rising further away into wide uplands which separate the basins of the streams. Toward the north some creeks occupy deeper and narrower flat bottoms which are now meadow land while the upland is generally a level plain with occasional shallow, undrained ponds and basins. The slope to the Mississippi has an almost perfect drainage and there are practically no undrained depressions except near the bluffs around Muscatine.

In general the uplands or plain areas are fairly well drained except for small areas, while the lowland or bottomland plains are very poorly drained.

THE SOILS OF MUSCATINE COUNTY

The soils of Muscatine county may be classed in three large groups: Loess soils, terrace soils and swamp and bottomland soils. There are no drift soils in the county, as the drift deposits have all been more or less deeply buried by the loess. Neither are any residual soils to be found. The areas of the different groups are given in table II.

<table>
<thead>
<tr>
<th>TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN MUSCATINE COUNTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Loess soils</td>
</tr>
<tr>
<td>Terrace soils</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
Over 60 per cent of the total area of the county is covered by the loess soils. These are somewhat variable both in color and composition but they belong in the large group of Mississippi loess soils. The terrace soils, or accumulations of drift and alluvial materials deposited on the banks of streams and later raised above the flood plains of the present rivers by deepening of the river channels, are of second importance in Muscatine county and cover 23 per cent of the total area. Those soils bordering on the streams and subject to overflow by the rivers during flood seasons are known as swamp and bottomland soils and cover over 12 per cent of the area of the county. They are largely composed of alluvial material and therefore complex in composition and usually badly in need of drainage.

The swamp and bottomland soils in Muscatine county are all level and the terrace soils, with three exceptions which vary from level to rolling, are likewise level. The loess soils are more variable, being generally rolling or level to rolling. There are 29 distinct soil types in Muscatine county, including the relatively unimportant riverwash, muck and marsh soils. Six are loess soils, 12 are terrace soils and the remaining 11 are classed as swamp and bottomland soils. Table III gives the extent of these individual soil types in acres and in per cent of the total area of the county.

Two of the loess soils, the Muscatine silt loam and the Memphis silt loam, are the chief soil types in the county. Together they cover over 56 per cent of the area of the county, the former occupying over 37 per cent and the latter over 19 per cent of the total area. No other soil type even approaches these in importance although one terrace soil, the Buckner silt loam is third in area, covering over 6 per cent of the county. The remainder of the soils are of small extent, ranging from a fraction to a small per cent of the area of the county.

THE FERTILITY OF MUSCATINE COUNTY SOILS

Of the 29 types of soil represented in Muscatine county 23 were studied for their plant food content. Three samples of each of the principal types and one of each of minor types were secured with the usual care, at three depths, from 0 to 6 inches, representing the surface soil, from 6 to 20 inches representing the subsurface soil, and from 20 to 40 inches representing the subsoil. Total phosphorus, nitrogen, organic carbon and inorganic carbon and limestone requirement were determined by the official methods, the Veitch method being employed for the lime requirement determination. The results of these analyses appear in tables IV, V, and VI. In the cases of the major soil types the figures are the average of several analyses and all the results are calculated on the basis of pounds per acre of 2,000,000 pounds of surface soil.

THE SURFACE SOILS

There is wide variation in the composition of the soil types of Muscatine county. The difference between the types within one large group is frequently greater than between types in different groups, a fact preventing any far-reaching comparisons between the soils of the large classes. By comparing the average composition of all the soils in the various groups, however, the loess soils are found to be somewhat lower in total phosphorus, in total nitrogen and in organic carbon, although the differences are not great. In lime requirement, on
### Table III. Areas of Different Soil Types

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Acres</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>102,912</td>
<td>37.2</td>
</tr>
<tr>
<td>31</td>
<td>Memphis silt loam</td>
<td>54,592</td>
<td>19.7</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>9,344</td>
<td>3.4</td>
</tr>
<tr>
<td>33</td>
<td>Knox fine sand</td>
<td>7,808</td>
<td>2.8</td>
</tr>
<tr>
<td>34</td>
<td>Muscatine silty clay loam</td>
<td>3,468</td>
<td>1.3</td>
</tr>
<tr>
<td>35</td>
<td>Knox fine sandy loam</td>
<td>448</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Buckner silt loam</td>
<td>17,600</td>
<td>7.5</td>
</tr>
<tr>
<td>37</td>
<td>Buckner silt loam (Colluvial phase)</td>
<td>3,072</td>
<td>7.5</td>
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<td>Buckner coarse sand</td>
<td>6,720</td>
<td>2.4</td>
</tr>
<tr>
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<td>Buckner sandy loam</td>
<td>6,720</td>
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<td>3,456</td>
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<td>Buckner fine sandy loam</td>
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<td>Buckner fine sand</td>
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<td>0.7</td>
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<tr>
<td>47</td>
<td>Buckner coarse sandy loam</td>
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<td>0.7</td>
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<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>12,680</td>
<td>4.6</td>
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<td>49</td>
<td>Wabash loam</td>
<td>8,000</td>
<td>2.9</td>
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<tr>
<td>50</td>
<td>Cass loam</td>
<td>2,638</td>
<td>1.0</td>
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<tr>
<td>51</td>
<td>Wabash silt loam</td>
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<tr>
<td>52</td>
<td>Cass sand</td>
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<td>0.9</td>
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<td>Wabash sandy loam</td>
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<tr>
<td>54</td>
<td>Cass sandy loam</td>
<td>896</td>
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<td>55</td>
<td>Riverwash</td>
<td>768</td>
<td>0.3</td>
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<td>56</td>
<td>Muck</td>
<td>576</td>
<td>0.2</td>
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<tr>
<td>57</td>
<td>Marsh</td>
<td>192</td>
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</table>

### Table IV. Plant Food in Muscatine County Soils, Iowa (Surface)
Pounds per acre of two million pounds of surface soil (0-6"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>1,550</td>
<td>4,610</td>
<td>45,658</td>
<td>162</td>
<td>9,382</td>
</tr>
<tr>
<td>31</td>
<td>Memphis silt loam</td>
<td>1,070</td>
<td>2,130</td>
<td>27,363</td>
<td>147</td>
<td>1,835</td>
</tr>
<tr>
<td>33</td>
<td>Knox fine sand</td>
<td>360</td>
<td>760</td>
<td>8,118</td>
<td>122</td>
<td>4,329</td>
</tr>
<tr>
<td>34</td>
<td>Muscatine silty clay loam</td>
<td>1,140</td>
<td>4,180</td>
<td>51,834</td>
<td>166</td>
<td>11,988</td>
</tr>
<tr>
<td>35</td>
<td>Knox fine sandy loam</td>
<td>740</td>
<td>1,540</td>
<td>16,720</td>
<td>0</td>
<td>6,660</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Buckner silt loam</td>
<td>1,520</td>
<td>4,220</td>
<td>46,516</td>
<td>344</td>
<td>8,991</td>
</tr>
<tr>
<td>37</td>
<td>Buckner silt loam (Colluvial phase)</td>
<td>1,660</td>
<td>3,640</td>
<td>46,980</td>
<td>trace</td>
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</tr>
<tr>
<td>38</td>
<td>Buckner loam</td>
<td>1,280</td>
<td>3,550</td>
<td>45,532</td>
<td>128</td>
<td>8,325</td>
</tr>
<tr>
<td>39</td>
<td>Buckner coarse sand</td>
<td>880</td>
<td>660</td>
<td>7,840</td>
<td>0</td>
<td>4,329</td>
</tr>
<tr>
<td>40</td>
<td>Buckner sandy loam</td>
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<td>2,950</td>
<td>30,913</td>
<td>122</td>
<td>4,329</td>
</tr>
<tr>
<td>41</td>
<td>Buckner sand</td>
<td>860</td>
<td>810</td>
<td>8,615</td>
<td>125</td>
<td>4,994</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,540</td>
<td>3,550</td>
<td>41,736</td>
<td>124</td>
<td>11,988</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>1,800</td>
<td>4,940</td>
<td>57,384</td>
<td>235</td>
<td>4,771</td>
</tr>
<tr>
<td>44</td>
<td>Bremer clay</td>
<td>1,860</td>
<td>5,080</td>
<td>64,316</td>
<td>164</td>
<td>Basic</td>
</tr>
<tr>
<td>45</td>
<td>Buckner fine sandy loam</td>
<td>1,240</td>
<td>1,900</td>
<td>22,264</td>
<td>5,508</td>
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<td>Buckner fine sand</td>
<td>740</td>
<td>320</td>
<td>3,670</td>
<td>trace 9,659</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Buckner coarse sandy loam</td>
<td>1,080</td>
<td>1,860</td>
<td>4,246</td>
<td>trace 10,989</td>
<td></td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,140</td>
<td>3,080</td>
<td>32,296</td>
<td>trace 6,327</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,470</td>
<td>3,480</td>
<td>40,312</td>
<td>trace 10,989</td>
<td></td>
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<tr>
<td>50</td>
<td>Cass loam</td>
<td>1,860</td>
<td>3,720</td>
<td>45,549</td>
<td>trace 2,469</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Cass sand</td>
<td>720</td>
<td>600</td>
<td>15,840</td>
<td>trace 0,840</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Cass silty clay loam</td>
<td>1,900</td>
<td>4,420</td>
<td>47,326</td>
<td>trace 11,01</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Cass sandy loam</td>
<td>1,220</td>
<td>2,020</td>
<td>27,296</td>
<td>204</td>
<td>4,771</td>
</tr>
</tbody>
</table>
the other hand, the terrace and swamp and bottomland soils are higher than the loess soils. The main soil type of the county, the Muscatine silt loam, a loess soil, is higher in phosphorus and nitrogen than the less important loess types and more nearly approaches the other soil groups. The lime requirement of this soil is more nearly like that of the terrace and swamp and bottomland soils and is higher than that of the other loess soils. In general, therefore, the needs of the soil types in Muscatine county cannot be considered in groups but must be studied individually.

Phosphorus is not found in any large amount in the soils of the county. Some of the terrace and swamp and bottomland soils are fairly well supplied but in no case is there enough present to warrant neglect of phosphorus fertilization in a system of permanent fertility. In several cases the need of phosphorus for good crop growth will probably be evident comparatively soon. The total phosphorus content of a soil fails to show how much of this element will be available and frequently a comparatively high content may be found in a soil in which the production of available phosphorus is too small to keep crops supplied. Because soil conditions are not right for rendering the phosphorus available, phosphorus fertilizers are sometimes profitable on soils containing enough phosphorus for several crops. Again, as the total phosphorus content of a soil decreases the proportionate amount made available decreases very much more rapidly and an actual need for phosphorus may occur in soils still possessing a considerable amount of that element. In a general way it may be said that phosphorus will need to be applied to all the soils of Muscatine county at some time in the future.

Fig. 4. Cedar river bottom on the east side of the river, near Saulsbury bridge, showing bottomland, abandoned channel and bluffs which mark the eastern edge of Wabash loam and Cass silt clay loam types.
The nitrogen content of the soils of Muscatine county is much higher than the phosphorus content. In most cases a considerable amount of nitrogen is present but the sandy soils are of course, much poorer in this constituent than the silt loams and other soil types and their need for nitrogen is unquestioned. Such extreme cases require special methods of treatment. In the chief soil types in the county, there is no immediate need for applications of nitrogen but this does not mean that the materials which are ordinarily used on soils to keep them fertile and maintain their humus content should not be applied. Such treatment as the use of crop residues, barnyard manure and green manures should never be neglected, for they supply nitrogen and at the same time produce other valuable effects. Furthermore, the present nitrogen content of the soils cannot be maintained without proper methods of soil management. Not only should all the manure produced on the farm be used, but crop residues, straw and corn stover should be returned to the soil. Green manure crops may often be used profitably in the rotation, legumes being most desirable because of their ability, when well inoculated, to use nitrogen from the air and make the soil richer in that plant food constituent. The rotation should always contain a legume in order to reduce the losses of nitrogen from the soil and secure frequent gains. At the same time the best yields of the other crops in the rotation may be obtained. If these methods are followed the use of commercial nitrogenous fertilizers will be unnecessary.

The carbon content of the Muscatine soils in most cases has rather a definite relation to nitrogen. Those types which are high in nitrogen are correspondingly high in organic carbon and vice versa. The application of humus forming materials to soils to improve their physical condition may improve the nitrogen conditions as is also the case with natural organic materials applied to soils. The soils in this county which are rather poorly supplied with humus are the same sandy soils which are low in nitrogen. It is therefore immediately necessary in the case of such soils that nitrogen-containing, humus-forming materials be used if the best crop growth is to be secured and if the soils are to be built up to a high state of fertility. With the heavier types there is not such an immediate need for special applications of humus-forming materials but the continued fertility of such soils demands reasonable applications of such materials at regular intervals. In short, the utilization of the manure and crop residues produced on the farm, and the proper introduction of legumes into the rotation as regular crops or as green manure crops or both, are essential on all the soils of Muscatine county to keep up the organic matter and nitrogen content. In the case of some sandy types, additional treatments are necessary.

The relation between the nitrogen and carbon in all the soils makes it evident that the organic matter present is undergoing active decomposition. With the proper maintenance of humus, therefore, there is no need of special treatment to encourage decomposition. Where manure is used the large number of microorganisms introduced in the soil will become active and rapid decomposition and the production of available plant food will result.

The total inorganic carbon content of the Muscatine county soils is very low. None of the soils contain any considerable amount of lime altho one loess soil, one terrace soil and one swamp and bottomland soil were shown by test not to be
acid. In general, however, the need of lime is very pronounced. Ground lime-
stone ranging in amount from one to five tons per acre is required to put the
soil in the best condition for crop growth. For definite recommendations for
the application of lime to individual soil types, tests of each special soil should
be made. The level soils are generally lower in lime requirement than the more
heavily cropped rolling soils. As soon as such level soils are properly drained
and otherwise managed to secure good crop yields they will be as much or more
in need of lime than the rolling types.

All soils tend to become acid under continued cultivation and the soils of
Muscatine county, if not immediately in need of lime, will very shortly become
so, for there is practically no supply of this constituent in any of the soils. All
the soils in this county should, therefore, be carefully tested and the proper
application of lime made if crop growth is to be satisfactory.

THE SUBSURFACE SOILS AND SUBSOILS

Samples of subsurface soils, (6% to 20 inches) and subsoils (20 to 40 inches)
corresponding to the surface soils, were secured and analyzed for the same con-
stituent as in the case of the surface soils. The results obtained with these
samples were calculated as pounds per acre of 4,000,000 pounds of subsurface
soils and 6,000,000 pounds per acre of subsoils, and appear in tables V and VI.

It is apparent from tables V and VI that there is no great stock of phosphorus
in the lower soil layers of this county and that the amount present will have
little effect on the time when this element must be applied. While a slightly
greater supply is indicated than in the case of the surface soils, it is distributed
throughout a larger mass of soil and can exert but a slight influence on lengthening
### TABLE V. PLANT FOOD IN MUSCATINE COUNTY SOILS, IOWA—(SUBSURFACE)

<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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>2,040</td>
<td>4,660</td>
<td>50,092</td>
<td>368</td>
<td>14,522</td>
</tr>
<tr>
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<td>Memphis silt loam</td>
<td>1,740</td>
<td>2,040</td>
<td>29,696</td>
<td>544</td>
<td>4,404</td>
</tr>
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<td>Knox fine sand</td>
<td>720</td>
<td>760</td>
<td>6,524</td>
<td>316</td>
<td>8,658</td>
</tr>
<tr>
<td>33</td>
<td>Muscatine silty clay loam</td>
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<td>5,440</td>
<td>79,436</td>
<td>404</td>
<td>12,278</td>
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<tr>
<td>34</td>
<td>Knox fine sandy loam</td>
<td>1,280</td>
<td>2,080</td>
<td>25,560</td>
<td>400</td>
<td>9,990</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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Buckner silt loam</td>
<td>2,560</td>
<td>5,840</td>
<td>71,568</td>
<td>184</td>
<td>16,650</td>
</tr>
<tr>
<td>37</td>
<td>Buckner silt loam (Colluvial phase)</td>
<td>2,640</td>
<td>2,980</td>
<td>75,816</td>
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<td>13,986</td>
</tr>
<tr>
<td>38</td>
<td>Buckner loam</td>
<td>2,160</td>
<td>4,300</td>
<td>50,384</td>
<td>176</td>
<td>13,986</td>
</tr>
<tr>
<td>39</td>
<td>Buckner coarse sand</td>
<td>2,160</td>
<td>1,160</td>
<td>23,800</td>
<td>0</td>
<td>8,658</td>
</tr>
<tr>
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<td>Buckner sandy loam</td>
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<td>9,324</td>
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<td>1,300</td>
<td>14,920</td>
<td>140</td>
<td>8,325</td>
</tr>
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<td>472</td>
<td>13,946</td>
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<td>3,560</td>
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<td>252</td>
<td>Basic</td>
</tr>
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<td>Bremer clay</td>
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<td>4,080</td>
<td>32,150</td>
<td>180</td>
<td>13,946</td>
</tr>
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<td>12,654</td>
</tr>
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<td>Buckner coarse sandy loam</td>
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<td>1,560</td>
<td>8,344</td>
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<td>5,994</td>
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### SWAMP AND BOTTOMLAND SOILS

<table>
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<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,960</td>
<td>4,080</td>
<td>49,700</td>
<td>180</td>
<td>Basic</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,800</td>
<td>4,160</td>
<td>50,892</td>
<td>trace</td>
<td>9,990</td>
</tr>
<tr>
<td>50</td>
<td>Cass loam</td>
<td>1,530</td>
<td>1,760</td>
<td>22,560</td>
<td>0</td>
<td>4,930</td>
</tr>
<tr>
<td>51</td>
<td>Cass sandy loam</td>
<td>1,150</td>
<td>400</td>
<td>18,640</td>
<td>0</td>
<td>Basic</td>
</tr>
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<td>52</td>
<td>Cass silty clay loam</td>
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<td>54,252</td>
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<td>4,930</td>
</tr>
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<td>Cass sandy loam</td>
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</table>

### TABLE VI. PLANT FOOD IN MUSCATINE COUNTY SOILS, IOWA (SUBSOIL)

<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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
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<td>30</td>
<td>Muscatine silt loam</td>
<td>3,510</td>
<td>3,480</td>
<td>40,185</td>
<td>765</td>
<td>15,264</td>
</tr>
<tr>
<td>31</td>
<td>Memphis silt loam</td>
<td>3,510</td>
<td>3,040</td>
<td>21,339</td>
<td>651</td>
<td>13,986</td>
</tr>
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<td>32</td>
<td>Knox fine sand</td>
<td>840</td>
<td>750</td>
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<td>264</td>
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</tr>
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<td>Muscatine silty clay loam</td>
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<td>2,820</td>
<td>128,196</td>
<td>384</td>
<td>Basic</td>
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<td>2,760</td>
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<td>0</td>
<td>12,987</td>
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</table>

### TERRACE SOILS

<table>
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<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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Buckner silt loam</td>
<td>3,420</td>
<td>4,920</td>
<td>44,988</td>
<td>372</td>
<td>11,010</td>
</tr>
<tr>
<td>37</td>
<td>Buckner silt loam (Colluvial phase)</td>
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<td>4,160</td>
<td>50,892</td>
<td>trace</td>
<td>9,990</td>
</tr>
<tr>
<td>38</td>
<td>Buckner loam</td>
<td>3,267</td>
<td>3,270</td>
<td>41,523</td>
<td>267</td>
<td>16,983</td>
</tr>
<tr>
<td>39</td>
<td>Buckner coarse sand</td>
<td>2,460</td>
<td>1,860</td>
<td>15,720</td>
<td>0</td>
<td>12,987</td>
</tr>
<tr>
<td>40</td>
<td>Buckner sandy loam</td>
<td>2,535</td>
<td>1,950</td>
<td>15,086</td>
<td>204</td>
<td>10,989</td>
</tr>
<tr>
<td>41</td>
<td>Buckner sand</td>
<td>1,740</td>
<td>1,380</td>
<td>10,167</td>
<td>243</td>
<td>13,986</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>4,332</td>
<td>1,860</td>
<td>14,676</td>
<td>264</td>
<td>16,515</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>3,300</td>
<td>2,100</td>
<td>32,982</td>
<td>378</td>
<td>Basic</td>
</tr>
<tr>
<td>44</td>
<td>Bremer clay</td>
<td>4,860</td>
<td>1,500</td>
<td>20,718</td>
<td>162</td>
<td>Basic</td>
</tr>
<tr>
<td>45</td>
<td>Buckner fine sandy loam</td>
<td>2,100</td>
<td>2,640</td>
<td>29,052</td>
<td>trace</td>
<td>5,005</td>
</tr>
<tr>
<td>46</td>
<td>Buckner fine sand</td>
<td>2,220</td>
<td>900</td>
<td>21,282</td>
<td>378</td>
<td>12,111</td>
</tr>
<tr>
<td>47</td>
<td>Buckner coarse sandy loam</td>
<td>2,400</td>
<td>960</td>
<td>17,880</td>
<td>0</td>
<td>10,989</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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,602</td>
<td>4,140</td>
<td>70,236</td>
<td>144</td>
<td>8,991</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>3,258</td>
<td>4,260</td>
<td>51,750</td>
<td>150</td>
<td>8,991</td>
</tr>
<tr>
<td>50</td>
<td>Cass loam</td>
<td>2,340</td>
<td>1,500</td>
<td>21,600</td>
<td>0</td>
<td>5,505</td>
</tr>
<tr>
<td>51</td>
<td>Cass sand</td>
<td>2,100</td>
<td>400</td>
<td>9,720</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>52</td>
<td>Cass silty clay loam</td>
<td>2,400</td>
<td>1,200</td>
<td>31,932</td>
<td>trace</td>
<td>7,395</td>
</tr>
<tr>
<td>53</td>
<td>Cass sandy loam</td>
<td>1,920</td>
<td>644</td>
<td>15,880</td>
<td>0</td>
<td>16,515</td>
</tr>
</tbody>
</table>
the "life" of the soil. The nitrogen and organic carbon content decreases in these lower soil layers and this indicates the need for the employment of proper methods of soil management which will keep up the organic matter and nitrogen content of the surface soils.

The lime requirement of the subsurface soils and subsoils is generally greater than that of the surface soils. In some instances acid surface soils overlie non-acid subsurface soils and subsoils. Inasmuch as lime rarely moves upward in the soil, the amount present in the lower soil layers, even if considerable, can exert no appreciable influence on the acidity of the surface soil. If the surface soil is acid, lime must be applied in sufficient amounts to neutralize that acidity regardless of the reaction of the subsurface soils and subsoils. Furthermore the content of lime in the surface soils must be kept up by regular applications and tests for acidity must be made at regular intervals. It may be that where the subsoils are supplied with lime the lime applied to the surface soils will not disappear so rapidly, but there is no evidence to that effect as yet. All experimental data tend to prove that soils under cultivation become acid more or less rapidly, depending on general soil and cropping conditions. If good crop growth is to be maintained, frequent tests must be made and lime applied as necessary.

GREENHOUSE EXPERIMENTS

A greenhouse experiment was carried out with one of the main soil types in Muscatine county to determine its needs and the effect of certain treatments. The soil chosen was the Muscatine silt loam, a loess soil which covers over 37 per cent of the total area of the county.

The treatments chosen for this experiment were the application of lime, the use of manure and the efficiency of phosphorus fertilization, using acid phosphate and rock phosphate.

Enough lime was applied to neutralize the acidity in the soil and supply an additional amount of two tons per acre.

Manure was used at the rate of 10 tons per acre, acid phosphate at the rate of 200 pounds per acre and rock phosphate at the rate of 1,000 pounds per acre. Wheat was grown in all the pots and the weight of grain secured. The results of this experiment are given in table VII.

Lime had practically no effect on the wheat crop. Wheat however, is not particularly sensitive to acid conditions in soils. The experiment was not planned, as much to test lime as the other fertilizing constituents and hence this result should not be accepted as showing no need of lime on this soil. If clover or alfalfa or some such crop had been used, the value of the lime on the soil would undoubtedly have been apparent. The surface soil of this type is uniformly

<table>
<thead>
<tr>
<th>Pot. No.</th>
<th>Treatment</th>
<th>Weight of grain gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>13.75</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>13.50</td>
</tr>
<tr>
<td>3</td>
<td>Lime + Manure</td>
<td>15.75</td>
</tr>
<tr>
<td>4</td>
<td>Lime + Rock Phosphate</td>
<td>13.75</td>
</tr>
<tr>
<td>5</td>
<td>Lime + Acid Phosphate</td>
<td>13.75</td>
</tr>
<tr>
<td>6</td>
<td>Lime + Manure + Rock Phosphate</td>
<td>14.25</td>
</tr>
<tr>
<td>7</td>
<td>Lime + Manure + Acid Phosphate</td>
<td>17.25</td>
</tr>
</tbody>
</table>

1 Yield on one pot only.
acid and lime should be used before attempting to grow well-inoculated legumes. It is very difficult to secure a good growth of legumes under greenhouse conditions and this is an additional reason why the use of lime for such crops was not tested. General field experience along this line leaves no room for doubt that lime must be used on this soil type in order to secure a satisfactory growth of legumes.

The value of manure on this soil type is very clearly indicated in table VII by a decided increase in yield over the check and the limed pots, a result which accords with many field observations. All methods of treatment for this soil type should include the use of manure in as large quantities as available in order to keep up the organic matter and nitrogen content.

Rock phosphate and acid phosphate when applied to this soil with lime apparently had no effect on the grain yield. Some other factor is evidently of more importance here than phosphorus and the indications are that manure supplies that factor. When phosphates are used with manure and lime the results indicate that acid phosphate possesses value in addition to that of the manure but rock phosphate seems to have no such effect. The general conclusion seems to be warranted that phosphorus does not at present give large increases in crops on this soil. The soil is not rich in this constituent but there is evidently still a large production of the element in an available form and the use of phosphorus fertilizers has only a small effect. At a later date, however, their use will undoubtedly be more necessary, for as the supply of this element decreases, a continually smaller amount of available phosphorus will be provided and crops will suffer. Experiments with this element should be made from time to time to ascertain the need of the soil in this direction.

Other fertilizers may be necessary for market garden crops on the light sandy soils of the county, but no experiments have been carried out along this line. The problem of fertilization of such soils is quite distinct and needs special at-

Fig. 6. A greenhouse pot experiment with wheat on the Muscatine silt loam, one of the main soil types in Muscatine county, in which the value of manure was distinctly shown
tention. They are of minor significance in the county as regards area and their needs will be considered in the discussion of the individual soil types which will be included later.

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 1 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.

Muscatine county has a typical "gumbo" soil known as the Bremer clay. It covers about 1 percent of the area of the county and occupies flat depressions which formerly were the bottoms of "Elephant Swamp" and "Goose Lake." The management of "gumbo" may profitably be 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 VIII.

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
TABLE VIII. FIELD EXPERIMENTS ON "GUMBO"

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. corn per acre 1909</th>
</tr>
</thead>
<tbody>
<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>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>

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 thoro 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 tilled 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 MUSCATINE SOILS INDICATED BY LABORATORY AND GREENHOUSE TESTS

The laboratory and greenhouse studies on the soils of Muscatine county indicate quite distinctly the chief needs of these soils to make them more profitably productive. It is unfortunate that no experimental field data other than that for the "gumbo" soils are available at the present time for inclusion in this report. Much unofficial work has been carried on in Muscatine county, however, and the observations made support in every particular the conclusions drawn in the following pages. It should be thoroughly understood that the recommendations made are not based entirely on the laboratory and greenhouse experiments but also on the results of many practical tests and general observations extending over a considerable period of time. Field experiments are now under way on some of the main types in the county and the results secured in these tests will be published later in a supplementary report.

LIME

Lime is one of the fundamental needs of Muscatine county soils. All but three of the soil types show acidity in the surface soil and in several cases the lime requirement is very large. The extent of acidity is exceedingly variable. In a general way the terrace soils seem to need the largest amount of lime to remedy their acidity. Practically all Muscatine county soils, however, are in need of lime. They have lost their original stock of this material and while satisfactory yields of some crops are still being secured where the acidity is not too large, greater returns would be obtained with limed soils. This is especially true for alfalfa and red clover although in the case of wheat the need for liming is not so evident. The amount of lime which should be applied cannot be stated to cover the general situation. Soils vary widely in their lime requirement, and different samples of the same soil type may be widely separated in their need for lime. It is urged that in all cases and at all times individual soils be tested for their lime requirements and the exact amount needed by each particular soil be determined. Only in this way can the proper application be made in all cases. Directions for making the test on the farm have been given and it is possible to ascertain fairly accurately by the use of the litmus paper method how much lime a soil needs, but it is usually much more satisfactory for a small sample of the soil in question to be sent to the Soils Section of the Agricultural Experiment Station.

The kind of lime to apply has been considered in another place and the relative merits of different materials need not be discussed here. It will be sufficient to say that ground limestone is the cheapest and best material to use.¹

¹ Further specific information regarding the question of liming, its need by different crops, the sources from which lime may be secured, the cost of such material, etc., may be found in Bulletin 151 of the Iowa Agricultural Experiment Station. Specific information for local circumstances not given in this publication may be secured by correspondence with the Soils Section.
MANURING

Except in a few cases where they are quite sandy in character—the Muscatine county soils, according to their analyses, are not especially low in organic matter. The experiments with manure indicate however considerable value from the use of this material and many unofficial observations confirm these results. In fact, manuring, next to liming, is the essential treatment of these soils. Its value exceeds that of other fertilizers and in most cases the use of other materials with it leads to only slight increases in crops. Manure does more than merely add organic matter to the soil; it supplies certain important amounts of nitrogen and other plant food constituents and it also adds countless microscopic bacteria and other organisms whose action in the soil brings about a materially greater production of available plant food. In many cases the effects of manure are undoubtedly the result of these physical, chemical, and bacteriological changes, but in most instances, its effect is mainly physical. It is without competition in improving the mechanical condition of the soil and this together with the chemical and bacterial action makes it an exceedingly valuable fertilizing material.

Too much emphasis cannot be placed on the proper storage and application of manure. It should be stored under cover to protect it from the alternate wetting and drying action of the weather. The liquid portion of the manure should be preserved with the solid since it is the most valuable part and that which is most easily lost. Specific information along this line may be found in Circular 9 on Farm Manures published by the Iowa Agricultural Experiment Station.

Fig. 7. Bottomland just east of Muscatine along the Mississippi river, showing width of bottom and slopes from bluffs
The necessity for the proper use of manure to keep the soils in Muscatine county fertile cannot be over-emphasized. This material not only increases their present productiveness but it aids in maintaining their permanent fertility as regards organic matter and it lengthens the "life" of the soil from the plant food standpoint. Therefore, in spite of the fact that these soils are generally not low in organic matter, manure should be applied in as large amounts as are available. Indeed, the fact that there is not already a deficiency in humus is perhaps the very best reason why care should be taken that it be not allowed to become deficient.

The color of the light sandy soils indicates clearly their need for organic matter, and such soils must be very thoroughly fertilized. The larger areas of richer soils must not be neglected, however, for the sake of the smaller infertile areas. If the manure produced on the farm is insufficient to keep the better soils supplied and also build up the poor soils, then some other material, such as green manure, should be used and the manure carefully distributed.

Ten tons of manure per acre once in a four-year rotation is an average application but the best effects have been secured with 20 tons per acre on the average soil. On light soils where the organic matter is very deficient, much heavier applications than this can be made if the material is available. In market gardening, trucking, and greenhouse work extremely large amounts of manure are employed. It is essential in such cases to make heavy applications in order to force the special crop which is grown.

On the average farm, there is not a sufficient production of manure to keep all the soils well supplied and other humus-forming materials such as green manures must be resorted to. Not only do they supply organic matter but if legumes are used and well inoculated there is an addition of nitrogen. By the use of such crops, the physical condition of the soil may be kept up and the nitrogen supply insured at small expense. Farm manures even when stored and applied under the very best conditions return only a portion of the plant food removed by crops which is variously estimated at about 75 to 85%. Leguminous green manures, on the other hand, when well inoculated supply considerable amounts of nitrogen which they have gathered from the atmosphere. Where nitrogen is low in soils, the value of such crops is very apparent especially when the high cost of commercial nitrogenous fertilizers is considered. The soils of Muscatine county, with the exception of some of the minor sandy types, are not particularly deficient in nitrogen and there is no necessity for its addition at present. It is true, however, that with the constant removal which occurs with all crops the content of nitrogen must continually decrease. Here is a cheap and effective method of adding nitrogen and insuring the constant supply of an expensive constituent. Green manures do not build up organic matter quite as efficiently as do farm manures, owing to their different chemical composition and the absence of bacteria, yet they are valuable for that purpose. Their use is best, however, in addition to farm manure and not as a substitute for that material. Farm manures should be used as far as they are available and green manures applied in addition.

The large number of legumes which may be used as green manure crops, the variable conditions under which they will grow and their different periods of
growth make these crops especially adaptable for use in almost any rotation. The particular legume to use will be determined by the rotation, the soil, the climate and the general farm conditions. Advice along this line will be gladly given by the Soils Section upon application.

If the legume has not been previously successfully grown on the same soil and well-inoculated, inoculation should be practiced. Soil from a field where the same legume has been grown and well inoculated may be used but if this is not available in the immediate vicinity and considerable expense would be involved in securing it, pure commercial cultures may be used. Without inoculation, the legume will not use nitrogen from the air and if the crop is to add this constituent to the soil when turned under, it must be well inoculated.

One further method of supplying organic matter to the soil should be mentioned. Crop residues, straw and stover contain certain amounts of plant food which has been removed from the soil and they also supply valuable organic matter. They are quite generally returned to the soil, either alone or in the manure applied, but in many instances are wasted or used uneconomically. The return of such material to soils should be the first means employed to keep up its organic matter content and to lengthen its "life." Care in their use will render the need for farm manure and green manures less pronounced and will also make the use of commercial fertilizers less immediately necessary.

The judicious use of these materials will keep Muscatine soils in a good physical condition indefinitely and will considerably lengthen the "life" of the soils from the plant food standpoint. Nitrogen fertilization need not be necessary and potassium is abundant so that phosphorus is the only element required.

THE USE OF COMMERCIAL FERTILIZERS

Commercial phosphorus fertilizers do not give large increases in crops at the present time according to the experiments on the Muscatine county soils, and their application cannot be generally recommended. There is no doubt, however, that phosphorus is low in all these soils and the need of this element will undoubtedly become much more apparent in the more or less distant future. Continuous cultivation and cropping will remove more and more phosphorus and the amount made available will soon be insufficient to meet the needs of the growing crop. Phosphorus fertilization will then be absolutely necessary and even at the present time applications of phosphorus fertilizers might be profitable on certain soils. The need in such cases can be determined only by experimentation as may also the kind of phosphorus fertilizer most profitable to apply. A simple and inexpensive test carried out on the farm will show the value of phosphorus fertilization. Specific directions for such tests are given in Circular 15—Testing Soils in the Laboratory and Field—published by the Iowa Agricultural Experiment Station. Any who are interested along the line of such experiments are urged to correspond with the Soils Section and receive definite advice and suggestions.

Two phosphorus fertilizers are at present available, acid phosphate, a soluble material, and rock phosphate, an insoluble, cheaper substance. Experimental data are insufficient to permit of a choice between these two fertilizers and their
relative economic value is probably different under different soil and farming conditions. If farmers will carry out tests for their particular conditions and inform the Soils Section of the results secured they can help materially in solving this important problem. In the course of the next few years, when phosphorus will undoubtedly become more necessary to the soils of this county, field results will show what fertilizers should be used.

Potassium is present in practically all Iowa soils in such large amounts that applications of potassium fertilizers are quite unnecessary if proper soil conditions are maintained so that there is a continuous production of it in an available form. Muscatine soils, with the possible exception of the proportionately small sandy areas, are not in need of potassium for general farm crops.

There is no deficiency of nitrogen in the average Muscatine soil and no need for the use of commercial nitrogenous fertilizers in the case of ordinary crops. If nitrogen does become a limiting factor of growth, it can be supplied much more cheaply by the use of leguminous green manures and additional value to the soil secured at the same time because of the introduction of organic matter. Except as top dressings for certain crops and under special conditions mentioned later nitrogenous fertilizers are unnecessary on these soils.

It is obvious, therefore, that complete commercial fertilizers containing nitrogen, phosphorus and potassium have no place on the general farm in Muscatine county at the present time. When fertilization with phosphorus proves profitable, however, fertilizers containing that element should be used.

These statements regarding the use of commercial fertilizers in Muscatine county must be understood to apply to general farming conditions in that county and not to truck farming. Where garden and truck crops are grown it is frequently desirable and profitable to use considerable amounts of commercial fertilizers in order to force the crops. The kind of fertilizer to use in such cases and the amount will depend on the crop grown and its value. The returns secured must be such that the expense of the fertilizer will be warranted. Organic matter must always be supplied in such cases in the form of farm manure or green manure in addition to the commercial fertilizer.

The soil is not worn out by using commercial fertilizers as is sometimes supposed. If greater crops are grown, greater removal of plant food from the soil occurs but if this loss is made good, organic matter is applied and the physical condition of the soil is kept satisfactory, the soil will continue productive. Truck crops need not deplete the fertility of a soil any more rapidly than general farm crops but greater care is necessary to keep it in good condition both physically and chemically. They are frequently extremely profitable and will warrant the use of much expensive fertilizer. When fertilizers can be used profitably can be settled only for special conditions and no general recommendations can be made.

DRAINAGE

There are several soils in Muscatine county which are in need of drainage. These are not restricted to the swamp and bottomland soils but include one loess or upland soil and several of the terrace soils. The Muscatine silty clay loam, a loess soil, and the Calhoun silt loam, the Bremer silty clay loam and the Bremer clay, all terrace soils, are especially in need of drainage, as are also the
swamp and bottomland soils which are of heavy texture. This is one of the first essentials for successful crop production. No other treatment will be successful if the drainage of the soil is poor and no other treatment will obviate the need for drainage.

Many tile drains have already been laid in the county and there is much evidence that they have proven of great value and while the expense involved has been considerable it has been more than offset by the results secured. The drainage factor should never be overlooked in any system of soil fertility.

CROP ROTATIONS

The value of definite crop rotations on all soils is well known. Continuous growing of any one crop wears out the soil much more rapidly than a rotation. If crop production is to be kept good, definite systems of crop rotation must be adopted and closely followed. Practical results have shown the value of rotations in so many cases that emphasis need hardly be placed on the profit resulting from a proper system of cropping. There are several rotations peculiarly adapted to Muscatine county and they may be listed as follows:

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.)

In live-stock farming, the products grown in the rotation should, for the most part, be fed or used for bedding, and the manure carefully saved and used as a fertilizer.

"Catch" crops, such as cowpeas, soybeans, vetch and clover, seeded in standing corn are frequently unprofitable in Iowa because of the high cost of the seed and the failure of the crop to make a satisfactory growth. The non-legumes, such as rye and rape usually do well when seeded in standing corn.
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 gullyng. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil will be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual 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 Muscatine county there are some areas where gullying occurs to an injurious extent. The bluffs extending from the upland to the alluvial bottoms are frequently very badly dissected as a result of erosion. The Lindley silt loam is especially subject to washing because of the steep slopes on which it occurs.
The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

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

"Plowing In." — It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "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 from being washed away as readily. 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 may be warranted on large farms which are operated on an extensive scale because of the saving in time, labor and inspection.

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

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

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

The rubbish dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.
The woven wire dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for preventing erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the “staking in” system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

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

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

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

HILLSIDE EROSION

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

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

Growing of crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite necessary 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 MUSCATINE COUNTY

LOESS SOILS

Six of the soil types in Muscatine county are classed as loess soils. Together they cover over 64 percent of the area of the county constituting, therefore, the most important group of soils. They include the Muscatine, Memphis, Lindley and Knox series.

MUSCATELINE SILT LOAM (30)

This soil is the most important type in the county. It covers 102,912 acres or 37.2 per cent of the total area of the county.

This soil occurs in extensive unbroken areas on the open prairie country, the main body of the type being found between the Cedar and Mississippi rivers extending from the northeastern to the southern boundary. Other smaller areas occur in the northwestern part of the county and on the West Liberty plain.

The surface soil is a black to brownish-gray mellow silt loam extending to a depth of 12 to 16 inches. The subsoil varies from a brownish-gray to a finely-mottled yellowish-brown or gray compact silty clay loam and is generally more than three feet in depth. While usually quite uniform in structure and color, there are small areas in which the subsoil is darker in color and more plastic than the typical soil, and in some cases a gray layer appears just below the surface soil or a hardpan layer is found in the three-foot section.

Within the large areas of this soil there occur small areas of a slightly different type which have not been separated or mapped because of their small extent and very local importance. The surface soil is not essentially different from that of the main soil type but the subsoil is yellow, rather sandy and more porous than that of the typical soil. This soil type is the Shelby loam.

The topography of the areas covered by the Muscatine silt loam is generally gently rolling with occasional hilly and slightly rough areas near the edges. As a whole the drainage conditions are fairly satisfactory, the flat phase and hardpan phase which are of minor importance being the only exceptions. Tile drainage has proven valuable in many cases as an aid to natural drainage and in the flat phase it is essential to make the soil productive.

The soil is of loessial origin and extends from 10 to 15 feet in depth in most places. Occasionally on the ridges it is only 6 to 8 feet deep, but it is apparent that the underlying drift material can have little influence on the soil conditions. Methods of treatment, therefore, need consider only the loessial material.

Corn, hay, oats, barley and wheat and some rye are the principal crops grown. The only special crop grown is cabbage, the yields of which are very good. Alfalfa is grown in some small areas, three or four cuttings being obtained each grown is fed to the cattle and hogs. Dairying is of small importance at present but the industry is expanding.

The crop yields secured on this soil are generally good altho the average returns are not large. Livestock and general farming are usually followed and the soil is better adapted for them than for the growth of special crops. Recommendations for treatment, therefore, apply to the growth of general farm crops used in such systems of farming.

The descriptions of individual soil types given in the Bureau of Soils report on Muscatine county have been rather closely followed in this section of the report.
This soil type is apt to be acid and in need of lime. Lime requirements vary in different samples and under changing conditions. Soils of this type should, therefore, be tested for acidity at regular intervals and the amount of lime indicated by the test should be applied. Three and one-half to four ton applications would probably satisfy the needs of the average soil. Alfalfa and other legumes should not be seeded without attention to the reaction of this soil.

The beneficial effects of manuring this soil have been shown in the previous pages and the thorough utilization not only of all the manure produced on the farm but also of the crop residues, straw and stover, should be emphasized as necessary means of improving the soil conditions, increasing crop production and maintaining fertility. Green manuring may also be of value as a supplement to farm manures and is an important means of maintaining the nitrogen content of the soil.

Commercial fertilizers seem to be unnecessary at present. Even phosphorus carriers are of only small value altho they will be necessary in the future and tests of such materials as rock phosphate and acid phosphate are extremely desirable.

Crop rotations are very generally practiced and their importance in keeping up crop yields and maintaining the soil in a satisfactorily fertile condition is unquestioned.

In short, crop growth on this soil type, altho not poor at present, can be increased by proper methods of treatment including manuring and in many cases liming, drainage, and the use of phosphorus fertilizers. In this way, maximum yields of crops can be secured without difficulty.

MEMPHIS SILT LOAM (31)

This soil covers the second largest area in the county, 54,592 acres, or over 19 percent of the total area. It is an upland soil, its largest area extending back from the Mississippi bottoms merging gradually into the Muscatine silt loam, the type just described. The lines of division between these two soils are frequently very difficult to locate as there is such a gradual intermixing but occasionally there is an abrupt change from one type to the other and more definite boundaries may be made. Small areas occur back from the bluffs along the east side of the West Liberty plain but they are not continuous and are interspersed with other soil types.

The surface soil of this type is a light-brown to light grayish-brown, mellow, friable silt loam extending to a depth of 10 to 16 inches. Its organic matter content is rather low and hence it is lighter in color than the Muscatine silt loam. The subsoil is a light-brown or yellowish-brown compact silty clay loam extending beyond the three-foot section.

The greater part of this type varies from gently rolling to slightly hilly, narrow flat areas occurring midway between the streams. Toward the edge of the bluffs the areas become somewhat more hilly and broken. As a general rule it is well drained altho some of the small flat areas have been benefited by tile drainage. In other cases the drainage is excessive and there is need for methods of retaining moisture in the soil such as mulching or green manuring.

This soil is particularly favorable for trucking because of its mellow, friable character, the ease of cultivation and the rapidity with which it warms up in
Fig. 8. Surface, subsurface and subsoils of five of the individual soil types in Muscatine county.

1 Cass loam
2 Buckner coarse sandy loam
3 Bremer silty clay loam
4 Buckner fine sand
5 Muscatine silty clay loam
Fig. 9. Surface, subsurface and subsoils of five of the individual soil types in Muscatine county

6 Buckner sandy loam
7 Wabash loam
8 Buckner fine sandy loam
9 Buckner silt loam
10 Buckner sandy loam
the spring, permitting early cultivation and seeding. Tomatoes, cabbage, onions, and cucumbers are grown in considerable quantities, and pumpkins and squashes are also grown to some extent.

General farming is followed on the larger portion of the soil area and corn is the staple crop, being grown on from one-third to one-half the total acreage devoted to general farm crops. Small grains are grown to some extent, oats being the most important. Rye, barley and winter wheat are also grown to some extent and give satisfactory yields. Clover alone and mixed with timothy constitutes the hay crop. Alfalfa is grown only on small areas.

The needs of the soil whether used for trucking or general farming are very similar. Practically all of the soil of this type is acid in reaction and one of the chief requisites for successful crop growth is the application of lime, particularly where legumes are to be grown. The soil should be carefully tested at regular intervals and lime applied as necessary, the amount needed in most cases being 3 to 4 tons per acre.

Manuring is also to be recommended, for the deficiency in organic matter is indicated by the light color of the soil. Crop growth both of general farm crops and of truck crops can be increased to a large extent by the use of manure in considerable amounts. Larger amounts are frequently used for the truck crops than are feasible for general farm crops and have proven profitable. Ten tons is the average application in the latter case but for truck crops the use of 20 to 30 tons may be advisable.

Crop residues and straw, should be used on all the general farms and it may be advisable in many cases to use leguminous green manure crops.

Commercial fertilizers have not proven profitable on this soil, at least under general farming conditions. For truck crops the use of special mixtures prepared for the particular crop may be valuable for forcing purposes. The complete fertilizer to be used can best be determined by careful tests but there are many mixtures which have proven satisfactory. These materials are usually applied at the rate of 200 to 300 pounds per acre and greater applications than these are rarely advisable.

Phosphorus fertilizers may prove of special value for general crops inasmuch as this type of soil is rather low in this element. They do not give large increases in yield at the present time but they will undoubtedly prove more valuable in the future. Tests of phosphorus fertilizers are certainly desirable.

Drainage is rarely necessary on this soil. Crop rotation is advisable as always and especially in the case of trucking because of the danger of plant diseases.

LINDLEY SILT LOAM (32)

This soil covers only a comparatively small area of Muscatine county and owing to the excessive drainage, drouth, and the injurious action of erosion to which it is subject, it is not important for cropping, the only uses for which it is suitable being forestry and pasture.

It occurs chiefly on the slopes between the uplands and the alluvial bottoms and extending back along the streams that drain the uplands. The surface soil is light-brown to grayish-brown in color and frequently contains fine sand and very fine sand in sufficient quantities to make it a fine sandy loam. The subsoil
is a brown to yellowish-brown clay, usually stiff and compact and containing some gravel and pebbles.

Inasmuch as it is unimportant from the cropping standpoint no analyses of this soil were made. The treatment needed to make it more satisfactory for pasture purposes consists in the adoption of a suitable method for the prevention of erosion. Its character and location are such that cropping cannot be advised and it should be used for pasturing where there are no forest trees.

**KNOX FINE SAND** (33)

The total acreage of this type is small and it occurs chiefly along the Cedar river, among the upland, terrace and bottomland soils.

Its topography is quite irregular, and is known as the "dune" formation. In some cases these dunes rise 50 feet above the surrounding land and depressions occur to a considerable depth. These latter are known as "kettle holes."

The surface soil to a depth of 10 to 12 inches is a brown, slightly loamy fine sand which grades into a lighter colored fine sand extending down to 36 inches. Occasionally layers of sandy clay or clay loam occur between 18 and 36 inches underlain by a light-brown or yellowish-brown sand but as a rule, the sandy nature of the soil persists for far greater depths than the three foot section.

Drainage is excessive and crops are apt to suffer from lack of moisture. This soil is well suited for growing watermelons, cantaloupes and grasses, the first yielding especially well in seasons of well-distributed rainfall. Corn and rye are the principal grain crops but owing to the unfavorable moisture conditions their yields are apt to be poor.

The soil is very low in plant food and particularly deficient in organic matter. If it is to be made productive, the first need is for the application of farm manures or the growing of green manure crops and turning them under.

The soil drifts badly when cultivated and frequently large "blow-holes" are formed. Organic matter will serve to a large extent to prevent such occurrences. Various legumes may be used as green manure for the purpose of providing organic matter and frequently non-legumes may be substituted with profit. Farm manure should be used in as large quantities as available, particularly if truck crops are to be grown. In any case a small amount of farm manure turned under with the green manure will prove of advantage.

The soil is generally acid in reaction and application of lime should be made according as the tests show the need for it. Fertilizing materials may prove of value in increasing and hastening the growth of truck crops. Complete brands suitable for the particular crops should be chosen.

For general farm crops, phosphorus fertilizers might prove of value, altho there is no data yet available which would indicate whether such materials would prove economical. Tests with rock phosphate and acid phosphate are urged. Nitrogenous fertilizers need not be used when leguminous green manure crops, well inoculated, are turned under, and potassium fertilizers are unnecessary for general farm crops. Complete fertilizers are not recommended therefore except for truck crops.

Rotation of crops is essential and this applies to truck crops as well as to general farm crops. Systems should be adopted which will not only fit the soil
Fig. 10. Surface, subsurface and subsoils of five of the individual soil types in Muscatine county
13 Cass sandy loam
14 Wabash silty clay loam
12 Calhoun silt loam
15 Buckner silt loam
11 Muscatine silt loam
Fig. 11. Surface, subsurface and subsoils of five of the individual soil types in Muscatine county
16 Memphis silt loam
17 Buckner coarse sand
18 Memphis silt loam
19 Cass silty clay loam
20 Knox fine sandy loam
and climatic conditions but also the market conditions. With proper treatment this soil may be made very productive, particularly for truck crops, and its occurrence in otherwise highly productive areas may cease to be a cause for lower land values.

**MUSCATINE SILTY CLAY LOAM (34)**

This is a small soil type in Muscatine county, covering only about 1 percent of the total area.

Its occurrence is confined to small areas or narrow strips along the streams which drain the Muscatine silt loam, the chief soil type in the county. It occurs also in small poorly-drained depressions most of which cannot be shown on the map.

The surface soil extends to a depth of 12 to 18 inches and is very compact in structure. It is black in color but when dry appears dark-gray. The subsoil is a black, tough, compact silty clay loam to silty clay. In some cases it is drab in color and occasionally there are layers of drab and yellowish-brown and mottlings of either color sometimes appear.

This soil is particularly in need of drainage in many cases. The subsoil is so tight that even where the topography is not flat or depressed, thorough drainage would undoubtedly be of considerable value.

Corn, hay and small grains give good yields on this soil when the seasonal conditions are satisfactory. Small grains, however, are apt to run to straw and lodge and hence are not grown extensively. Mixed clover and timothy are grown for hay and ordinarily yield well.

While the typical sample of this soil which was examined did not show acidity, there was no large amount of lime present and the need of this material will probably be apparent in the near future. In fact, with thorough drainage, the lime requirement of the soil will undoubtedly increase. Even at the present time there are probably cases where lime would be of value.

Organic matter is not low in this soil, but applications of farm manure should be made at regular intervals to maintain the supply. Crop residues should be applied, for these aid considerably in keeping up the humus in the soil. With thorough drainage, cultivation and increased cropping, the organic matter will be depleted much more rapidly than at present and more frequent applications of manure may be necessary. In cases where farm manure is insufficient green manures may be used to supplement it.

Fertilizing materials are generally unnecessary on this soil at the present time but as in the other types phosphorus is low and phosphorus fertilizers may prove of value in the future. Drainage is also important to keep soil of this type profitably productive for general farm crops.

**KNOX FINE SANDY LOAM (35)**

This soil occurs in small areas on the uplands, rising slightly above the surrounding areas. Its total area is only 448 acres or 0.2% of the area of the county and it is therefore relatively unimportant.

The surface soil is a brown fine sandy loam extending to a depth of 10 to 12
inches and overlying a brown to light-brown loamy fine sand, which at 24 to 28 inches grades into a light-brown to yellowish-brown fine sand. In some instances there is a sandy clay layer from 4 to 8 inches thick occurring in the three-foot section. This is underlain by yellowish-brown medium sand.

The crops grown are corn, wheat, rye and hay and small areas are in pasture. Satisfactory yields are not obtained without proper soil treatment.

The needs of the small areas of this soil are largely for organic matter and lime. Heavy manuring is the first treatment required to bring the soil into a condition of fertility corresponding to the surrounding upland and all available manure should be used on such spots. Crop residues should be applied and green manuring will be of material assistance in addition to the farm manure in making the soil productive. The soil is generally acid and lime should be applied as the tests show it to be required. Commercial fertilizers, particularly phosphorus carriers, may be of use on this soil. Field tests, giving definite information along this line are urged.

Drainage of this soil is excessive and some treatment to retain moisture, such as cultivation and manuring should be adopted. Crop rotation should be followed as on all soils. With proper treatments as indicated, the areas of this rather poor soil may be made as productive as the surrounding land.

TERRACE SOILS

Twelve distinct soil types in Muscatine county are recognized as terrace soils and the total area covered by them amounts to 23.0 per cent of the area of the county, so that, with one exception, the area of the individual types is small. The Buckner, Calhoun and Bremer series are included here.

BUCKNER SILT LOAM (36)

This soil covers over six percent of the area of the county and is an important type. It occurs in rather extensive areas along the drainage lines particularly in the central part of the county, and is quite level in topography, altho gentle slopes connect it with the adjoining uplands.

The surface soil is a friable silt loam usually black to dark-gray but occasionally brownish in color, extending to a depth of 12 to 16 inches. The subsoil is a black to chocolate brown silty clay loam which at 24 to 30 inches grades into a light-brown silty clay loam likewise compact in structure.

There is quite a little variation in the color of the subsoil in different areas more or less thoroughly drained. It may be light to yellowish-brown or black to dark drab or grayish and frequently brown mottling is found. Ordinarily it is rather tough but when wet it becomes quite plastic; occasionally a gray silt layer occurs between the surface soil and subsoil but such areas are very small and have not been mapped separately.

Corn is the main crop on this soil and good crop yields are generally secured. Oats, winter wheat, rye and barley are also grown to a considerable extent. Clover hay and timothy hay are commonly included in the rotations and bluegrass pasture does well on this soil. Live stock farming prevails.

This soil is relatively fertile and compares very favorably with the Muscatine silt loam. The natural drainage of the greater portion of the type is not en-
tirely satisfactory and when this is the case, drainage systems should be installed which will insure the removal of excessive moisture.

The need of lime is apparent in many cases on this soil and where tests show acidity, the proper amount of lime to make the reaction neutral should be applied. After one application, subsequent needs may be supplied at regular intervals, perhaps once in a rotation. Manure constitutes the chief fertilizing material recommended for application on this soil. Crop residues should be thoroughly utilized in all cases and farm manure applied in addition is always valuable. Care should be taken that all the manure produced is applied to the soil and that losses of this material thru improper storing or application be reduced to a minimum. Insufficient amounts of manure may be made up by the proper use of green manures, particularly by well inoculated legumes which supply nitrogen from the air.

Complete commercial fertilizing materials are unnecessary on this type. Phosphorus is not high, however, and altho phosphorus fertilizers show no great value at present they will need to be used in the near future. Tests of the relative merits of rock phosphate and acid phosphate are extremely desirable. Nitrogenous and potassic fertilizers are not needed, the former element may be supplied by leguminous green manures and the latter is present in such large amounts that, with proper decomposition processes in the soil, sufficient would be present for satisfactory crop production. With proper treatment this soil can be made even more productive than it is at the present time.

BUCKNER SILT LOAM (COLLUVIAL PHASE) (37)

This soil is of minor significance in the county. It occurs at the bottoms of the slopes extending from the uplands to the alluvial bottomland soils and is made up largely of wash from the surrounding upland mixed to some extent with river-carried material.

The surface soil to a depth of 8 to 12 inches is a grayish-brown to dark-brown friable silt loam containing a moderate amount of fine sand and very fine sand. The subsoil is a light-brown silty clay loam, quite compact and generally uniform thru the three-foot section. Occasionally there is sufficient sand in the soil to make it a fine sandy loam rather than a silt loam but these areas are very small and of little importance.

This soil is all under cultivation and truck crops as well as general farm crops are successful. Tomatoes, cabbage, onions and cucumbers are grown with excellent yields. Strawberries are also produced in considerable quantities. Corn, oats and wheat are the main farm crops grown with generally satisfactory results.

The needs of this soil are very similar to those of the preceding type, except that the drainage is generally satisfactory. Liming is required in many cases and the soil should be tested and the proper amount of lime applied according to the indicated need of the soil. The organic matter content should be kept up by the use of crop residues and farm manure. Green manures are also valuable and their use to as great an extent as possible is to be strongly urged. Complete commercial fertilizing materials are not necessary; nitrogenous and potassic fertilizers need not be used in systems of permanent fertility. Phosphorus
fertilizers while of no great value at present must be applied in the near future if the soil is to be kept productive, and their use should therefore be tested under local farm conditions.

The soil can readily be kept productive and with proper treatment with lime and manure, proper rotation of crops and cultivation it can be made more profitably productive at the present time.

**BUCKNER LOAM (38)**

This soil occupies a terrace position along the Mississippi river east of Muscatine, on the east side of the Muscatine slough, on both sides of the Cedar river and on the West Liberty plain. It is a minor soil type covering 3 per cent of the area of the county.

The surface soil to a depth of 12 to 18 inches consists of a black to dark grayish-brown loam to fine loam of mellow structure. The subsoil is a heavy loam to clay loam of a black to dark-brown color which grades into a brown clay loam at 24 to 28 inches and at 3 feet the color becomes a light-brown. In several small areas the surface loam is underlain at about 30 inches by a loamy sand but these areas are of small significance.

The topography of this type varies somewhat with its location but it is generally level to gently rolling. Knolls and ridges of the Knox fine sandy loam occur scattered over the type. Slight depressions are found where the soil is somewhat heavier in texture. On the elevations it is lighter.

The terraces slope gradually toward the streams and the drainage is fair even on the level areas. The surface soil and subsoil both retain moisture well but crops suffer during periods of long-continued drouth.

Corn is the principal crop on this soil and oats, wheat, rye, and barley are grown to a smaller extent. Clover, timothy and cowpeas are grown for hay. Cabbage, tomatoes, potatoes, cucumbers, and onions are the main vegetable crops grown and they are produced mainly on the terrace east of Muscatine. Some watermelons and cantaloupes are produced on this type but their quality is inferior to that of the melons grown on some of the other soils and they mature later. A large part of this soil type is used for pasture.

The needs of this soil for treatment include first the use of lime to remedy its generally acid condition, then the use of manure and crop residues supplemented by leguminous green manures to keep up the organic matter and nitrogen content of the soil, and eventually the addition of phosphorus fertilizers to supply deficiencies in that element and keep the soil permanently fertile.

Where vegetables are grown, applications of commercial fertilizers suitable for special crops may prove quite profitable. The abundant use of farm manure for such crops is also important not only to enrich the soil but to hasten the growth and early maturity of the crop.

With proper treatment the ordinary farm crops produce very satisfactory yields on this soil and vegetables do well when it is fertilized according to their special needs.

**BUCKNER COARSE SAND (39)**

This soil occurs almost exclusively on Muscatine island where it occupies a second-bottom position above ordinary overflow. It is a minor type in the county covering 2.4 per cent of the total area.
The surface soil to a depth of 20 to 30 inches is a brown to dark-brown loamy coarse sand sometimes containing much fine material. The subsoil is a brown to light-brown coarse sand also somewhat loamy in nature but less so than the surface soil and lighter in color.

In topography, this soil is almost level. The drainage is excessive on account of the open, porous nature of the soil and subsoil. Because of the fact that the water table is rather near the surface the soil will withstand drouths fairly well, but irrigation is practiced to some extent to aid in dry seasons and it has proven quite profitable. This soil is very low in plant food and needs careful treatment for successful crop growth.

The chief crops grown are watermelons, cantaloupes, and sweet potatoes although asparagus and many other vegetables do well. Corn and rye are grown mainly to complete rotations rather than for crop yields. Cowpeas are grown for hay.

When the water conditions are satisfactory the chief need of this soil is for organic matter which may be applied as farm manure and green manures. The use of such materials aids considerably in holding moisture in the soil besides making it more fertile and better suited in general for the growth of satisfactory vegetable crops.

Various green crops may be turned under as green manures but the legumes are specially recommended on account of the nitrogen they add to the soil. These materials in addition to abundant amounts of farm manures are the primary means for making this soil fertile. Commercial fertilizing materials prepared to suit the needs of special vegetable crops may also be used and lime should be applied when necessary.

The rotation of crops is essential on this soil for the best growth of truck crops, even more so than where general farm crops are grown on account of the danger of diseased conditions arising in the soil.

General farm crops are grown only to complete the rotations and are of little value compared with vegetable crops. They are not necessary however as rotations of vegetables prove quite as satisfactory.

BUCKNER SANDY LOAM (40)

This soil like the preceding covers 2.4 per cent of the area of the county. It occurs mainly on Muscatine Island and the West Liberty plain, although there are small areas along the Mississippi river east of Muscatine and along the Cedar river. The surface soil is a dark-brown to black sandy loam extending to a depth of 15 to 20 inches. The subsoil grades from a brown to light-brown sandy loam to a brownish-yellow sand at a depth of 2½ to 3 feet and the underlying material is sand or gravelly sand. In topography it is level to gently undulating and the drainage is generally good except in small depressed areas.

This soil is rather poor in plant food and organic matter and needs special treatment to make it productive. It is used chiefly for truck crops although in some places general farm crops grow well. On Muscatine island watermelons, cantaloupes, and sweet potatoes are the chief crops grown. Near Conesville, watermelons and sweet potatoes are grown, to some extent but corn, oats, wheat, and hay crops are more generally grown and yield well. The yields of the truck crops on this soil are exceptionally good although the quality is not as good as on the lighter sandy types.
The needs of this soil are very similar to those of the preceding type. Farm manure should be applied in as large amount as available and green manures used to supplement it. With the abundant use of these materials the organic matter and nitrogen content of the soil may be built up and maintained. Lime should be applied as needed and commercial fertilizing materials prepared for certain crops may be profitably employed. Rotation of the various vegetable crops should be practiced. Where general farm crops are grown the treatment should be similar except that complete commercial fertilizers would probably not prove profitable and incomplete brands supplying the necessary constituents should be used.

BUCKNER SAND (41)

This soil covers 1.6 per cent of the total area of the county and occurs as terraces along the Mississippi and Cedar rivers and on the West Liberty plain but its main occurrence is on Muscatine island.

The surface soil to a depth of 18 to 20 inches is a brown to dark-brown or black loamy sand of medium texture and loose, porous, friable structure. The subsoil is a brown to yellowish-brown or grayish-brown slightly loamy sand medium to coarse in texture grading into a fine sand in many instances within the three-foot zone. Occasionally the surface soil is grayish-brown and the subsoil at 20 to 28 inches may be a yellow to lemon-yellow sand. In small areas, the typical soil may be underlaid by fine gravel or pebbles at a depth of 15 to 24 inches or even nearer the surface, but these areas are relatively unimportant.

The soil is generally flat to gently rolling in topography with occasional depressions where sandy loams occur, and some ridges of lighter sandy material. The drainage is good owing to the open nature of the soil and subsoil. The rather high water-table enables the soil to withstand drought better than might be expected. Irrigation is practiced to some extent and proves very profitable in seasons of insufficient rainfall.

This soil is used primarily for vegetable crops for which it is particularly well suited. Watermelons, cantaloupes, sweet potatoes and asparagus are the chief crops, although other vegetables are grown to some extent. Corn and rye are grown but mainly in the rotations and cowpeas are grown for hay. The yields of watermelons, cantaloupes and sweet potatoes vary with the season and are larger where irrigation is practiced. The soil is poor in plant food and organic matter and needs application of farm manure, green manures, lime and commercial fertilizers just as do the two preceding types.

CALHOUN SILT LOAM (42)

This type covers 1.4 per cent of the area of the county and its chief occurrence is along and east of Wapsinonoc Creek on the West Liberty plain. The surface soil to a depth of 10 to 12 inches is a light grayish-brown to light brownish-gray silt loam of a mellow and friable structure. When exposed to the weather for some time the soil becomes white in color and forms a striking contrast to the dark surrounding soils. The soil grades into a gray or ashy-gray silt layer from 6 to 10 inches in thickness. The subsoil is a heavy, tough, extremely compact and impervious silty clay loam, mottled, dark-gray and yellowish-brown in color beginning at 16 to 20 inches and grading into a silty clay to clay of a mottled or drab color.
Com, oats, wheat, and hay with some rye and barley are the principal farm crops. While the yields of all these crops are fair, they can be increased by proper soil treatment, particularly drainage.

Drainage is very poor on account of the flat topography and heavy, impervious character of the subsoil. The first need for good crop growth therefore is to insure adequate drainage either by ditching or tiling or both. When this is accomplished applications of farm manure will prove extremely valuable in increasing crop growth. Green manures may be used to supplement farm manure and increase the organic matter and nitrogen content of the soil and keep it permanently fertile. Phosphorus will be required in the near future, and might prove useful now. Lime is necessary on this soil and should be applied as required. With proper rotations ordinary farm crops will give satisfactory yields, if the soil is handled as indicated.

**BREMER SILTY CLAY LOAM (43)**

This soil covers 1.3 per cent of the area of the county. It is closely associated with the terrace silt loams and clays and occurs chiefly in the vicinity of Nichols and southeast of West Liberty. The surface soil to a depth of 8 to 12 inches is a black, generally plastic silty clay loam, the upper 2 or 3 inches in some cases being a fine-textured black loam. The subsoil is a heavy, tough plastic black silty clay which at 20 to 30 inches grades into a dark-drab silty clay to clay. Brown to yellowish-brown mottlings are quite common below 24 to 30 inches and occasionally at that depth the subsoil becomes a yellowish-brown or yellowish-mottled clay grading into a yellowish-brown clay.

The topography of the type is generally flat and this together with the impervious character of the subsoil makes the drainage poor. The primary need is for better drainage and great care must be given to the establishment of an adequate drainage system if the soil is to be made productive.

Corn is the chief crop and it yields well. Oats is the main small grain but the yields of grain are small and heavy straw growth frequently causes lodging. Some cabbage and potatoes are grown but not generally on a commercial scale. A large part of the type is in grass. Cattle raising and feeding is conducted extensively on this type.

Farm manure, green manures and lime are of value on this soil while phosphorus will also be needed. The permanent fertility of the soil may be maintained by the use of all these materials, and with satisfactory drainage the soil may be made very productive.

**BREMER CLAY (44)**

This soil covers 1.2 per cent of the area of the county and it occurs on the West Liberty plain being closely associated with the Bremer silty clay loam, the type just described. The boundary lines between these two types are not sharply defined, the gradation from one to the other being very gradual in all cases. There is only one area of this soil and it is about 10 miles in length and one-half to three-fourths of a mile in width. This soil type is popularly called "gumbo."

The surface soil to a depth of 18 to 29 inches is an intensely black heavy clay to silty clay, plastic, tenacious and very impervious. The subsoil is likewise a heavy tough clay to silty clay usually black in color but sometimes it becomes...
Fig. 12. Surface, subsurface and subsoils of five of the individual soil types in Muscatine county

21 Muscatine silt loam
22 Buckner silt loam (colluvial phase)
23 Buckner sand
24 Knox fine sand
25 Bremer clay
somewhat lighter in color in the three-foot zone, grading into a dark-drab, drab-brown, yellowish-brown or gray mottled clay.

In topography this soil is generally flat with a very slight slope toward the center of the depression where ditches have been constructed. It formerly occupied the bottoms of "Elephant Swamp" and "Goose Lake" and the drainage system which has been established was necessarily the first step toward making the soil of agricultural value. Proper drainage and fall plowing have been found effective in making this "gumbo" soil productive at the present time and with such treatment it can be made equal in value to the best land in the state.

Corn is the principal crop. Oats is grown to some extent but the rich soil tends to produce straw rather than grain and lodging is common. Clover and timothy hay yield well on this soil and it also supports good bluegrass pastures. Considerable stock feeding and raising is practiced.

This soil is very high in organic matter and its needs along this line are therefore small although moderate applications of farm manure would be of value in increasing the decomposition processes in the soil. It is basic in reaction and hence is not in need of lime at the present time. If cultivated crops are grown, however, lime will become necessary in the near future and it would be wise to test the soil from time to time to insure the presence of abundance of lime.

The content of phosphorus is not high and this element will eventually need to be applied if the soil is to be kept fertile for the production of general crops. Crop rotation should be followed and while good crops may be grown for several years on this soil as it is naturally very productive, care should be taken that the fertility is maintained for future crops.

BUCKNER FINE SANDY LOAM (45)

This type covers less than one per cent of the total area of Muscatine county. The largest area occurs on a terrace of the Cedar river near Moscow. Other small areas are found, some on Muscatine island. The surface soil is a brown to dark-brown fine sandy loam extending to a depth of 15 to 24 inches, grading gradually into the subsoil which is very similar but lighter in color.

The topography of this soil is flat with small depressions containing the Buckner loam. The natural drainage ranges from good to excessive and in seasons of drouth crops suffer for moisture.

Chiefly truck crops are grown on this soil, watermelons, cantaloupes and sweet potatoes proving very profitable; general farm crops are grown only to complete the rotation, fair yields being secured in favorable seasons. A number of vegetables do well but scarcely any are grown for the market.

The chief needs of this soil are for manure, lime and sufficient moisture. The first may be supplied by farm manure in as large quantities as available supplemented with green manures. Large amounts are necessary to put the soil in the best condition for truck crops and to force a desirable rapid growth. Where the soil is acid, lime should be applied, the amount used being determined by tests. Moisture conditions can be improved by the addition of organic matter and proper cultivation and where these treatments are insufficient irrigation may prove valuable.

When truck crops are grown, complete commercial fertilizers suited for the particular crop may be applied with profit. These materials are frequently
of great value in forcing early growth of truck crops even when con­
siderable amounts of the plant food contained are already present in the soil.
For general farm crops phosphorus fertilizers only will be necessary. By these
methods this soil can readily be made highly productive for truck crops and the
present yields considerably increased.

**BUCKNER FINE SAND (46)**

This soil occupies less than 1 per cent of the total area of the county. It
occurs in terrace positions along the Cedar and Mississippi rivers and on the
West Liberty plain, small areas being found near Moscow, Conesville and on
the Muscatine island. The surface soil to a depth of 16 to 20 inches is a brown
or grayish-brown to dark-brown loamy fine sand. It rests on a similar subsoil,
somewhat less loamy with increasing depth and becoming lighter in color.

The topography of the soil is level but the drainage is good altho not exces­
sive. Various vegetables are grown successfully on this soil and are much more
valuable than general farm crops. At Conesville, watermelons are the chief
crop produced on this type while cantaloupes and sweet potatoes are grown at
Moscow and on Muscatine island. Asparagus and other vegetables are grown
to some extent. Corn and rye are grown mainly to complete the rotation.
Cowpeas are grown to some extent in the Conesville section.

Treatments very similar to those of the preceding type are needed by this soil.
Organic matter in the form of farm manure and green manures is necessary to
put the soil in the best physical condition and make it better suited for the early
and rapid growth of truck crops. Lime should be used as needed and com­
mercial fertilizers suited for vegetables may be applied with profit. If these
methods of treatment are carried out the yields at present secured on this soil
should be increased considerably.

**BUCKNER COARSE SANDY LOAM (47)**

This soil, like the preceding, covers less than 1 per cent of the area of the
county and occurs chiefly on Muscatine island in close association with the
coarse sands. The surface soil is a dark-brown to black coarse sandy loam ex­
tending to a depth of 12 to 18 inches and resting on a dark brown to brown
coarse sandy loam subsoil which becomes less loamy and lighter brown in color
with increasing depth. Occasionally considerable fine gravel occurs in the sub­
soil and in some cases the color approaches a yellowish-brown. The type has a
flat topography but the open nature of the soil and subsoil causes good drainage.

As in the case of the sandy loams truck crops are grown mainly on this soil,
and large yields of watermelons, sweet potatoes and cantaloupes are secured.
Corn and rye are grown to fill in the rotation and some cowpea hay is produced.

The needs of the soil are very similar to those of the fine-grained truck soils
on Muscatine island. Manure in the form of farm manure or as green manure
crops or both should be applied in large amounts not only in order to build up
the low organic matter content and to keep it at the optimum but also to make
the physical conditions in the soil, especially the moisture retaining capacity,
more satisfactory. The soil is generally very acid in reaction and in need of
lime. Sufficient applications of this material should be made to insure the
proper soil conditions for the special crop to be grown.
Commercial fertilizing materials, especially designed to meet the needs of certain crops may be profitably used in many cases in addition to the use of manure and green manure. Such fertilizers may serve a two-fold purpose in supplying plant food and in forcing the crop to earlier growth and maturity.

With proper attention this soil can be made productive and the yields of truck crops more profitable than at present.

**SWAMP AND BOTTOMLAND SOILS**

There are eleven types of soil included under this group in Muscatine county if the riverwash, muck, and marsh, which are hardly soil types, are included.

Together they cover 34,048 acres or 12.4 per cent of the area of the county, several types being very unimportant from the agricultural standpoint.

**WABASH SILTY CLAY LOAM (48)**

This is the most important bottomland soil. It covers 4.6 per cent of the total area of the county, occurring as first bottoms along the Mississippi river, Muscatine slough, the Cedar river, Wapsinonoc creek and as islands in the Mississippi river. The most extensive areas are along the Cedar river and Muscatine slough.

The surface soil to a depth of 8 to 15 inches consists of a black silty clay loam to clay loam which is sticky and plastic when wet and becomes compact and hard upon drying out. The subsoil is slightly lighter in color varying from a silty clay loam to a silty clay. In some instances at about 28 to 30 inches it passes into a brownish fine sand loam to sandy loam, which grades into a loamy fine sand. The color frequently changes into a mottled brown and gray or drab where the heavy material continues through the three-foot section.

The topography of the type is nearly flat with slight slope toward the streams. Depressions occur which are filled with water when the rivers overflow. Sloughs and drainage ways occur near the larger streams and these are likewise flooded at times of high water. Drainage is poor, and on account of the slight slope, ditching and tiling are hardly practicable in most cases.

The greater part of the soil is sufficiently distant from the streams to be overflowed only by very high water. When timbered it is used only for pasture, but those areas above frequent overflow may be cultivated and ordinary crops grown. Corn, oats, rye, and wheat do fairly well under such conditions. Some hay is grown also.

The needs of the soil when cultivated include first, drainage, which is of special importance; liming to remedy acidity and manuring to benefit the physical condition of the soil and increase the decomposition processes and to supply organic matter and plant food. Green manuring is of value for the same reasons. Fertilizers are commonly of little value altho phosphorus would be necessary in a system of permanent fertility and this, together with lime, manure and the best rotation of crops would permit the continued growth of satisfactory crops.

**WABASH LOAM (49)**

This soil covers 2.9 per cent of the total area of the county and is of minor importance. It occurs in the first bottom of the Cedar river and along Muscatine slough. The surface soil is a black to dark-brown loam extending to a depth of 10 to 14 inches and is quite friable in structure. The subsoil grades from a
black to dark-brown silty clay loam into a silty clay at 20 to 24 inches. In some places at about 24 to 26 inches there is a sandy clay loam or loam which grades into a sandy loam and this in turn grades into a loamy fine sand at the three-foot depth. Small pockets and layers of sand occur throughout the type, and these are moved about by the water during periods of overflow.

The topography is generally flat with very little slope toward the streams. The drainage although slightly better than on the silty clay loam. The forested areas are used for pasture and general farm crops are grown on the other areas which are not subject to frequent overflow.

Corn is the main crop but some wheat, rye, oats, and hay are grown also. All these crops do fairly well when the soil is drained and with proper treatment of the soil yields may be increased.

The needs of the soil are very similar to those of the silty clay loam and include liming, manuring and eventually, the addition of phosphorus. Drainage is of course the first essential and good crop growth cannot be secured where this is not provided.

CASS LOAM (18)

This soil covers 1 per cent of the total area of the county. It occurs as first bottoms chiefly along the Cedar river. One area is found along the Muscatine slough, and one along the Mississippi river.

The surface soil is a black or dark brown loam or fine loam to a depth of 6 to 14 inches, and is quite friable, but compact and hard when dry. The subsoil is a loose, grayish-brown to brownish-gray clay loam and there is generally an abrupt change from the surface to the subsoil, although occasionally there is an intervening layer of a sandy loam. Layers and pockets of sand frequently occur in the surface soil. The topography is flat and the type is overflowed by high water. The main value of the soil is for pasturage and timber, and it is not of agricultural importance.

WARASH SILT LOAM (26)

This soil covers 1 per cent of the total area of the county. It occurs along the courses of the streams and is generally subject to overflow, constant changes in the material occurring with each overflow. Along the smaller streams it is a gray to black silt loam overlying a subsoil of a similar or heavier texture. The largest area is mapped along Pine creek where it is a gray to dark-drab in color and somewhat heavier in texture overlying a subsoil of dark-gray to dark-brown sticky, impervious clay at a depth of 6 to 20 inches.

Along the Mississippi river the soil varies considerably in texture but is usually quite heavy except for a few sandy loam spots. The subsoil is a plastic sticky impervious clay loam or clay of dark-gray, drab, pink, or black color. In this location the soil has no agricultural value but in other cases it serves for pasture.

CASS SAND (50)

This soil covers less than 1 per cent of the area of the county and occurs mainly along the first bottoms of the Cedar river, although other small areas are also found.

The surface soil to a depth of 6 to 10 inches consists of a grayish-brown to light-brown or brownish-gray sand of medium to coarse texture and only slightly loamy in structure. The subsoil is a rusty brownish-gray to grayish-brown coarse sand containing some fine gravel. The topography is flat and the type
MUSCATINE COUNTY SOILS

is subject to overflow and consequent change in surface material. It has no agricultural value.

CASS SILTY CLAY LOAM (51)

This type covers less than 1 per cent of the area of the county. It occurs as first bottoms mainly along the Cedar river and to a less extent along the Muscatine slough and the Mississippi river. It is found along drainage ways, in depressions and old slough channels and on islands in the Cedar river.

The surface soil is a black silty clay loam extending to a depth of 6 to 18 inches. The subsoil consists of a grayish-brown to brownish-gray coarse sand to sand and in some cases contains some fine gravel. In some small areas the soil is more nearly a silty clay or clay than a silty clay loam, but these areas are too small to map. The soil is compact, tough, and tenacious and generally quite impervious to water. The topography is flat but is well dissected by old sloughs, old river channels and drainage ways. The soil is frequently overflowed and the character of the surface material constantly changed. It is used mainly for pasture and is of no value for cultivated crops.

WABASH SANDY LOAM (52)

This soil covers only 0.3 per cent of the area of the county. It occurs in several very small areas, the largest south of Cedar river near Simpson’s bridge.

The surface soil is a black to dark-gray sandy loam extending to a depth of 8 to 12 inches and rests on a black heavy loam to clay loam. Some areas consist of 8 to 12 inches of brown or dark-brown sandy loam or fine sandy loam overlying a brown clay loam which is quite compact. Occasionally a sandy layer occurs between the surface and subsoil, at 24 to 30 inches, and in such cases the subsoil is a silty clay loam rather than a clay loam.

The topography is flat, but the areas are dissected by old slough and drainage ways. The soil is only fairly well drained. It is subject to overflow, but except for a small pasture area is all under cultivation, general farm crops being grown. Corn is the principal crop. Wheat and oats are the chief small grains although some rye is grown. Hay is also grown to some extent.

The needs of the soil include liming, the use of manure and eventually the application of phosphorus. These treatments following better drainage and protection from overflow should make the soil satisfactorily productive.

CASS SANDY LOAM (19)

This soil covers 0.3 per cent of the area of the county. It occurs entirely along the Cedar river. The surface soil is a brown to dark-brown sandy loam extend-
ing to a depth of 8 to 15 inches and is generally friable in structure. The subsoil is yellowish-brown in color and varies from a loamy sand to a sandy clay in texture. In several small areas, the soil is a grayish-brown to brown sandy loam and is underlaid at 24 to 30 inches by a brown fine sand.

In topography it is flat, but somewhat dissected by old sloughs and drainage ways. It is subject to overflow. Where protection from overflow is provided by levees, the soil is cultivated and general farm crops, mainly corn and rye, are grown. Onions are also grown. All crops are apt to suffer from drought, as on account of its open nature the soil does not retain water well.

The soil needs, first, protection from overflow and, second, means of supplying the water needed by crops, if it is to be used for cultivated crops. Lime is necessary to neutralize its acidity and farm manure and green manure would be of value in improving the physical conditions for crop growth by retaining moisture in the soil and in supplying plant food. For permanent fertility phosphorus would also need to be supplied and rotation of crops should be followed. Truck crops would probably prove more valuable than general farm crops on this soil.

RIVER WASH (53)

Riverwash occurs chiefly as islands and sand bars in the Cedar river and to some extent as islands or parts of islands in the Mississippi. It is found along the channel of the Cedar river and also in abandoned channels of this stream.

It covers 0.2 per cent of the area of the county and is of no agricultural importance. It comprises brown, grayish-brown or gray sand of medium or coarse texture which extends more than 3 feet in depth. It is all subject to overflow and is constantly changing in character.

MUCK (21)

Muck occurs in several small areas, covering 0.2 per cent of the total area of the county. Some of the largest areas are found near Adams, Saulsbury Bridge and southeast of Atalissa.

The surface material consists of 6 to 24 inches of black well-decomposed organic matter mixed with mineral material, mainly silt from the surrounding upland. The underlying material is a black to dark-drab mucky plastic, impervious clay containing some coarse sand of a grayish-brown to light-grayish color. In some cases there is no clay, a coarse sandy loam or coarse sand making up the subsoil. Several small areas of typical peat are included in the muck area. In such material, the surface to 24 to 36 inches is slightly decomposed, coarse organic matter with little mineral matter overlying coarse sandy loam or coarse sand.

Muck is generally in a wet, boggy condition, and must be drained to be made of value agriculturally. Subsequent treatments necessary consist in cultivation, the use of farm manure and proper systems of cropping. (See Bull. 157.)

MARSH (54)

Two areas of Marsh are mapped, one east of Conesville and the other southeast of Nichols. They occupy first-bottom positions at the edge of West Liberty plain and consist of former ponds and shallow lakes, which are filled with the remains of former plant growth, consisting of a brownish peat-like substance. Water covers the greater part of the areas during the wet seasons and they are of no value agriculturally.
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, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

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
TABLE I. PLANT FOOD IN CROPS AND VALUE

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Food Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$12.00</td>
<td>$1.53</td>
<td>$0.84</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn crop</td>
<td>......</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>......</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats crop</td>
<td>......</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Barley grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley crop</td>
<td>......</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>......</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>19</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

Loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of 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 through proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

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

**THE ROTATION OF CROPS**

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

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

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotations. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be
hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under they not only supply organic matter to the soil, but they also increase the nitrogen content.

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

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

**MANURING**

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

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

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

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

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

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

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.
By using all the crop residues, all the manure produced on the farm, and giving well inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions given in bulletin 151, referred to above.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one to two tons per acre.

SOIL AREAS IN IOWA

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

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.
The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa to-day, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching action in the time which has elapsed since its formation.

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

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows 1 according to the Bureau of Soils:

- **Organic Matter**: All partially destroyed or undecomposed vegetable and animal material.
- **Inorganic Matter**: Stones—over 32 mm.*
  - Gravel—32—2.0 mm.
  - Very coarse sand
  - Coarse Sand—1.0—0.5 mm.
  - Medium Sand—0.5—0.25 mm.
  - Fine Sand—0.25—0.10 mm.
  - Very fine Sand—0.10—0.05 mm.
  - Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The different general groups of soils by types are indicated thus by the Bureau of soils:2

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

* 25 mm. equals 1 in.
1 Bur. of Soils Field Book.
2 1 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.