Soil Survey of Iowa, Report No. 7—Van Buren County Soils

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SOIL SURVEY OF IOWA
VAN BUREN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 7
December, 1918
Ames, Iowa
# IOWA AGRICULTURAL EXPERIMENT STATION

## PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

### BULLETINS

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

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>78</td>
<td>Drainage Conditions in Iowa.*</td>
</tr>
<tr>
<td>82</td>
<td>The Principal Soil Areas of Iowa.*</td>
</tr>
<tr>
<td>95</td>
<td>The Maintenance of Fertility with Special Reference to the Missouri Loess.*</td>
</tr>
<tr>
<td>98</td>
<td>Clover Growing on the Loess and Till Soils of Southern Iowa.*</td>
</tr>
<tr>
<td>119</td>
<td>The Gumbo Soils of Iowa.*</td>
</tr>
<tr>
<td>150</td>
<td>The Fertility in Iowa Soils (Popular edition).</td>
</tr>
<tr>
<td>151</td>
<td>Soil Acidity and the Liming of Iowa Soils.*</td>
</tr>
<tr>
<td>157</td>
<td>Improving Iowa's Peat and Alkali Soils.</td>
</tr>
<tr>
<td>161</td>
<td>Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa.</td>
</tr>
<tr>
<td>167</td>
<td>Rotation and Manure Experiments on the Wisconsin Drift Soil Area.</td>
</tr>
<tr>
<td>177</td>
<td>The Alkali Soils of Iowa.</td>
</tr>
<tr>
<td>183</td>
<td>Soil Erosion in Iowa (In press).</td>
</tr>
</tbody>
</table>

### CIRCULARS

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Liming Iowa Soils.*</td>
</tr>
<tr>
<td>7</td>
<td>Bacteria and Soil Fertility.</td>
</tr>
<tr>
<td>8</td>
<td>The Inoculation of Legumes.</td>
</tr>
<tr>
<td>9</td>
<td>Farm Manures.</td>
</tr>
<tr>
<td>10</td>
<td>Green Manuring and Soil Fertility.</td>
</tr>
<tr>
<td>15</td>
<td>Testing Soils in Laboratory and Field.</td>
</tr>
<tr>
<td>24</td>
<td>Fertilizing Lawn and Garden Soils.</td>
</tr>
<tr>
<td>49</td>
<td>Soil Inoculation.</td>
</tr>
<tr>
<td>51</td>
<td>Soil Surveys, Field Experiments and Soil Management in Iowa.</td>
</tr>
</tbody>
</table>

### RESEARCH BULLETINS

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Chemical Nature of the Organic Nitrogen in the Soil.*</td>
</tr>
<tr>
<td>2</td>
<td>Some Bacteriological Effects of Liming.*</td>
</tr>
<tr>
<td>4</td>
<td>Bacterial Activities in Frozen Soils.*</td>
</tr>
<tr>
<td>5</td>
<td>Bacteriological Studies of Field Soils, I.*</td>
</tr>
<tr>
<td>6</td>
<td>Bacteriological Studies of Field Soils, II.*</td>
</tr>
<tr>
<td>8</td>
<td>Bacteria at Different Depths in Some Typical Iowa Soils.*</td>
</tr>
<tr>
<td>9</td>
<td>Amino Acid and Acid Amides as Sources of Ammonia in Soils.*</td>
</tr>
<tr>
<td>11</td>
<td>Methods for the Bacteriological Examinations of Soils.*</td>
</tr>
<tr>
<td>13</td>
<td>Bacteriological Studies of Field Soils, III.</td>
</tr>
<tr>
<td>17</td>
<td>The Determination of Ammonia in Soils.</td>
</tr>
<tr>
<td>18</td>
<td>Sulfation in Soils.</td>
</tr>
<tr>
<td>25</td>
<td>Bacterial Activities and Crop Production.</td>
</tr>
<tr>
<td>24</td>
<td>Studies in Sulfation.</td>
</tr>
<tr>
<td>35</td>
<td>Effects of Some Manganese Salts on Ammonification and Nitrification.</td>
</tr>
<tr>
<td>36</td>
<td>Influence of some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.</td>
</tr>
<tr>
<td>43</td>
<td>The Effect of Sulphur and Manure on the Availability of Rock Phosphate in Soil.</td>
</tr>
<tr>
<td>44</td>
<td>The Effect of Certain Alkali Soils on Ammonification.</td>
</tr>
<tr>
<td>45</td>
<td>Soil Inoculation with Azotobacter.</td>
</tr>
</tbody>
</table>

### SOIL REPORTS

<table>
<thead>
<tr>
<th>No.</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bremer County.</td>
</tr>
<tr>
<td>2</td>
<td>Pottawattamie County.</td>
</tr>
<tr>
<td>3</td>
<td>Muscatine County.</td>
</tr>
<tr>
<td>4</td>
<td>Webster County.</td>
</tr>
<tr>
<td>5</td>
<td>Lee County.</td>
</tr>
<tr>
<td>6</td>
<td>Sioux County.</td>
</tr>
<tr>
<td>7</td>
<td>Van Buren County.</td>
</tr>
<tr>
<td>8</td>
<td>Clinton County.</td>
</tr>
<tr>
<td>9</td>
<td>Scott County.</td>
</tr>
<tr>
<td>10</td>
<td>Ringgold County. (In press).</td>
</tr>
</tbody>
</table>
SOIL SURVEY OF IOWA

Report No. 7—VAN BUREN COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of G. E. Corson and H. W. Reid

A Van Buren county farmstead

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CONTENTS

Introduction ....................................................................................................... 5
The geology of Van Buren county .................................................................... 7
Physiography and drainage........................................................................... 8
The soils of Van Buren county ...................................................................... 9
The fertility in Van Buren county soils .......................................................... 10
  The surface soils ....................................................................................... 10
  The subsurface soils and subsoils .............................................................. 13
Greenhouse experiments .............................................................................. 14
Field experiment with gumbo ...................................................................... 18
The needs of Van Buren county soils as shown by laboratory and greenhouse
tests ........................................................................................................... 21
  Liming ..................................................................................................... 21
  Manuring ................................................................................................. 22
  Commercial fertilizers ............................................................................. 23
  Drainage .................................................................................................. 24
  Crop rotation ............................................................................................ 25
The prevention of erosion ............................................................................ 25
  Dead furrows ......................................................................................... 27
  Small gullies ............................................................................................ 27
  Large gullies ........................................................................................... 29
  Bottomlands ............................................................................................ 30
  Hillside erosion ....................................................................................... 30
Individual soil types in Van Buren county .................................................. 31
  Drift soils ............................................................................................... 31
  Loess soils .............................................................................................. 32
  Terrace soils ........................................................................................... 36
  Swamp and bottomland soils .................................................................. 40
Appendix: The soil survey of Iowa .............................................................. 43
Characteristic topography of Grundy Silt Loam. Shelby Loam along draws
Van Buren County is located in southeastern Iowa bordering the state of Missouri on the south and Lee county, which is in the southeast corner of the state, on the east. It is entirely within the Southern Iowa loess soil area and the soils are mainly loessial in character.

The county has an area of 482 square miles, or 308,480 acres, of which area 258,494 acres, or 83.7 percent is in farm land. There is a total of 1,834 farms in the county with an average size of 140.9 acres.

The utilization of the farm land of the county is shown by the following figures taken from the Iowa Yearbook of Agriculture of 1916:

<table>
<thead>
<tr>
<th>Acreage in pasture</th>
<th>131,810</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in farm buildings, feed lots and public highways</td>
<td>8,069</td>
</tr>
<tr>
<td>Acreage in orchards</td>
<td>1,778</td>
</tr>
<tr>
<td>Acreage in gardens</td>
<td>1,240</td>
</tr>
<tr>
<td>Acreage in waste land</td>
<td>112,630</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>688</td>
</tr>
</tbody>
</table>

The type of agriculture followed in Van Buren county is chiefly livestock farming. Beef cattle, hogs, sheep and to some extent horses and mules are raised in the county. Crop production is mainly for the support of the animal industries.

A small area in the county is in waste land and it is highly desirable that such land be reclaimed and made productive. It is not possible to recommend definite methods for the reclamation of waste land in general as the causes of unproductiveness vary considerably but in the discussion of individual soil types given later in this report the treatments required to make the various soils more productive will be given. More specific information regarding the best treatments for any particular soil may be secured from the Soils Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Van Buren county in the order of their importance are corn, hay, oats, wheat, rye, alfalfa and potatoes. Average data regarding the production and value of these crops in the county are given in table I.

Corn is the most important crop in the county both from the standpoint of acreage and value, the average yields amounting to about 28 bushels per acre. Most of the corn produced in the county is utilized as a feed for livestock, only a small amount being sold outside of the county.

The second crop of importance is hay. Very little wild hay is grown but there is a large acreage in timothy, clover or a mixture of the two. Their average yields amount to 1.5 tons per acre. Most of the hay crop is employed for feeding purposes.

1 Soil Survey of Van Buren county, Iowa, by Clarence Lounsbury of the U. S. Dept. of Agr. and H. W. Reid of the Iowa Agricultural Experiment Station.
TABLE I. ACREAGE, YIELDS AND VALUES OF FARM CROPS IN VAN BUREN COUNTY

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm land in county</th>
<th>Bushels or tons per acre</th>
<th>Total bush. or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>50,800</td>
<td>19.6</td>
<td>28</td>
<td>1,422,400</td>
<td>$0.81</td>
<td>$1,152,144</td>
</tr>
<tr>
<td>Oats</td>
<td>17,500</td>
<td>6.7</td>
<td>24</td>
<td>420,000</td>
<td>$0.49</td>
<td>205,800</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>5,500</td>
<td>2.1</td>
<td>14</td>
<td>77,000</td>
<td>$1.58</td>
<td>121,680</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>100</td>
<td>.03</td>
<td>8</td>
<td>800</td>
<td>$1.54</td>
<td>1,232</td>
</tr>
<tr>
<td>Barley</td>
<td>20</td>
<td>.03</td>
<td>24</td>
<td>480</td>
<td>$0.90</td>
<td>432</td>
</tr>
<tr>
<td>Rye</td>
<td>1,900</td>
<td>0.7</td>
<td>13</td>
<td>24,700</td>
<td>$1.15</td>
<td>28,405</td>
</tr>
<tr>
<td>Potatoes</td>
<td>36,000</td>
<td>13.9</td>
<td>1.5</td>
<td>54,000</td>
<td>$9.00</td>
<td>486,000</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>600</td>
<td>0.2</td>
<td>2.5</td>
<td>1,500</td>
<td>$11.71</td>
<td>17,565</td>
</tr>
<tr>
<td>Pasture</td>
<td>131,810</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Oats ranks third in value among all the crops of the county and average yields of 24 bushels per acre are secured. As in the case of corn and hay this crop is used almost entirely on farms for feeding purposes.

Wheat is grown to some extent, the winter varieties being most commonly used. The yields secured average 14 bushels per acre.

The acreage of alfalfa is being increased in the county, as its value is becoming more generally recognized. Average yields of 2.5 tons per acre are secured.

Rye is grown on a small area and average yields of 13 bushels per acre are secured. Barley is of minor importance, being grown only to a small extent. Potatoes are likewise grown on a small area, and are produced mainly for home consumption.

Minor crops which are small sources of income include apples, pears, strawberries, various bush berries, cucumbers, and tomatoes, the two latter crops being grown mainly in the southern and southeastern parts of the county.

Van Buren county is largely a livestock county and the following figures taken from the Iowa Yearbook of Agriculture of 1916 give some idea of the extent of the livestock industry.

<table>
<thead>
<tr>
<th>Livestock</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses (all ages)</td>
<td>10,854</td>
</tr>
<tr>
<td>Mules (all ages)</td>
<td>859</td>
</tr>
<tr>
<td>Swine (July 1, 1916)</td>
<td>40,300</td>
</tr>
<tr>
<td>Cattle (cows and heifers kept for milk)</td>
<td>7,986</td>
</tr>
<tr>
<td>Cattle (other cattle not kept for milk)</td>
<td>13,196</td>
</tr>
<tr>
<td>Cattle (total, all ages)</td>
<td>27,546</td>
</tr>
<tr>
<td>Sheep (all ages, on farms)</td>
<td>31,704</td>
</tr>
<tr>
<td>Sheep (shipped in for feeding)</td>
<td>463</td>
</tr>
<tr>
<td>Sheep (total pounds wool clipped)</td>
<td>220,362</td>
</tr>
</tbody>
</table>

The most important livestock interests in the county are the raising of beef cattle, hogs, and sheep. Horses and mules are also raised in considerable numbers. Dairying is only incidental in most cases to general stock raising. The excellent pasturage makes stock raising particularly profitable and the crops produced are used as feed on the farms.

Altho the value of land in Van Buren county is variable it is advancing very rapidly. The land in the more productive soil areas sells for $60 to $150 per acre, while less desirable lands are held as low as $30 to $40 per acre. In general the broad level area in the northeastern part has a somewhat higher value than that in other parts of the county.

1 Iowa Yearbook of Agriculture, 1916.
In general the soils of Van Buren county are satisfactorily productive, but with proper methods of soil treatment the yields of farm crops may be increased. The application of manure has been found by experiments and farm experience to bring about large increases in crop yields. Many of the soils are acid in reaction and lime should be applied for the best crop production. Drainage is sometimes necessary. The use of phosphorus fertilizers may be profitable now and certainly will be needed in the future. The field experiments under way on the main soil types in the county will show the value of the use of manure, lime, phosphorus fertilizers and a complete commercial fertilizer. The results of these field studies will be published later in a supplementary report.

**THE GEOLOGY OF VAN BUREN COUNTY**

The bedrocks underlying the soils of Van Buren county are buried so deeply under the covering of drift and loess that they have no influence whatever on the soil conditions in the county.

The entire county was once covered by a great glacier which upon its retreat left behind a vast quantity of material which it had accumulated from the land over which it passed. This glacial material or drift is known as Kansan drift. It extends to a depth of 50 to 100 feet and is somewhat thicker in the southwestern than in the northeastern part of the county. It consists of two well-marked divisions of bowlder clays; a lower blue clay and an overlying yellow clay, both of which include more or less sand and gravel. There is no well defined boundary between these two clays but they grade gradually into each other. The lower clay is dark-blue, compact and hard and filled with pebbles and small bowlders. It varies in thickness from a few feet up to 75 feet. The overlying clay is usually a buff to reddish-yellow in color and it frequently con-

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1 C. H. Gordon — **Ia. Geol. Rep. 4:197.**

Fig. 1. Des Moines river at Keosauqua
Soil Survey of Iowa

It contains sandy areas. It contains more life than the underlying material. Usually the yellow clays vary from 25 to 50 feet in thickness.

At some previous geological time, a layer of fine dust-like, ash-colored material, called loess was deposited over the glacial drift. Much of this material has been washed away since its deposition, especially along the Des Moines river and the remainder forms a thin covering over the upland areas. This loess covering is usually 2 or 3 feet and never more than 10 feet in depth.

Along the rivers in the county there are terrace soils, or former bottomlands which have been raised above the overflow of the streams by the shrinkage in volume of water or by the deepening of the channel of the stream. There are also several bottomland soils, occurring adjacent to the streams and subject to overflow.

Both the terrace and bottomland soils are mixtures of materials of drift and loess origin and vary considerably in characteristics. They are both the result of stream action on the original covering of drift and loess over the county.

Physiography and Drainage

Van Buren county is roughly divided into two triangular areas by the Des Moines river which cuts the county diagonally from northwest to southeast. In the northeastern corner the topography is rough and broken on account of the erosion of the streams flowing into Big Cedar creek. The southwestern corner is cut by the narrow valleys of Fox and Little Fox rivers. The general slope of the entire county is toward the southeast.
VAN BUREN COUNTY

The Des Moines river drains probably three-fourths of the area of the county. The wide valley of this river and the strip of more or less eroded land which borders it constitute over one-half the area of the county.

With the Des Moines river and its numerous tributaries, the Fox and Little Fox rivers in the southwestern part of the county and the Big Cedar creek in the northeastern part, each with tributary streams bring about the drainage of the county. The location of these main streams and their tributaries is shown on the accompanying map. The drainage of the county as a whole is fairly good. Only on the level upland in the northeastern part is it unsatisfactory and there the use of tile may sometimes be of value.

THE SOILS OF VAN BUREN COUNTY

There are four groups of soils in Van Buren county — drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils consist of material deposited by retreating glaciers. Loess soils are deposits of fine dust-like material probably made by the wind at some previous period when climatic conditions were very different than at present. Terrace soils are old bottomlands now raised above overflow by the deepening of the river channels. Bottomland soils are made up of alluvial material and vary in composition.

The areas of the different groups of soils in Van Buren county are shown in table II.

| TABLE II. AREAS OF GROUPS OF SOILS IN VAN BUREN COUNTY |
|-----------------------------------------------|----------|---------|
| Drift soils                                    | 18,074   | 5.9     |
| Loess soils                                    | 251,494  | 81.6    |
| Terrace soils                                  | 7,360    | 2.3     |
| Swamp and bottomland soils                     | 31,552   | 10.2    |
| **Total**                                     | **308,480** | **...** |

The loess soils cover by far the largest area in the county, over 81 percent of the total acreage. There is only one drift soil but it is quite extensive in acreage. The swamp and bottomland soils are likewise extensive. The terrace soils are small in area and relatively unimportant.

The various soil types included among these large groups of soils are listed in table III together with the acreage of each type. The characteristics of the soils which serve to distinguish them as separate types, are given in the appendix to this report.

The only drift soil is the Shelby loam which is found on the eroded areas bordering on some of the streams in the county. There are six loess soils, the Clinton silt loam with the broken phase being the most extensive type while the Grundy silt loam is second in extent. The Grundy clay loam, Marion silt loam and Lindley loam are all minor in area, but important upland soils.

Of the four terrace soils, the Calhoun silt loam is the most extensive. The other types are very small in area and minor in importance. There are four swamp and bottomland soils — all belonging to the Wabash series. The silt loam is the most extensive but the loam, clay loam and fine sandy loam are all important soils in the county.

Most of these soils are rolling in topography and the drainage of the county as a whole is good. Only on the Grundy clay loam which occurs mainly in the
### TABLE III. TYPES OF VAN BUREN COUNTY SOILS AND THEIR AREAS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Types</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>18,074</td>
<td>5.9</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>72,256</td>
<td>42.4</td>
</tr>
<tr>
<td>80A</td>
<td>Clinton silt loam (broken phase)</td>
<td>58,240</td>
<td>36.4</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>113,152</td>
<td>64.2</td>
</tr>
<tr>
<td>67</td>
<td>Marion silt loam</td>
<td>3,540</td>
<td>1.2</td>
</tr>
<tr>
<td>68</td>
<td>Grundy clay loam</td>
<td>3,456</td>
<td>1.1</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>550</td>
<td>0.1</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>5,696</td>
<td>1.8</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>704</td>
<td>0.2</td>
</tr>
<tr>
<td>46</td>
<td>Buckner fine sand</td>
<td>576</td>
<td>0.2</td>
</tr>
<tr>
<td>82</td>
<td>Buckner gravelly sandy loam</td>
<td>384</td>
<td>0.1</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>14,912</td>
<td>4.8</td>
</tr>
<tr>
<td>40</td>
<td>Wabash loam</td>
<td>8,898</td>
<td>2.9</td>
</tr>
<tr>
<td>63</td>
<td>Wabash clay loam</td>
<td>4,352</td>
<td>1.4</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>3,592</td>
<td>1.1</td>
</tr>
</tbody>
</table>

The northeastern part of the county is the drainage poor and in that type the topography is flat and the soil itself is heavy and impervious. With this exception the soils in the county do not need artificial drainage.

### THE FERTILITY IN VAN BUREN COUNTY SOILS

Samples were taken from all but two of the soil types in Van Buren county and their plant food content determined. The Marion silt loam and the Lindley loam were not analyzed as they are minor in extent. Three samples were taken from all the major types while only one sample was drawn from the minor types. All the samples were secured with care that they should represent the soil type and that any variations due to local conditions or recent treatments be eliminated. The soils were sampled at three depths — 0-6 2/3 inches, 6 2/3 to 20 inches, and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil respectively. The samples were analyzed for total phosphorus, total nitrogen, organic carbon and inorganic carbon. The official methods were employed for the phosphorus, nitrogen, and carbon determinations and the Veitch method was used for the limestone requirement determinations.

### THE SURFACE SOILS

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

Phosphorus is low in all the soils of the county, only one type, the Wabash clay loam, showing more than 1500 pounds per acre. Most of the types have much less than that amount present in them. There is no apparent relation between the phosphorus content of the soils in the various soil groups. The drift soil, the Shelby loam, is the lowest of any of the types. The terrace soils seem to be somewhat higher than the loess soils but the difference is not great. The swamp and bottomland soils with the exception of the Wabash clay loam average about the same as the other groups.
### TABLE IV. PLANT FOOD IN VAN BUREN COUNTY, IOWA, SOILS

Pounds per Acre of Two Million Pounds of Surface Soil (0-6"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,095</td>
<td>2,860</td>
<td>32,570</td>
<td>trace</td>
<td>6,800</td>
</tr>
<tr>
<td>80A</td>
<td>Clinton silt loam (broken phase)</td>
<td>1,010</td>
<td>2,010</td>
<td>18,650</td>
<td>0</td>
<td>7,200</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,050</td>
<td>3,493</td>
<td>44,220</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>68</td>
<td>Grundy clay loam</td>
<td>1,190</td>
<td>3,700</td>
<td>56,870</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,220</td>
<td>3,300</td>
<td>39,480</td>
<td>0</td>
<td>8,000</td>
</tr>
<tr>
<td>46</td>
<td>Buckner fine sand</td>
<td>1,110</td>
<td>1,800</td>
<td>21,130</td>
<td>0</td>
<td>3,600</td>
</tr>
<tr>
<td>42</td>
<td>Buckner gravelly sandy loam</td>
<td>1,190</td>
<td>1,900</td>
<td>18,800</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,220</td>
<td>3,260</td>
<td>31,490</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,090</td>
<td>2,460</td>
<td>29,710</td>
<td>0</td>
<td>4,800</td>
</tr>
<tr>
<td>63</td>
<td>Wabash clay loam</td>
<td>1,640</td>
<td>3,820</td>
<td>44,860</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>1,205</td>
<td>2,070</td>
<td>24,950</td>
<td>210</td>
<td>0</td>
</tr>
</tbody>
</table>

These results indicate that phosphorus fertilizers will undoubtedly be needed on the soils of this county in the future, and indeed may prove valuable now. When the content of phosphorus becomes as low as it is in these soils, it is quite probable that crops are not receiving as much of that element in an available form as is necessary for the best crop production. While it cannot be definitely stated that phosphorus fertilizers would prove profitable, it is highly desirable that tests of such materials be made on the farm to ascertain the value of their use. The field tests now under way, the results of which will be published later, will throw some light on this problem but farmers are urged to test the use of phosphatic fertilizers on their own farms.

There is a much better supply of nitrogen in the soils of the county than is the case with phosphorus. None of the soils, however, are so abundantly supplied with that element that the maintenance of the supply can be disregarded. The use of commercial nitrogenous fertilizers, however, is probably unnecessary inasmuch as the turning under of well-inoculated legumes as green manures is a cheaper method of increasing the nitrogen supply of soils. Farm manure and crop residues such as straw and stover aid materially in keeping up the nitrogen content in soils, but at best they only return to the land a part of the nitrogen which was removed by the crops fed on the farm. Even under the best conditions there are some losses in nitrogen and the stock in the soil gradually decreases. Hence the importance of using leguminous green manures is evident. The soils of Van Buren county would undoubtedly be improved in many cases by the application of such materials now and eventually they will be absolutely necessary.

The organic carbon in the soils of the county, like the nitrogen, is not particularly high. These two constituents are always closely related and if one is low the other is apt to be low also. The color of a soil indicates quite definitely the content of organic matter and nitrogen. If a soil is light in color, it is known to be deficient in organic matter and in nitrogen and methods of
treatment should be adopted which will build up the soil in both constituents. Van Buren county soils should, therefore, receive applications of farm manure in as large amounts as practicable and crop residues should all be returned to the soils to keep them supplied with organic matter. Leguminous green manures should also be used to aid in keeping up the organic matter content and to increase the nitrogen supply.

The relation between the carbon and nitrogen in some of the soils of the county is evidently such as to prevent the decomposition processes from proceeding sufficiently rapidly to keep the production of available plant food at the optimum for crop production. The Clinton silt loam (broken phase), the Jackson silt loam and several other minor types are apparently especially in need of treatment to increase the decomposition of the organic matter. Farm manure is the best material to use on such soils for it not only adds organic matter and plant food but it also contains numerous bacteria and other micro-organisms which bring about a rapid increase in the decomposition of the organic matter and hence stimulate the production of available plant food thus serving a three-fold purpose.

There is no inorganic carbon present in the soils of the county except for a small amount in one case. The soils are evidently not supplied with a lime content which would prevent them from becoming acid and determinations show that a large amount of lime is necessary to remedy the acidity present in the soils. In only one case was there no need for lime and in that instance the amount of lime present in the soil is so low that acidity will soon occur. Van Buren county soils are all apt to be in need of lime to put them in the best condition for crop growth and should be tested for acidity and lime applied as necessary. The actual amount needed by any one soil should be determined.
for that particular soil. There is a wide variation in the need for lime and even average figures such as those in table IV based on a large number of analyses should not be considered as more than indicating the needs of the soil.

THE SUBSURFACE SOILS AND SUBSOILS

Samples of subsurface soils and subsoils corresponding to the surface soils were analyzed for the same constituents. The results of these analyses are given in tables V and VI, the figures representing pounds per acre of four million pounds of subsurface soil and of six million pounds of subsoil respectively.

There are apparently no large amounts of plant food constituents present in the lower soil layers. The needs of the soils as shown by the analyses of the surface samples are therefore not changed by the plant food content of the

**TABLE V. PLANT FOOD IN VAN BUREN COUNTY, IOWA, SOILS**

Pounds per Acre of Four Million Pounds of Subsurface Soil (6%“-20”)

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>1,920</td>
<td>3,680</td>
<td>74,620</td>
<td>0</td>
<td>9,600</td>
</tr>
</tbody>
</table>

**LOESS SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinton silt loam</td>
<td>2,110</td>
<td>2,900</td>
<td>28,640</td>
<td>0</td>
<td>7,700</td>
</tr>
<tr>
<td>Clinton silt loam (broken phase)</td>
<td>1,690</td>
<td>1,220</td>
<td>24,520</td>
<td>0</td>
<td>10,400</td>
</tr>
<tr>
<td>Grundy silt loam</td>
<td>1,653</td>
<td>4,960</td>
<td>63,973</td>
<td>trace</td>
<td>5,533</td>
</tr>
<tr>
<td>Grundy clay loam</td>
<td>1,840</td>
<td>5,720</td>
<td>30,860</td>
<td>0</td>
<td>4,800</td>
</tr>
</tbody>
</table>

**TERRACE SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calhoun silt loam</td>
<td>1,580</td>
<td>2,480</td>
<td>30,820</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>Jackson silt loam</td>
<td>1,920</td>
<td>3,680</td>
<td>32,680</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>Buckner fine sand</td>
<td>2,020</td>
<td>3,060</td>
<td>27,260</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>Buckner gravelly sandy loam</td>
<td>2,760</td>
<td>2,560</td>
<td>27,260</td>
<td>0</td>
<td>4,000</td>
</tr>
</tbody>
</table>

**SWAMP AND BOTTOMLAND SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wabash silt loam</td>
<td>1,720</td>
<td>5,280</td>
<td>30,920</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>Wabash loam</td>
<td>2,020</td>
<td>3,120</td>
<td>35,100</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>Wabash clay loam</td>
<td>1,640</td>
<td>3,820</td>
<td>44,860</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>Wabash fine sandy loam</td>
<td>2,300</td>
<td>2,700</td>
<td>29,940</td>
<td>0</td>
<td>4,000</td>
</tr>
</tbody>
</table>

**TABLE VI. PLANT FOOD IN VAN BUREN COUNTY, IOWA, SOILS**

Pounds per Acre of Six Million Pounds of Subsoil (20”-40”)

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>2,100</td>
<td>1,200</td>
<td>16,890</td>
<td>0</td>
<td>7,200</td>
</tr>
</tbody>
</table>

**LOESS SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinton silt loam</td>
<td>2,570</td>
<td>3,090</td>
<td>31,040</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>Clinton silt loam (broken phase)</td>
<td>2,420</td>
<td>1,680</td>
<td>21,780</td>
<td>0</td>
<td>12,000</td>
</tr>
<tr>
<td>Grundy silt loam</td>
<td>2,424</td>
<td>4,029</td>
<td>43,890</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>Grundy clay loam</td>
<td>2,640</td>
<td>4,360</td>
<td>119,970</td>
<td>0</td>
<td>3,200</td>
</tr>
</tbody>
</table>

**TERRACE SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calhoun silt loam</td>
<td>2,140</td>
<td>3,480</td>
<td>18,720</td>
<td>0</td>
<td>9,600</td>
</tr>
<tr>
<td>Jackson silt loam</td>
<td>2,280</td>
<td>4,680</td>
<td>29,220</td>
<td>0</td>
<td>5,600</td>
</tr>
<tr>
<td>Buckner fine sand</td>
<td>2,040</td>
<td>1,320</td>
<td>14,670</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>Buckner gravelly sandy loam</td>
<td>2,040</td>
<td>1,020</td>
<td>18,900</td>
<td>0</td>
<td>3,200</td>
</tr>
</tbody>
</table>

**SWAMP AND BOTTOMLAND SOILS**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wabash silt loam</td>
<td>2,460</td>
<td>6,240</td>
<td>82,200</td>
<td>0</td>
<td>6,400</td>
</tr>
<tr>
<td>Wabash loam</td>
<td>2,460</td>
<td>5,290</td>
<td>81,150</td>
<td>0</td>
<td>4,800</td>
</tr>
<tr>
<td>Wabash clay loam</td>
<td>2,340</td>
<td>4,960</td>
<td>55,450</td>
<td>0</td>
<td>3,200</td>
</tr>
<tr>
<td>Wabash fine sandy loam</td>
<td>2,655</td>
<td>2,160</td>
<td>30,780</td>
<td>270</td>
<td>0</td>
</tr>
</tbody>
</table>
underlying subsurface soils and subsoils. Unless the amount of plant food present in the lower soil layers is very large, there is little effect on the "life" of the soil, or in other words on the time when the soil will become infertile because of the lack of some essential constituent. The subsoils in Van Buren county are lower in all constituents than the surface soils and hence any deficiency in the surface soil will not be supplied from the deeper soil.

Phosphorus will be needed on all the soils in the future and may be of use now. Nitrogen is not present in large amounts and organic matter is not abundant and hence farm manure and leguminous green manures as well as crop residues should be added to the soils to keep them fertile. Lime is lacking and the soils should all be tested and the amounts indicated as necessary by the tests should be applied. These conclusions confirm those drawn from a consideration of the analyses of the surface soils and indicate distinctly the needs of the soils of the county.

GREENHOUSE EXPERIMENTS

Experiments were carried out in the greenhouse on three of the soil types in Van Buren county, the Grundy silt loam, the Grundy clay loam and the Clinton silt loam.

The first experiment consisted in the treatment of the soil with lime, manure, rock phosphate and acid phosphate according to the plan shown in table VII.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wt. grain grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>5.7</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>7.5</td>
</tr>
<tr>
<td>3</td>
<td>Lime+Rock Phosphate</td>
<td>9.0</td>
</tr>
<tr>
<td>4</td>
<td>Lime+Acid Phosphate</td>
<td>10.5</td>
</tr>
<tr>
<td>5</td>
<td>Lime+Manure</td>
<td>16.5</td>
</tr>
<tr>
<td>6</td>
<td>Lime+Manure+Rock Phosphate</td>
<td>15.0</td>
</tr>
<tr>
<td>7</td>
<td>Lime+Manure+Acid Phosphate</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Lime was applied in the amount necessary to neutralize the acidity of the soil and two tons additional used to put the soil in the best reaction for crop growth. Manure was added at the rate of 10 tons per acre, rock phosphate at the rate of 1000 pounds per acre and acid phosphate at the rate of 200 pounds per acre.
Fig. 5. Lime proved of some value and lime and manure of decided value in increasing the crop yield in this greenhouse pot experiment with mature wheat grown on Grundy silt loam. The pots were seeded to Marquis spring wheat and kept as near the best conditions of temperature and moisture as was possible under greenhouse conditions. When the crop was matured, it was harvested and the yields of grain obtained. The average results for the duplicate pots are given in table VII.

Fig. 6. A greenhouse pot experiment on Grundy clay loam in which manure, rock phosphate, acid phosphate and commercial fertilizer all exerted a slight beneficial influence on wheat.
These results show that lime brought about only a slight increase in crop growth. When rock phosphate or acid phosphate was applied with the lime, somewhat larger yields were secured, the acid phosphate showing up somewhat better than the rock, but the differences were not large. When manure was added with the lime a very decided increase in crop yield was obtained, over twice as large a crop being secured as was the case with lime alone, and a very much larger yield obtained than with the lime and phosphorus fertilizers. When the acid phosphate, or rock phosphate was applied with the lime and manure no increase was secured over the treatment with manure and lime. In fact the yields which were almost identical for the two phosphorus fertilizers are actually slightly lower than that given by the lime and manure. The difference, however, is not great and merely indicates that the phosphorus fertilizers have not increased the crop yields.

These results show that the application of lime is of some value on this soil and that manure used with the lime is of great importance in increasing the crop yield, having a much greater effect than other fertilizing materials. The use of phosphorus fertilizers in addition to the manure did not prove profitable. Manure is evidently the best fertilizing material to be used on this soil type now but phosphorus fertilizers will also be needed in the future.

The second experiment was on the Grundy clay loam. Manure was applied at the rate of 8 tons per acre, lime in sufficient amount to neutralize the acidity and supply 2 tons additional, rock phosphate at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat was

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wt. wheat grain, grams</th>
<th>Wt. clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>9.05</td>
<td>63.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>9.47</td>
<td>73.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>9.48</td>
<td>75.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock Phosphate</td>
<td>11.18</td>
<td>76.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid Phosphate</td>
<td>10.35</td>
<td>78.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Commercial Fertilizer</td>
<td>11.75</td>
<td>84.0</td>
</tr>
</tbody>
</table>
grown in the pots and about one month after the wheat was up, clover was seeded. The yields of both crops were secured and the results appear in table VIII.

The manure caused a small increase in wheat but the clover crop was influenced considerably. The addition of lime had a small beneficial effect on the clover and none at all on the wheat. The rock phosphate, acid phosphate and commercial fertilizer all exerted a beneficial influence on the wheat crop and also on the clover crop but the increases were not large. There was little difference in the effects of the various materials but the commercial fertilizer seemed to give slightly greater effects than the phosphates. There are indications from these results that phosphates may be profitable for use in the field. Field experiments are necessary, however, before definite conclusions can be drawn and experiments are urged on individual farms.

The third experiment was on the Clinton silt loam and the treatments were the same as in the preceding test. The results appear in table IX.

Manure brought about a decided increase both in the wheat and in the clover

TABLE IX. GREENHOUSE EXPERIMENT. CLINTON SILT LOAM, VAN BUREN COUNTY

<table>
<thead>
<tr>
<th>Pot. No.</th>
<th>Treatment</th>
<th>Wt. wheat grain, grams</th>
<th>Wt. clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cheek</td>
<td>11.86</td>
<td>15.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>13.11</td>
<td>27.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>13.95</td>
<td>28.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock Phosphate</td>
<td>13.27</td>
<td>35.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid Phosphate</td>
<td>13.95</td>
<td>30.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Commercial Fertilizer</td>
<td>14.10</td>
<td>30.5</td>
</tr>
</tbody>
</table>
crop particularly the latter. Lime showed only a small increase over the ma­
ure. The phosphates and commercial fertilizer had no influence on the wheat
but there were evidences of benefit on the clover crop. While the increases were
not large it is apparent that there is a possibility that these materials might
prove profitable when applied in the field and tests on this soil type are desira­
able. The effect of the manure is especially noticeable and indicates that if ma­
nure is applied to the soil in as large amounts as practicable and available
profitable crop increases will be secured.

These experiments, as a whole, indicate clearly that manure is the best fertil­
ing material for this soil and that frequent applications of it will prove decidedly
profitable. The possible value of rock phosphate, acid phosphate and commercial
fertilizers is also indicated and the importance of tests of these materials on in­
dividual soils is evident. Lime should also be used on these soils when acid and
beneficial effects are obtained with other fertilizers only when the soil is well
supplied with lime and manure.

FIELD EXPERIMENT 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 best 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.

Van Buren county has two typical "gumbo" soils known as the Grundy clay loam and the Wabash clay loam. The former covers 1.1 percent of the area of the county and occupies level, depressed areas on the upland within the Grundy silt loam. The latter covers 1.4 percent of the total area of the county and occurs only along Fox river where it occupies the bottoms which are from one-half to three-fourths of a mile wide. 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 X.

Plots 101, 102, 103, 201 and 202 were green manured in 1908 with rape, buckwheat, clover and clover and timothy, respectively. The clover and timothy on plots 201 and 202 had been a meadow for several years and produced a crop of hay in 1908 which made a yield of 2½ tons per acre. The aftermath was plowed under for green manure. All, except plots 205 and 206, were fall plowed in 1908, the treatments indicated being made prior to plowing.

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

Great differences in yield occurred but these should undoubtedly be attributed to differences in drainage rather than to the effects of treatment. It was impossible to get a satisfactory outlet for the tile drain and on each side of the experiment field there was a swampy place in which the water stood nearly all

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Drained</th>
<th>Bu. corn per acre 1909</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Rape (too wet)</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Buckwheat</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>Clover</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>Check</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>Lime — 10 T per acre</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>Straw — 4 T per acre</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>Check</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>Manure — 12 T per acre (too wet)</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>Manure — 6 T per acre (too wet)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>Clover and timothy sod</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>202</td>
<td>Clover and timothy sod</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>Manure — 12 T per acre</td>
<td>15</td>
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</tr>
<tr>
<td>204</td>
<td>Check</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>Manure — spring plowed</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>206</td>
<td>Check — spring plowed</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
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 one cracked open, leaving wide fissures to a depth of more than a foot. On the best drained plots, the fine crumbly surface soil prevented this cracking. On the hard, cracked ground the corn turned yellow and “fired” about the middle of August, but on the other plots it remained green at least three weeks longer.

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

This experiment shows very definitely the possibilities of “gumbo” soils when properly drained and fall plowed. The drainage of “gumbo” is more readily accomplished than would be supposed. On the upland the tile should be laid 8 rods apart to secure good drainage, altho reports have been made of successfully drained “gumbo” when the tile was 10 to 12 rods apart. On the lowland “gumbo” the tile should be somewhat closer together, but the securing of a satisfactory outlet is the chief necessity for thorough drainage and in some cases it may be necessary to run an open ditch thru to the river, in which case a drainage district must be organized. When properly 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

Fig. 10. Characteristic rough topography of Shelby loam, largely cleared
THE NEEDS OF VAN BUREN COUNTY SOILS AS SHOWN BY LABORATORY AND GREENHOUSE TESTS

No field experiments have as yet been carried out in Van Buren county and hence the recommendations for soil treatment which are given here are based primarily on the laboratory and greenhouse results. However, the experiences of many farmers throughout the county and many observations support the suggestions which will be made and they may be considered as rather definite. Field experiments are now under way on the main soil types in the county and it is hoped that the results of these tests will be available within the next few years. They will be published in a supplementary report on the soils of the county, as soon as several years’ results are secured.

LIMING

The need of lime is evident on all the soils of Van Buren county. Only one soil did not show an immediate need and that one will be acid very soon as there is no large supply of lime present.

The first treatment needed to make and keep the soils of the county productive is the application of lime. Legumes, such as clover and alfalfa are especially sensitive to acidity in the soil and much general farm experience has shown the value of lime in increasing the yields of such crops. All crops are not benefited to so large an extent by the use of lime and it should not be expected that corn and small grain crops will always show large increases from the use of this material. Lime improves the physical conditions in the soil, keeps it in the condition for the best production of available plant food and is absolutely essential for the best growth of the legume which should form a part of every rotation system. The subsurface soils and subsoils of the county are all acid and hence there is no possibility of remedying acid conditions in the surface soils by bringing up lime from the lower soil layers. Indeed it is questionable whether the surface soil is affected by the presence of lime in the subsoil.

All the soils in the county should be tested for their reaction and lime requirement and the necessary amount of lime applied. Farmers may test their own soils but it will usually be more satisfactory to them if they will send a sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In that way they will learn just how much lime should be applied to their soil and will be in no danger of applying too small or too large an amount either of which is undesirable from an economic standpoint. General figures cannot be given to show how much lime should be applied to any soil and it is only by special tests that it is possible to determine the proper amount.

The effects of lime on various crops, the methods and time of application and
other questions regarding liming are discussed in another bulletin and need not be considered here. It is sufficient to say that lime can be secured quite cheaply and the returns secured from its use more than warrant the expense involved.

**MANURING**

There is a very definite need for organic matter in the soils of Van Buren county in most cases according to the analyses. None of the soils are so abundantly supplied that the addition of organic matter can be considered unnecessary for the best crop production. The greenhouse experiments show very decided increases in yields from the application of manure to two of the main soil types in the county and general farm experience indicates very definitely that farm manure will bring about increases on any of the soils of the county and it should be used in as large amounts as practicable.

No other fertilizing material has been found to produce anything like the effects on crop growth shown by manure. Manure does more than add organic matter to the soil, altho because of its content of organic matter the action is very important in keeping the soil in the best physical condition for crop growth and in aiding in the production of available plant food. Moreover manure is of great value in returning plant food to the soil. Much of the plant food removed from the soil by crops is contained in the manure of animals. When all the crops produced to the farm are fed and the manure carefully stored and applied to the soil, the losses of valuable plant food constituents are kept at the lowest point. It has been estimated that from 75 to 85 percent of the plant food contained in the crops may thus be returned to the soil but this cannot be done if the manure is not properly stored. If it is piled in a loose heap, and exposed to the weather the losses from manure may amount to as much as 90 percent of the valuable constituents. The loss falls mainly on the nitrogen which is present largely in the liquid portion and is leached away. If manure is stored so that it is kept moist, compact and covered, or if it is applied to the soil as produced, the losses may be reduced to a small percent. Losses from manure mean actual losses of plant food which may be calculated in dollars and cents from the cost of the same constituents in artificial commercial fertilizers. No farmer should fail to make the best possible use of that material which is not only the cheapest fertilizer which he can apply to his soil but the one which brings about the greatest increases in crop production and aids in keeping soil permanently fertile. Manure is valuable also because of the bacteria which it contains. No matter how much plant food is present in soils, unless there is a proper production in an available form, the best yields will not be secured. Bacteria are the agents which make plant food available. Manure adds bacteria to the soils thereby increases decomposition processes and the production of available plant food. It is particularly valuable in certain cases where the organic matter present in the soil is not decaying properly.

There is little danger of applying too much manure to soil provided the amount produced on any farm is distributed over the entire farm. However, 8 to 10 tons of manure per acre is the amount which is used with the best effects on the average soil and larger applications cannot be recommended.

On the livestock farm there is not a sufficient production of manure to keep
up the fertility of the soil and on the grain farm there is usually such a small production that some other treatment must be resorted to if the organic matter and nitrogen content of the soil is to be maintained. In such cases green manures are a valuable supplement to farm manure. Of the many crops which may be employed as green manures legumes are by far the most preferable. When well inoculated, as they always should be, they take the nitrogen from the air and use it in their growth. When turned under in the soil, therefore, they increase the nitrogen content of the soil. They also supply much organic matter and thus aid in keeping the physical condition of the soil at the best. Many legumes are available for use under all soil and climate conditions and turning them under as green manures is often distinctly profitable and indeed absolutely necessary if the soils are to be kept permanently fertile. Frequently, non-legumes are used as green manures and while they may be of value in increasing the organic matter content of the soil they do not increase the nitrogen supply and hence they are not generally as desirable.

Like many other farm practices green manuring should be followed with care and understanding as it may not be of great value if not properly practiced. Specific information regarding green manuring on certain soils under local conditions may be secured from the Soils Section. Further general information along this line is given in Circular 10 of the Iowa Agricultural Experiment Station.

Crop residues such as straw and stover should be utilized on all farms as they not only constitute a valuable means of increasing the organic matter in the soil but they also return to the soil much plant food. Such materials should never be burned or otherwise destroyed as their value to the soil well warrants care in keeping and applying them. Properly used they considerably lengthen the "life" of the soil and they constitute a valuable addition to farm manure and green manures in keeping up the organic matter in the soil and thus insuring the proper physical condition so essential for the best crop production.

THE USE OF COMMERCIAL FERTILIZERS

The greenhouse experiments described earlier in this report showed no large effects from the use of phosphatic fertilizers but the soils of the county are so low in phosphorus as to warrant the conclusion that phosphorus will be necessary in the future. Indeed, phosphorus fertilizers might yield profitable returns at the present time on some of the soils of the county. The field experiments now under way will give much more definite information regarding the use of phosphorus fertilizers and it is hoped that the results to be secured during the next few years will show very definitely whether phosphorus applications on the main soil types in the county are needed. For the present general recommendations cannot be made and farmers are urged to test the use of phosphatic materials on their own soils and thus ascertain whether phosphorus will prove profitable under their local farm conditions. Furthermore, by the carrying out of such tests every farmer will aid considerably toward the solution of the problem in general.

There are two kinds of phosphorus fertilizers which may be used on the farm, rock phosphate, an insoluble form, and acid phosphate, a soluble but more expensive material. If phosphorus is necessary on any soil it is desirable that
tests be made to determine whether the rock or the acid phosphate should be used. The field experiments referred to above are planned to test the use of these two materials and farmers are urged to use both fertilizers in tests on their own farms. Specific directions for carrying out tests on the farm are given in Circular 51 of the Iowa Agricultural Experiment Station and farmers who are interested in determining the needs of their own soils may secure further information to aid them in their experiments by corresponding with the Soils Section. While no data are yet available to show the value of phosphate fertilizers, the soils in Van Buren county are so low in that constituent that it is certain that some of them would respond profitably to the use of such materials.

The use of nitrogenous fertilizers cannot be generally recommended on the soils of Van Buren county for if well inoculated legumes are grown and used as green manures, nitrogen may be added to the soil at a less cost. The nitrogen present in the soils of the county is not abundant but neither is it extremely low and if farm manure and crop residues are properly applied and green manures used as indicated above there is no necessity for nitrogen becoming deficient. However, if nitrogenous fertilizers have been used profitably on any particular soil there is no objection to the practice. In general the use of commercial nitrogenous fertilizers in the county cannot be advised except in small amounts as a top dressing or to encourage the early growth of certain crops.

Potassium is present in all the soils of the state in such large amounts that no analyses were made of the soils of Van Buren county for that constituent. The use of potassium fertilizers is not very likely to prove of value and cannot be recommended. If the soil is kept in the best possible physical condition and well supplied with organic matter and lime, bacterial action will be vigorous and there undoubtedly will be a sufficient production of available potassium to keep the crops supplied. Potassic fertilizers may possibly be used in small amounts as top dressings or to encourage the early growth of certain crops but their general use for ordinary farm crops cannot be recommended.

Complete commercial fertilizers are being used in the field tests already referred to in order to determine their value on the main soil types in the county. Results from these tests are not yet available and at the present time complete commercial fertilizers cannot be recommended as profitable. Nitrogen can be supplied more cheaply as leguminous green manures and potassium is not apt to be needed and fertilizers containing those two constituents cannot be expected to prove as profitable as phosphatic fertilizers, with which they should be compared. Tests on the farm may include the use of a standard brand of commercial fertilizer and if it is shown to be profitable there is no objection to its use. Commercial fertilizers do not wear the soil out as sometimes is believed and if the increases secured are worth more than the cost of the materials they may be used without fear of injuring the soil. When commercial fertilizers are used, organic matter should be applied to the soils and care be taken that the physical condition be kept at the best, just as in all other cases, inasmuch as commercial materials do not take the place of manure or lime or other natural fertilizing materials.

**DRAINAGE**

With but few exceptions the soils in Van Buren county are fairly well drained. The Grundy clay loam and the Wabash clay loam both of which are locally
known as "gumbo" are especially in need of drainage. The impossibility of securing good crop growth and preparing such soil for seeding until it is properly drained has been discussed earlier in this report in the section on "gumbo." A few other types in the county such as the Calhoun silt loam and the Jackson silt loam are sometimes in need of drainage.

Whenever any soil is improperly drained, the installation of tile is the first treatment necessary to put it in the best condition for crop growth. Other soil treatments will have little or no value if the soil is too wet.

The need for drainage on soils is easily determined and the method of installation of drainage systems is generally known. Tile drains should be installed in any Van Buren county soils that are improperly drained and the expense involved will be well warranted by the returns secured. Specific information regarding the drainage of soils may be secured from the Soils Section upon request.

**CROP ROTATION**

It is a matter of common knowledge that the continuous growing of one crop depletes the fertility of a soil much more rapidly than when a rotation is practiced. No particular experiments with different rotations have been carried out in Van Buren county but several satisfactory ones may be suggested. Whatever rotation of crops is followed, a legume should be included and care taken by the use of crop residues, farm manure and green manures that the organic matter content of the soil be kept up. The following rotations are suggested:

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 (The crop may remain on the land five years. This field should then be used for the four year rotation outlined above)

3. **Three-Year Rotation**
   
   - *First year:* Corn.
   - *Second year:* Oats or wheat (with clover seeded in the grain).
   - *Third year:* Clover (Only the grain and clover seed should be sold; in grain farming most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil).

**THE PREVENTION OF EROSION**

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or "the lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.
Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroughly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner.

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a
large extent that the subsoil 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 Pottawattamie county gullying occurs to an injurious extent mainly in the bluffs along the Missouri river and a belt one-half mile to three miles back from the bluffs.

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, 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 somewhat higher than the surrounding land and act in much the same way as the stakes used in the “staking in” operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in “dead furrows.”

**SMALL GULLIES**

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

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

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

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

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

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

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

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

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

The concrete dam.—One of the most effective means of controlling erosion is by
the concrete dam, provided the Dickey system is used in connection with it.
They are, however, rather expensive. Then, too, they may overturn if not
properly designed and the services of an expert engineer are required to insure
a correct design. Owing to their high cost and the difficulty involved in secur-
ing 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 pre-
cautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

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

Straightening and tiling.—The straightening of the larger streams in bottom land areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottom land and it often proves very efficient.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

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

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

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

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

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

INDIVIDUAL SOIL TYPES IN VAN BUREN COUNTY

DRIFT SOILS

There is one drift soil in Van Buren county, called the Shelby loam. It covers 18,074 acres or 5.9 percent of the total area of the county.

SHELBY LOAM (79)

The Shelby loam occurs on slopes approaching stream courses, the areas lying between the stream bottoms and the uplands. It is found in narrow strips with branching areas following the smaller tributary streams. Practically all of this soil type is located in the southwestern and southern parts of the county although there are several other scattered areas.

The surface soil of this type is a brown to dark-brown loam or gritty loam to a depth of 10 or 12 inches. This is underlain by a brownish-gray or yellow stiff sandy clay loam which at about 18 inches shows mottlings of yellow and orange-yellow. At lower depths the material changes to a yellow plastic clay or sandy clay, mottled with orange-yellow or reddish-yellow and drab. In places pockets of fine sand, coarse sand and gravel are found at various depths. The topography of the soil is rolling to steep and it is well drained. Erosion occurs to a considerable extent in some places.

Most of the type is too rough and steep to be under cultivation. It is generally used for pasture while on the rougher slopes there occurs a growth of prickly, oak and elm. General farming is followed on the smooth areas and gentler slopes and corn, oats, wheat and clover are the chief crops grown. Fairly satisfactory yields of all these crops are secured, but large increases might be secured through proper treatment. The soil is in need of manure to build it up in organic matter, it is apt to be acid and in need of lime and the phosphorus content is so low that phosphorus fertilizers might prove profitable. The chief need of the soil, however, is for protection from erosion. This may be accomplished by one of the methods discussed in a previous section of this report. Other treatments may be entirely useless if the washing of the soil is not prevented. In general the best use of this soil is for pasture, and it is well suited to bluegrass which is the chief pasture grass.
LOESS SOILS

There are six loess soils in Van Buren county and together they cover 81.4 percent of the total area of the county. They include soils of the Clinton, the Grundy, the Marion and the Lindley series.

CLINTON Silt Loam (80)

This soil covers 72,256 acres or 23.4 percent of the total area of the county. It is the second largest individual soil type in the county and with the broken phase covers the largest area in the county. It occurs in two irregular belts 6 to 10 miles wide extending thru the county from northwest to southeast on both sides of the Des Moines river. A small area of the type occurs on the slopes along Big Cedar creek in the northeastern part of the county and on the slopes bordering the lower half of Indian creek.

The surface soil is a light-brown or grayish-brown moderately compact silt loam extending to a depth of 8 inches. This is underlain by a yellowish-brown silty clay loam sometimes mottled with yellow and gray, which becomes heavier in texture until at a depth of 20 to 24 inches it grades into a heavy plastic silty clay, yellowish-brown or light-grayish brown in color and mottled with yellow and gray or dark-brown and black. Occasionally the lower part of the surface soil is a gray silt loam. In topography this soil varies from undulating to gently rolling. The drainage is generally adequate but in some places tile drains have proven of value.

General farm crops are grown on this soil. Corn, oats, wheat, rye, timothy, clover and alfalfa are the chief crops. Corn yields 25 to 50 bushels per acre; oats, 30 to 60; and wheat, 20 to 25 bushels per acre. The yield of timothy and clover hay is usually about 1 1/2 tons per acre.

The needs of this soil include the application of manure, the use of lime and probably also the application of phosphorus. Manure has been found particularly profitable on this soil and when the soil is acid lime should also be used if the best crops of clover and alfalfa are to be secured.

Phosphorus fertilizers have not yet proven profitable but the tests now under way will throw some light on this question and it is urged that tests be made on this soil type in order to ascertain the value of rock phosphate and acid phosphate under individual soil conditions.

CLINTON Silt Loam, Broken Phase (80A)

This soil type, a broken phase of the Clinton silt loam covers 58,240 acres or 19 percent of the total area of the county. It occurs in the same localities as the Clinton silt loam, occupying the more or less steep slopes bordering the stream courses.

The soil is not very different from the typical Clinton except that there is usually a shallower surface soil which in many cases is lighter in color. The subsoil is less mottled than the typical Clinton silt loam. There are very small areas of this broken phase along the ravines where the underlying till has been exposed. The soil in these places is really Shelby loam but has not been shown on the map because of the small size of the areas. The topography of the broken phase Clinton is steeper and rougher than that of the typical soil. The drainage varies from good to excessive and in seasons of low rainfall crops are apt to suffer.
Much of this soil is too rough to be cultivated. The greater portion is in pasture, some areas being in forest, of hickory, white oak, red oak and elm. The pastures are usually excellent. General farm crops are grown on those areas which are not too rough but the yields are lower than those secured on the true Clinton because of the shallower surface soil and the variability of the soil on the slopes.

The chief need of this soil is the adoption of methods to prevent erosion. Some one of the methods suggested earlier in this report should be chosen and if properly installed may serve to reclaim the land for cultivated crops. For general farm crops the needs of the soil are the same as in the case of the typical Clinton, namely, organic matter supplied as farm manure, lime when the soil is acid and phosphorus fertilizers either at the present time or in the near future.

**GRUNDY SILT LOAM (64)**

This is the largest and most important soil type in the county. It covers 11,152 acres or 36.7 percent of the total area of the county. It occurs on the ridges and other elevated areas and is the main soil type in the southwestern and northeastern parts of the county. There is also a small area east of Selma and another southwest of Farmington.

The surface soil to a depth of 8 to 12 inches is a dark-gray or dark-brown to nearly black friable silt loam. The subsoil is a grayish-brown silt loam to a depth of 18 to 20 inches, occasionally showing yellowish-brown mottlings. Below 20 inches the material changes to a bluish-gray or drab, dense plastic silty clay, mottled with brown and yellow. The color becomes lighter and the mottling more pronounced with increasing depths. Sometimes in the lower part of the surface soil there is found a thin, grayish-white layer consisting of a mealy silt material.

The topography is nearly level to undulating becoming somewhat rolling along the streams. The drainage of the soil is usually adequate although in some of the flatter, more level areas, the heavy character of the subsoil prevents the rapid removal of water and in wet seasons crops may suffer. Tile drainage has been used with profit in some areas of this soil.

Practically all the soil of this type is under cultivation. Corn yields from 30 to 80 bushels per acre averaging about 45 bushels. Oats averages 42 bushels, yields as high as 85 bushels being secured in favorable seasons. Wheat averages 25 bushels and rye somewhat less. Timothy and clover hay yields 1 to 2 tons per acre and alfalfa 2½ to 3 tons per acre.

This soil is highly productive at the present time but proper treatment will increase its productivity. The application of manure is especially valuable and should be used in as large amounts as practicable. The soil is generally acid and the amount of lime shown to be necessary according to tests should be applied if the best growth of legumes is to be obtained and the soil kept in good condition. The amount of phosphorus in the soil is low but phosphorus fertilizers have not yet been found to give profitable returns. Further tests are highly desirable on this soil type and farmers are urged to determine the needs of their own soils for phosphorus. Phosphorus fertilizers will undoubtedly be needed on this soil in the future.
Fig. 12. Surface, subsurface and subsoils of five of the individual soil types of Van Buren county.

2. Bucenker fine sand.
4. Shelby loam.
5. Jackson silt loam.
This is a minor type covering only 1,664 acres or 0.5 percent of the total area of the county. It occurs on the flat-topped ridges which are either forested at the present time or were at some previous time.

The surface soil is a light-brown to gray silt loam extending to a depth of 6 to 10 inches and resting on a subsurface layer 8 to 12 inches thick, gray or white in color and flour-like in structure. Below this there is a layer of tough, plastic clay which becomes very hard and compact when dry. It is brown in color in the upper portion becoming mottled gray and rusty-brown at lower depths. It extends to a depth of 24 to 36 inches, and is underlain by a more friable silty clay layer.

This soil is low in fertility and special treatments are necessary to bring it to a condition in which it will produce satisfactory crops. Applications of farm manure in as large quantities as practicable are especially necessary. If farm manure is not available in any considerable amounts, then leguminous green manures should be employed to build the soil up in organic matter and nitrogen. It is apt to be acid and should be tested and the proper amount of lime applied. Phosphorus fertilizers might prove profitable even now and certainly will be necessary in the future. With these treatments satisfactory yields of general farm crops may be secured and without them profitable crops cannot be obtained.

This soil covers 3,456 acres of 1.1 percent of the total area of the county. It occurs entirely in the northeastern part of the county being found in strips and isolated patches one-fourth to one-half mile wide on flat, level divides. The principal area is near Stockport. The soil is locally known as "gumbo."

The surface soil to a depth of 10 or 12 inches consists of a dark-brown to black, fairly friable clay loam. This grades into a dark-brown to dark-brownish drab, compact, plastic silty clay which at 18 inches shows dull-brown mottlings. From 22 to 36 inches, the material consists of a sticky, plastic clay or heavy silty clay, light-drab or grayish-drab in color, mottled with yellow or rusty yellow. The texture of the soil varies from a silty clay loam to a silty clay. Throughout this type there are found small unproductive white spots from a few square yards to an acre in size. The soil in these spots differs from the typical Grundy clay loam. There is a layer 6 to 8 inches deep consisting of a dark-brown to grayish-brown clay loam or silty clay loam. This rests on a gray or drab-gray silty clay loam which at 10 or 12 inches passes into a grayish-brown or dull-drab sticky plastic impervious clay or silty clay, mottled with brown or yellowish-brown. In topography this soil is nearly level or flat and drainage is usually poor.

Practically the whole type is under cultivation and general farm crops are grown. The yields secured in normal seasons are satisfactory but they are not large and may be increased with proper treatment.

The first need of the soil is for drainage and without this other treatment will be of little value. The experiment on a typical "gumbo" described earlier in the report shows definitely the need of draining in order to prepare the soil for cropping and to secure good crop yields. When thorough drainage is accomplished the soil may be kept fertile and productive by the same treatments recommended.
for use on the other upland soils—the application of manure, the addition of lime and the use of phosphorus fertilizers either now or in the future.

**LINDLEY LOAM (65)**

This soil type occurs to a very small extent, covering only 550 acres or 0.2 percent of the county. It occupies the slopes leading to upland drainage courses, in the eastern part of the county and is well drained.

The surface soil extending to a depth of about 10 inches is a reddish to yellowish-brown loam to silt loam. On the tops of the slopes the soil approaches a silt loam while on the slopes themselves it is more loamy in texture. The subsoil material is a reddish to yellowish-brown clay loam to silty clay or sandy clay. Pockets of sand and clay frequently occur in the lower soil layers. Fragments of various rock materials are found scattered throughout the surface soil as well as the subsoil and some large boulders also occur.

The slopes on which this soil occurs are sometimes rather steep and in such cases the land is not suited for cultivation. Little of the type in the county is under cultivation. There are some uncleared areas where a growth of scrub oak, white oak, red oak and black and shellbark hickory is supported.

On the more level portions of the soil, oats, rye and grass do well but corn does not produce as good crops as on the darker soils. Alfalfa gives satisfactory yields in some cases, but it is not grown to any large extent. Where such crops cannot be grown, bluegrass makes an excellent pasture. The type has little agricultural value and when used for cultivated crops is in need of manure, lime and phosphorus.

**TERRACE SOILS**

There are four terrace soils in the county belonging to the Calhoun, the Jackson and the Buckner series. Together they cover only 2.3 percent of the area of the county, only one, the Calhoun silt loam being at all extensive.

**CALHOUN SILT LOAM (42)**

This soil covers 5,696 acres or about 1.8 percent of the total area of Van Buren county. It occurs in terraces along the Des Moines river. The principal areas are those in the river bend at Keosauqua and along each side of the river valley between Kilbourn and Selma. Smaller areas are found along Chequest creek and Lick creek.

The surface soil to a depth of 10 to 12 inches is composed of brown to grayish-brown, compact, but fairly friable silt loam which when dry often appears almost white. In some areas the surface soil is somewhat darker than the typical. Beneath the surface there is a layer 3 to 4 inches thick of whitish or grayish-white mealy silt loam, which changes below into a gray clay loam mottled with brown. The material from 20 to 24 inches usually becomes a drab or bluish-gray, plastic silty clay mottled with yellow and brown. Below 30 inches the color becomes lighter with mottlings of yellow and gray.

In topography this soil is level or undulating to slightly sloping. The slope from the terrace to the bottoms is gradual, extending for as much as one-eighth of a mile in length and this slope is often cut by ravines. Small streams frequently cut up the larger areas. The elevation above the bottoms is usually 50 or 60 feet but in the smaller areas the difference is often only 20 or 30 feet. In
Fig. 13. Surface, subsurface and subsoils of five of the individual soil types of Van Buren county.

6. Wabash clay loam.
7. Clinton silt loam.
8. Grundy clay loam.
9. Wabash fine sandy loam
10. Buckner gravelly sandy loam
most of the type the drainage is good but on the flat areas it is apt to be deficient.

Almost of the soil is under cultivation, corn, oats, wheat, rye and timothy being the chief crops grown. Corn yields 25 to 50 bushels, oats 30 to 60 bushels, wheat 20 to 25 bushels and rye 10 to 20 bushels per acre. Bluegrass makes good pastures. Alfalfa might prove a valuable crop on this soil but it is not grown to any extent at the present.

The needs of this soil to make it more productive are drainage of some areas, the application of farm manure, the use of leguminous green manures, the addition of lime as needed, and the use of phosphorus fertilizers either at the present time or in the future.

JACKSON SILT LOAM (81)

This is a minor soil type covering only 704 acres or 0.2 percent of the total area of the county. It is found only in a few small areas along the Fox river, where it occupies a terrace position.

The surface soil is a brown to dark-brown compact, friable silt loam, or silty loam 10 to 12 inches deep. The subsoil is a gray or brownish-gray silt loam mottled below 16 to 18 inches, with yellowish-brown. The material becomes heavier with increasing depth and at about 24 inches is a dense, plastic, silty clay, mottled gray, brown and yellowish-brown. In topography this soil is undulating or slightly sloping to nearly level. The type lies 10 to 15 feet above the flat bottoms. In general the drainage is adequate.

Practically all the soil is under cultivation and good yields are generally secured. Corn gives 30 to 50 bushels per acre and the small grains and hays also give fairly satisfactory returns. With proper treatment the yields of general farm crops can be increased to a considerable extent. The application of farm manure is of considerable value on this soil and should be applied in as large amounts as practicable. The soil is apt to be acid and lime should be applied as needed. Phosphorus is not abundant and phosphorus fertilizers may be necessary and profitable now and they certainly will be needed in the future. These treatments and the proper use of leguminous green manures will make it possible not only to increase crop yields in the soil but to keep it permanently fertile.

BUCKNER FINE SAND (46)

This is a very minor type covering only 576 acres or less than 0.2 percent of the area of the county. It occurs in narrow strips on terraces along the Des Moines river.

The surface soil to a depth of 8 to 12 inches is a brown to grayish-brown loamy fine sand. The subsoil consists of yellowish-brown fine sand extending to a depth of 36 inches or more but in places changing at a depth of 28 or 30 inches into a yellowish, sticky fine sandy loam or clay loam. The topography of the type is level to somewhat undulating. It lies 10 to 20 feet above the first bottoms and owing to its light open nature the drainage is excessive and the soil is drouthy.

Practically all the type is under cultivation but it is too small in extent to be of any great agricultural importance. The needs of the soil are for organic matter such as farm manure or green manures or both, for lime and for phosphorus fertilizers now or in the future. With these treatments good crop yields may be secured in seasons of satisfactory rainfall.
BUCKNER GRAVELLY SANDY LOAM (82)

This soil is a very minor type covering only 384 acres or 0.1 percent of the county. It occurs almost entirely in the vicinity of Farmington but there is also a small area just west of Mount Sterling.

The surface soil is a sticky, slightly gravelly, gritty loam, brown to dark-brown in color and extending to a depth of about 12 inches. The subsoil at 18 to 20 inches is a light-brown gravelly loam and below this depth the content of coarse gravel and pebbles becomes very great. The topography of the type is nearly level to slightly sloping. It lies 10 to 30 feet above the first bottoms. Drainage is excessive and the type is apt to be drouthy.

Most of the soil type is cultivated and general farm crops are grown, fair yields being ordinarily secured. The needs of the soil are very much the same as in the case of the Buckner fine sand. Applications of manure would be valuable, green manures should be used, lime applied as necessary and phosphorus fertilizers tested and employed when profitable. With these treatments and particularly the abundant application of organic matter, crop yields may be increased and the soil kept highly productive.
SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland soils in Van Buren county together covering 10.2 percent of the total area of the county and all included in the Wabash series.

WABASH Silt Loam (26)

This is the most important bottomland soil covering 14,912 acres or 4.8 percent of the total area of the county. It occurs along all the larger streams in the county. It is found along the Des Moines river and is the predominant soil along Indian creek and Little Fox river. It is also developed along Fox river, Lick creek, west of Birmingham and in narrow strips along smaller streams in other parts of the county. Areas of the soil seldom exceed one-half mile in width and generally the strips are one-fourth mile wide.

The surface soil is a grayish-brown to dark-brown silt loam 10 to 12 inches deep. This changes into a somewhat more compact silt loam which at about 20 inches becomes a silty clay loam of a lighter color. At 24 to 30 inches the material becomes a heavy silty clay loam or silty clay of a gray or drab color mottled with brown or yellowish-brown. The subsoil in some areas is a silty clay loam of a grayish color, mottled at 12 to 18 inches with yellow and yellowish-brown. In places bordering the streams, loamy and sandy variations of the type occur.

In topography the soil is level to slightly undulating. In some areas it is overflowed at rare intervals. Along the Des Moines river the type is not so subject to overflow as along the smaller streams. Drainage is good and when the soil is not subject to overflow crops usually do well.

A large part of the soil is under cultivation. Corn yields from 20 to 75 bushels per acre, averaging about 45 bushels. Oats yields 30 to 50 bushels per acre and wheat, 15 to 25 bushels. Timothy does well and clover and alfalfa also yield satisfactory crops in most cases. The lower-lying areas are in pasture and some areas are forested with oak, hickory, elm, sycamore, and willow.

When not overflowed, this soil gives fair yields of crops but treatments with farm manure, green manures and lime would undoubtedly prove profitable. Phosphorus fertilizers might also prove of value now and certainly will be necessary in the future.

Wabash Loam (49)

The type covers 8,896 acres or 2.9 percent of the area of the county. It occurs mainly along the Des Moines river, where it lies adjacent to the stream. Most of the narrower bottomlands of the smaller streams are of this type.

The surface soil is a brown to dark-brown loam or gritty loam extending to a depth of 10 or 12 inches. This passes into a light-brown, sticky loam or silty loam which at 18 to 20 inches becomes slightly mottled with yellow or dark-brown. At 28 to 30 inches the material is a somewhat sticky sandy clay loam of a mottled drab and yellowish-brown color. The type is extremely variable, areas of sandy, silty, and claylike materials occurring both in the surface soil and subsoil. In topography the soil is level or gently undulating. Drainage is usually good altho' in some areas there are poorly drained spots.

The soil is utilized for the same crops as the Wabash silt loam and about the same yields are secured. The needs for treatment are also very similar to those
for the silt loam. Farm manure should be applied in as large amounts as practicable, green manures may also be used to advantage in certain cases and lime is necessary on most of the type where acid conditions prevail. The use of phosphorus will also be necessary in the future and might prove profitable now. If the soil is protected from overflow and properly treated crop yields may be increased and the soil kept permanently fertile.

WABASH CLAY LOAM (63)

This is a minor type covering only 4,352 acres or 1.4 percent of the total area of the county. It occurs only along the Fox river where it occupies most of the bottoms which are one-half to three-fourths miles wide. The soil is locally known as "gumbo."

The surface soil is a dark-grayish-brown to nearly black clay loam or silt loam extending to a depth of 12 inches. The subsoil is a dark-brown or dark-drab, dense plastic clay or silt loam, mottled with dull-brown, yellowish-brown or gray. This material continues down to 36 inches without much change in texture becoming only slightly more stiff and plastic. In topography the soil is level and smooth, in places being slightly depressed. The drainage is extremely poor.

General farm crops are grown on this soil, but unless the drainage is adequate, yields are not satisfactory. The soil is difficult to cultivate and great care must be taken in selecting the time for plowing. The suggestions made in the section on "gumbo" soils in this report are directly applicable to this soil type. Drainage is the first essential for making the soil productive and when that is accomplished the use of manure, lime as necessary and possibly phosphorus fertilizers will aid in increasing crop yields and keeping the soil productive.

WABASH FINE SANDY LOAM (62)

This is a minor type in the county occupying only 3,392 acres or 1.1 percent of the total area of the county. It occurs along the Des Moines river in the southeastern part of the county below Bonaparte and in the vicinity of Farmington. Small areas are found above Keosauqua and along Chequest, Holcomb and Big Cedar creeks.

The surface soil is a brown to grayish-brown fine sandy loam of mellow structure extending to a depth of 12 inches. The subsoil is a light-brown to brown slightly sticky fine sandy loam extending usually without change to 36 inches. Sometimes at 20 to 24 inches the subsoil becomes heavier and mottled with yellow. A variation of the type occurs near Kilbourn. The soil here consists of a brown to dark-brown sandy loam 10 to 15 inches deep underlain by a light-brown sandy loam which at 24 inches changes into a light yellowish-brown loamy sand. In topography the soil is level to slightly undulating. Drainage is good except in a few cases in depressed areas.

Nearly all the soil is under cultivation and general farm crops are grown. Corn yields 25 to 45 bushels per acre; oats, 30 to 40 bushels; and wheat, 15 to 20 bushels per acre. Clover and alfalfa also yield fairly satisfactorily. Near Farmington tomatoes are grown to some extent.

The need of this soil is mainly for organic matter. Farm manure should be applied in as large amounts as practicable and green manures might also be used
with profit to supplement the farm manure. Lime may be required in some cases and the soil should be tested and the required amount of lime applied. Phosphorus fertilizers may be profitable even now and certainly will be needed in the future, inasmuch as the soil is not rich in phosphorus. With protection from overflow and treatments as indicated this soil may be made and kept more productive.
What soils need to make them highly productive and to keep them so, and how their needs may be supplied are problems which are met constantly on the farm today.

To enable every Iowa farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

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

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

**PLANT FOOD IN SOILS**

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, although many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

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

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true in Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage in this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proven of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food.

The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

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

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

**REMOVAL OF PLANT FOOD BY CROPS**

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

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

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

It is evident from the table that the continuous growing of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil there is a large loss of fertility, and if the entire crop is removed and no return made, the
TABLE I. PLANT FOOD IN CROPS AND VALUE

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Food Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>- 39</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td>9.21</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats crop</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
<td>7.76</td>
</tr>
<tr>
<td>Barley grain</td>
<td>25</td>
<td>9.5</td>
<td>13</td>
<td>1.52</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>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
<td>6.22</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>65</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of 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 rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

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

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

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

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

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

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

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.
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 thus 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 eolian.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
10. The ultimate chemical composition and reaction.

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

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

<table>
<thead>
<tr>
<th>Inorganic Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stones—over 32 mm.*</td>
</tr>
<tr>
<td>Gravel—32—2.0 mm.</td>
</tr>
<tr>
<td>Very coarse sand—2.0—1.0 mm.</td>
</tr>
<tr>
<td>Coarse Sand—1.0—0.5 mm.</td>
</tr>
<tr>
<td>Medium Sand—0.5—0.25 mm.</td>
</tr>
<tr>
<td>Fine Sand—0.25—0.10 mm.</td>
</tr>
<tr>
<td>Very fine Sand—0.10—0.05 mm.</td>
</tr>
<tr>
<td>Silt—0.05—0.00 mm.</td>
</tr>
</tbody>
</table>

SOILS GROUPED BY TYPES

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

Peats—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 per cent of organic matter mixed with much sand and silt and a little clay.

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

Clays—Soils with more than 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.