Soil Survey of Iowa, Report No. 6—Sioux County

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SOIL SURVEY OF IOWA
Report No. 6—SIOUX COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 6
November, 1918
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

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4 Bacterial Activities in Frozen Soils.*  
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6 Bacteriological Studies of Field Soils, II.*  
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9 Amino Acid and Acid Amides as Sources of Ammonia in Soils.*  
11 Methods for the Bacteriological Examination of Soils.*  
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35 Effects of Some Manganese Salts on Ammonification and Nitrification.  
43 The Effect of Sulphur and Manure on the Availability of Rock Phosphate in Soil.  
44 The Effect of Certain Alkali Salts on Ammonification.  
45 Soil Inoculation with Azotobacter.

SOIL REPORTS

1 Bremer County  
2 Pottawattamie County.  
3 Muscatine County.  
4 Webster County.  
5 Lee County.  
6 Sioux County.  
7 Van Buren County (In press).  
8 Clinton County (In press).  
9 Scott County (In press).
SOIL SURVEY OF IOWA
Report No. 6—SIOUX COUNTY

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

A typical Sioux County farmstead

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

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

Sioux county is located in the northwestern part of Iowa along the Missouri river. It is entirely within the Missouri loess soil area and its soils are mainly loessial in character.

The county has an area of 765 square miles, or 489,600 acres. Of this total area 452,380 acres or 92.4 percent is in farms, of which there are 2,418 with an average size of 187.1 acres.

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

| Acreage in pasture | 77,541 |
| Acreage in farm buildings, feed lots and public highways | 22,115 |
| Acreage in orchards | 953 |
| Acreage in gardens | 1,862 |
| Acreage in waste land | 2,024 |
| Acreage in general farm crops | 287,320 |
| Acreage in crops not otherwise listed | 742 |

General farming is practiced to some extent in Sioux county but the livestock industry is particularly important. Hog raising, beef cattle feeding and dairying are all followed extensively.

There is a considerable area in waste land in the county and means should be taken to reclaim such land and make it productive. It is not possible to make general recommendations along this line, as the treatments necessary will vary widely in different cases. In the discussion of the individual soil types given later in this report the treatments needed by various unproductive soils will be given. Further information regarding the needs of special soils may be secured from the Soils Section upon request.

The farm crops grown in Sioux county in the order of their importance are corn, oats, hay, wheat, barley, potatoes, alfalfa, and rye. The yields and value of these crops in 1916 are given in Table I.

**TABLE I. ACREAGE, YIELDS AND VALUES OF FARM CROPS IN SIOUX COUNTY**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm land in county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>117,000</td>
<td>23.8</td>
<td>46</td>
<td>5,382,000</td>
<td>$0.81</td>
<td>$4,359,420</td>
</tr>
<tr>
<td>Oats</td>
<td>101,000</td>
<td>20.6</td>
<td>46</td>
<td>4,646,000</td>
<td>0.49</td>
<td>2,276,540</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>760</td>
<td>0.1</td>
<td>15</td>
<td>11,400</td>
<td>1.58</td>
<td>18,012</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>11,600</td>
<td>2.3</td>
<td>13</td>
<td>150,800</td>
<td>1.54</td>
<td>232,232</td>
</tr>
<tr>
<td>Barley</td>
<td>13,600</td>
<td>2.7</td>
<td>34</td>
<td>462,400</td>
<td>0.90</td>
<td>416,160</td>
</tr>
<tr>
<td>Rye</td>
<td>60</td>
<td>...</td>
<td>18</td>
<td>1,080</td>
<td>1.15</td>
<td>1,242</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2,200</td>
<td>0.4</td>
<td>49</td>
<td>107,800</td>
<td>1.75</td>
<td>188,650</td>
</tr>
<tr>
<td>Tame hay</td>
<td>21,300</td>
<td>4.3</td>
<td>1.8</td>
<td>38,300</td>
<td>9.00</td>
<td>344,700</td>
</tr>
<tr>
<td>Wild hay</td>
<td>15,200</td>
<td>3.1</td>
<td>1.5</td>
<td>22,800</td>
<td>7.89</td>
<td>179,892</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>4,600</td>
<td>0.9</td>
<td>2.8</td>
<td>12,900</td>
<td>11.71</td>
<td>151,059</td>
</tr>
<tr>
<td>Pasture</td>
<td>77,541</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

2 Iowa Yearbook of Agriculture, 1916.

Corn is the principal crop grown both in acreage and in value. Over 50 percent of the corn produced in the county is used as feed for work stock, for fattening hogs and cattle and for dairy cattle. The remainder is sold out of the

1 Soil Survey of Sioux County, Iowa, by E. H. Smies of the U. S. Department of Agriculture and W. C. Bean of the Iowa Agricultural Experiment Station.
county. This crop averages 46 bushels per acre although larger yields are often secured under favorable seasonal conditions.

Oats is the crop of second importance occupying an area almost as large as that used for corn. About one-half of the oats produced in the county is utilized as feed for stock. The yields are usually satisfactory, depending largely upon seasonal conditions. The average yield of 46 bushels of oats per acre for this county is a good showing for the crop. The early varieties give the best results and are being used the most extensively.

The third crop in importance is hay, the largest acreage being in tame hay consisting of timothy and clover, timothy alone or clover alone. Clover yields 2 tons per acre on the average, timothy 1.7 tons and the mixture, 1.8 tons per acre. The yield of wild hay generally averages 1.5 tons per acre. All the hay produced on the farms is used for feeding work stock and beef and dairy cattle. Not enough hay is produced in the county for feeding purposes and considerable amounts are shipped in.

Wheat is grown to some extent in Sioux county, the spring varieties being used in most cases. Winter wheat is produced to only a very small extent as it too frequently winter kills. The average yield of the spring varieties is about 13 bushels per acre.

Barley is grown to some extent, the yields averaging 34 bushels per acre. Potatoes are raised on practically every farm with highly satisfactory yields but are not grown on a commercial scale.

Alfalfa is being grown on gradually increasing acreages throughout the county as its value is becoming more widely recognized. It usually yields greater returns than either clover or clover and timothy and it is largely supplanting these crops in the rotation. The average yield amounts to nearly three tons per acre.

Apples are the only fruit of any importance in the county although there is a small production of grapes, cherries, plums, and peaches. There is no fruit production on a commercial scale.

The livestock interests of Sioux county are large. The following figures taken from the Iowa Yearbook of Agriculture for 1916 give some idea of the extent of the industry.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses (all ages)</td>
<td>19,128</td>
</tr>
<tr>
<td>Mules (all ages)</td>
<td>258</td>
</tr>
<tr>
<td>Swine (July 1, 1916)</td>
<td>235,258</td>
</tr>
<tr>
<td>Cattle (cows and heifers kept for milk)</td>
<td>17,772</td>
</tr>
<tr>
<td>Cattle (other cattle not kept for milk)</td>
<td>28,591</td>
</tr>
<tr>
<td>Cattle (total, all ages)</td>
<td>58,692</td>
</tr>
<tr>
<td>Sheep (all ages, on farms)</td>
<td>3,072</td>
</tr>
<tr>
<td>Sheep (shipped in for feeding)</td>
<td>1,630</td>
</tr>
<tr>
<td>Sheep (total pounds wool clipped)</td>
<td>8,940</td>
</tr>
</tbody>
</table>

Hog raising is one of the most important livestock interests in the county. The feeding of beef cattle is also an important industry, most of the cattle being raised on the farm although some are shipped in for feeding purposes. Dairying is rapidly increasing in importance and as the value of dairy products is becoming more widely recognized, the number of dairy farms is increasing. Draft horses are raised in considerable numbers for farm use. Sheep and poultry are produced to some extent and are a considerable source of income to the county.

Land values in Sioux county vary widely depending upon soil conditions, topography, distance from the markets and other factors. In the eastern two-thirds
The livestock industry is very important in Sioux county of the county. Unimproved land sells at $125 to $175 per acre while improved land brings $150 to $225 or more per acre. In the extreme western part of the county the average price of the land is $150 per acre.

In general, crop yields in Sioux county are satisfactory but in some areas better methods of soil treatment than those employed at present are necessary to bring about profitable crop yields. Experience and some experimental data indicate definitely that many areas in the county would respond very profitably to applications of manure which is probably the fertilizing material most needed on the soils of the county. The soils are rarely acid but when acidity is found, lime should be applied. Drainage is usually adequate but in some cases it should be improved. Organic matter is low in the soils of the county and the use of manure or green manures is necessary to supply that need of the soils and make them more productive. Phosphorus fertilizers may be necessary in some cases but thus far their use has not proven profitable. The field experiments which are now undery way will show not only the need of phosphorus fertilizers but the kind to use, the value of a complete commercial fertilizer, and the value of lime and of manure.

THE GEOLOGY OF SIOUX COUNTY

Sioux county was at one time entirely covered by a thick layer of loess but since this material was deposited there has been considerable erosion and over a part of the area the loess has become rather thin. It now varies in thickness from a few inches to about 20 feet, the average depth being about 6 feet. The unweathered loess is a light-brown or buff-colored silty material and at depths of 3 feet or more there occurs an abundance of lime. At the surface the lime has been removed by leaching and in some cases the soils are acid and in need of lime.

The origin of loess is still somewhat in question but it is usually believed that...
it is fine dust-like material deposited by wind at some period when the atmos­pheric conditions were very different than at present. There are some charac­teristics of loess which distinguish it from other soils, such as the property of standing in straight cuts. The light, open, porous nature of loess soils makes them well aerated. Decomposition processes proceed rapidly and consequently they are usually in greater need of organic matter than many other soils. They are generally well supplied with mineral plant food and except for the lack of organic matter are in a condition of good fertility.

Underlying this loess covering and appearing close to or even at the surface in some places, there is a glaciol drift layer about 200 feet in thickness. The source of this drift layer is not definitely known but it is believed to be a Kansan drift, or the material deposited by the glacier of that name which once invaded Iowa. It is composed of a uniform mass of clay and silt with some sand, gravel, and boulders. The line of separation between the loess and drift is always distinct and a layer of sand, gravel or boulders often occurs between the two. Where the drift material has been exposed it is a yellowish-brown, brown or reddish-brown in color but below the surface and to a depth of 90 feet it is yellow or grayish-yellow. This material is underlaid by a blue clay extending down to the underlying shale.

The original rock material in Sioux county is of no importance from the soil standpoint as it is buried too deeply under the layers of drift and loess. The latter material comprises most of the soils but the former has been exposed to some extent in the western part of the county. In other places throughout the rolling uplands the covering of loess has become thin and the drift material is so close to the surface that it has considerable influence on crop production. The special treatment needed by some of the soils in the county depends upon the depth of the loess layer or the nearness of the drift to the surface. The so-called "worn hill-tops" are areas where the loess is thin and in such cases special treatment of the soils is necessary to make them satisfactorily productive.

PHYSIOGRAPHY AND DRAINAGE

The topography of Sioux county varies from undulating to sharply rolling, the original loess-covered plain having been modified by erosion to its present condition. The whole plain of the county slopes slightly to the southwest, in which direction the streams or drainage channels flow.

The upland in the eastern three-fifths of the county is almost flat varying to gently rolling in some areas. The whole upland plain is cut by the flat, alluvial bottomland along the various streams. In the western part of the county these bottomlands are bordered by exposures of drift soils on uplands which have been much eroded. Some so-called "rough broken land" is also found adjoining the bottoms as well as some terraces, old bottomlands which have been raised above the level of flooding by the deepening of the stream channels. In some areas, in the western part of the county the topography becomes sharply rolling to rough.

The county is quite thoroly drained by a series of parallel streams having a general southwestward flow. The rivers and creeks rise in the smooth, level uplands in the eastern part of the county and cutting their courses deep into or thru the loess empty into the Big Sioux river which forms the western boundary of the county.
Fig. 2. Natural drainage system of Sioux county
Along the Rock river and the Big Sioux in the northern part of the county, the slopes are steep and the land is rather rough. In general the slopes to the terraces are gradual, the land above being gently to sharply rolling in topography. The terraces themselves are usually level, being broken in places by old stream channels or minor streams.

Several of the creeks in the county are entirely without water during the summer but at times of heavy rainfall, because of the large areas they drain, they become of considerable size. The entire system of rivers and creeks in the county is shown in the accompanying map and it is apparent that the county is adequately drained and artificial drainage is necessary in only a few instances.

**THE SOILS OF SIOUX COUNTY**

There are four groups of soils in Sioux county, namely, drift soils, loess soils, terrace soils, and swamp and bottomland soils. Drift soils are of glacial origin, being composed of material left by a retreating glacier. Loess soils are deposits of very fine material supposedly made by wind at some previous geological time. Terrace soils are accumulations of drift and alluvial material formerly deposited on the banks of streams and now located above the flood plains of the present rivers as a result of the decrease in volume of the streams and the consequent lowering of the river channels. Swamp and bottomland soils occur in lowlying undrained areas or border on streams and are subject to overflow by the rivers during flood seasons. They are largely composed of alluvial material and vary in composition.

The areas of these different groups of soils in Sioux county are shown in table II. By far the largest portion of the county is covered by soils of loessial origin as might be expected from the fact that the county is within the Missouri loess soil area. The small acreage of drift soils consist of areas in the rough portion of the county to the west where the surface covering of loess has been removed and the underlying drift material exposed. The terrace and bottomland soils cover a considerable acreage and are composed of rather complex materials, partly loess and partly drift in origin.

Within these large groups of soil are included various soil types which are distinguished on the basis of various characteristics enumerated in the appendix to this report. The areas of individual types are shown in table III. There are two areas of drift soils, the Carrington loam and a small acreage of so-called "rough broken land" which can not be classified as a soil type. There are two loess soils, the Marshall silt loam and the smooth phase of the same type which together make up over 80 percent of the area of the county. Two terrace soils, the Waukesha silt loam and the Sioux loam cover over five percent of the county and are about equal in area. Five swamp and bottomland soils and the river wash which is included in that group cover about ten percent of the total area of the county. Among the bottomland soils the Wabash silt loam is the most im-

| TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS, SIOUX COUNTY |
|---------------------------------|--------|------|
| Drift soils                     | 17,856 | 3.7  |
| Loess soils                     | 395,520| 80.8 |
| Terrace soils                   | 25,472 | 5.2  |
| Swamp and bottomland soils      | 50,752 | 10.3 |
| **Total**                      | 489,600|      |
TABLE III. TYPES OF SIOUX COUNTY SOILS AND THEIR AREAS

<table>
<thead>
<tr>
<th>Soil Types</th>
<th>Acres</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Carrington loam</td>
<td>15,488</td>
<td>3.2</td>
</tr>
<tr>
<td>78. Rough broken land</td>
<td>2,368</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Marshall silt loam</td>
<td>151,232</td>
<td>80.8</td>
</tr>
<tr>
<td>74. Marshall silt loam (smooth phase)</td>
<td>244,288</td>
<td></td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75. Waukesha silt loam</td>
<td>14,720</td>
<td>3.0</td>
</tr>
<tr>
<td>76. Sioux loam</td>
<td>10,752</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Wabash silt loam</td>
<td>32,000</td>
<td>6.5</td>
</tr>
<tr>
<td>49. Wabash loam</td>
<td>12,800</td>
<td>2.6</td>
</tr>
<tr>
<td>77. Lamoure silt loam (Colluvial phase)</td>
<td>3,264</td>
<td>0.7</td>
</tr>
<tr>
<td>53. Riverwash</td>
<td>1,152</td>
<td>0.2</td>
</tr>
<tr>
<td>62. Wabash fine sandy loam</td>
<td>832</td>
<td>0.2</td>
</tr>
<tr>
<td>48. Wabash silty clay loam</td>
<td>704</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Some of these soil types are rolling in topography as, for example, the typical Marshall silt loam and the Carrington loam, but the other soils are generally level to only very gently rolling and in some areas almost flat. In spite of the level character of much of the land, the need of drainage is evidenced only in a few cases, such as the Lamoure silt loam and some of the Wabash soils.

**THE FERTILITY IN SIOUX COUNTY SOILS**

Samples were secured from all the soil types in Sioux county and analyzed for their plant food content. The rough broken land and the riverwash, being extremely variable and of no agricultural importance were not sampled. Three samples were drawn from all the major types while only one sample of each of the minor types was analyzed. These samples were secured with great care that

---

Fig. 3. Marshall silt loam (smooth phase) typical topography
they might be typical of the soil types and that variations due to local conditions or recent treatment be eliminated. The soils were sampled at three depths: 0 to 6 inches, representing the surface soils; 6 to 20 inches, representing the subsurface soils and 20 to 40 inches, representing the subsoils. Analyses were made for total phosphorus, total nitrogen, organic carbon, inorganic carbon and limestone requirement. The official methods were used for phosphorus, nitrogen and carbon and the Veitch method for the limestone requirement.

THE SURFACE SOILS

The analyses of 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. Duplicate determinations of each constituent were made on each sample of soil and the results given are the averages of these determinations where only one sample was analyzed and the average of all determinations where several samples were analyzed.

The phosphorus content of the soils of the county seems to be rather low. There is not a wide range of difference in the amount of phosphorus present in the various soil types, nor is there much difference in the average content of the soils in the different groups. The drift soil seems to be the lowest while the loess and terrace soils are the highest and are about the same in amount. The bottomland soils occupy an intermediate position. The Waukesha silt loam is highest of any of the types and the Wabash silty clay loam is second, these being the only soils which show a content of more than 1500 pounds of phosphorus per acre. There is apparently little relation between the character of the soil and its phosphorus content although in some instances the darker soils seem to be better supplied with this constituent than the light colored soils. In general the phosphorus present in Sioux county soils is low and rather variable depending upon the general soil conditions and characteristics. The need of phosphorus fertilizers on the soils of this county will be apparent some time in the future and their use might prove profitable at the present time. This point will be discussed more in detail later in this report.

TABLE IV. PLANT FOOD IN SIOUX COUNTY SOILS, IOWA, POUNDS PER ACRE OF TWO MILLION POUNDS OF SURFACE SOIL (0-6"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,160</td>
<td>3,860</td>
<td>45,080</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>9-4</td>
<td>Marshall silt loam</td>
<td>1,453</td>
<td>5,326</td>
<td>52,100</td>
<td>0</td>
<td>2,133</td>
</tr>
<tr>
<td>74</td>
<td>Marshall silt loam (smooth phase)</td>
<td>1,486</td>
<td>5,006</td>
<td>60,833</td>
<td>0</td>
<td>2,266</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,660</td>
<td>4,990</td>
<td>58,790</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>1,300</td>
<td>3,113</td>
<td>35,706</td>
<td>0</td>
<td>1,200</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>940</td>
<td>2,800</td>
<td>37,860</td>
<td>2,080</td>
<td>Basic</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,400</td>
<td>3,480</td>
<td>44,120</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>77</td>
<td>Lamoure silt loam (colluvial phase)</td>
<td>1,220</td>
<td>7,460</td>
<td>78,190</td>
<td>1,220</td>
<td>Basic</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>1,040</td>
<td>3,260</td>
<td>32,020</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,520</td>
<td>6,220</td>
<td>80,880</td>
<td>0</td>
<td>2,400</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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wabash silt loam</td>
<td>940</td>
<td>2,800</td>
<td>37,860</td>
<td>2,080</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash loam</td>
<td>1,400</td>
<td>3,480</td>
<td>44,120</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>Lamoure silt loam (colluvial phase)</td>
<td>1,220</td>
<td>7,460</td>
<td>78,190</td>
<td>1,220</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash fine sandy loam</td>
<td>1,040</td>
<td>3,260</td>
<td>32,020</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>Wabash silty clay loam</td>
<td>1,520</td>
<td>6,220</td>
<td>80,880</td>
<td>0</td>
<td>2,400</td>
</tr>
</tbody>
</table>
The soils of the county are much better supplied with nitrogen than with phosphorus but there is not an especially large amount of that constituent present. Bottomland soils are generally the best supplied with nitrogen of any group of soils but, in Sioux county on the contrary, the loess soils average somewhat higher in this element than the bottomland soils. This is probably due to the more level character of the Marshall silt loam and the less rapid loss of organic matter.

The poorly drained soils such as the colluvial phase of the Lamoure silt loam, and the Wabash silty clay loam, are the highest in nitrogen among all the soil types. There is often a distinct relation between the color of a soil and its nitrogen content. A dark colored soil indicates an abundance of organic matter and usually also an abundance of nitrogen. The nitrogen content of these soils while not very low is not inexhaustible and inoculated legumes should be used as green manures in order to add nitrogen to the soils and as much as possible of that removed by the crops should be returned to the soils by the use of all crop residues and farm manure.

The carbon content of the various soils of the county varies as much as does the nitrogen content. In general there is a rather close relation between these two constituents, the carbon indicating the amount of organic matter and the nitrogen and carbon together, the character of the decomposition processes going on in the soil. Those soils in Sioux county which are highest in organic carbon are highest in nitrogen and those lowest in carbon are lowest in nitrogen. Hence the darker colored soils which are richer in organic matter are actually better supplied with nitrogen.

The relation between the nitrogen and carbon is generally satisfactory, indicating that the decomposition processes are proceeding with sufficient rapidity to bring about the best production of available plant food. In a few instances, however, as in the case of the Marshall silt loam and the Carrington loam the
relation between these two elements is such that the application of farm manure would be particularly valuable because of its action in starting the decay processes and aiding in making plant food available. A high content of organic matter does not always insure the best decay processes and manure frequently proves very profitable on soils which are apparently well supplied with organic matter. In the case of soils low in organic matter, the addition of manure is particularly valuable in adding nitrogen and carbon and also in increasing the decay processes.

While the soils of the county are fairly well supplied with organic matter, they are benefited by applications of farm manure and by the use of crop residues and in some cases also by the use of leguminous green manures. On all the soils of the county these organic materials should be used if the soils are to be kept permanently fertile.

In only two cases is there more than a trace of inorganic carbon present in any of the soils of the county. They are not generally strongly acid in reaction, however, as the limestone requirement determinations show in all cases only a small need for lime. The Carrington loam is basic in reaction and two of the bottomland soils are also basic while the average lime requirement of the other soils in the county is about one ton per acre showing that altho the soils of the county are not strongly acid in reaction, they are just approaching a condition when lime will be required, especially for such crops as alfalfa and clover. The actual amount of lime needed by any of these soils to put them in a basic condition should not be determined from the analyses given in the table as other samples would undoubtedly vary widely in lime requirement. The figures given are merely indicative of the general needs of the soils and show that while they are not strongly acid they are in need of small applications of lime to keep them properly productive. All the soils of the county should be tested at regular intervals in order to insure the maintenance of the soil in the best reaction for crop growth.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil.

**TABLE V. PLANT FOOD IN SIOUX COUNTY SOILS, IOWA, 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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Carrington loam</td>
<td>1,720</td>
<td>5,040</td>
<td>58,320</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>9.</td>
<td>Marshall silt loam</td>
<td>2,573</td>
<td>8,973</td>
<td>69,146</td>
<td>0</td>
<td>1,600</td>
</tr>
<tr>
<td>74.</td>
<td>Marshall silt loam (smooth phase)</td>
<td>2,480</td>
<td>8,893</td>
<td>95,066</td>
<td>0</td>
<td>1,733</td>
</tr>
<tr>
<td>75.</td>
<td>Waukesha silt loam</td>
<td>2,900</td>
<td>7,960</td>
<td>92,620</td>
<td>0</td>
<td>1,600</td>
</tr>
<tr>
<td>76.</td>
<td>Sioux loam</td>
<td>2,213</td>
<td>4,586</td>
<td>50,586</td>
<td>0</td>
<td>666</td>
</tr>
<tr>
<td>26.</td>
<td>Wabash silt loam</td>
<td>2,220</td>
<td>7,880</td>
<td>133,120</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>49.</td>
<td>Wabash loam</td>
<td>2,600</td>
<td>5,960</td>
<td>62,530</td>
<td>0</td>
<td>240</td>
</tr>
<tr>
<td>77.</td>
<td>Lamoure silt loam (colluvial phase)</td>
<td>2,400</td>
<td>9,760</td>
<td>78,840</td>
<td>3,560</td>
<td>Basic</td>
</tr>
<tr>
<td>62.</td>
<td>Wabash fine sandy loam</td>
<td>1,840</td>
<td>4,720</td>
<td>27,000</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>48.</td>
<td>Wabash silty clay loam</td>
<td>2,480</td>
<td>9,200</td>
<td>124,880</td>
<td>0</td>
<td>Basic</td>
</tr>
</tbody>
</table>
TABLE VI. PLANT FOOD IN SIOUX COUNTY SOILS, IOWA, 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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>2,520</td>
<td>2,520</td>
<td>32,940</td>
<td>0</td>
<td>Basic</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>3,620</td>
<td>11,500</td>
<td>46,780</td>
<td>0</td>
<td>533</td>
</tr>
<tr>
<td>74</td>
<td>Marshall silt loam (smooth phase)</td>
<td>3,560</td>
<td>7,580</td>
<td>53,870</td>
<td>0</td>
<td>1,200</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>4,170</td>
<td>6,810</td>
<td>74,550</td>
<td>0</td>
<td>1,600</td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>2,966</td>
<td>4,020</td>
<td>42,820</td>
<td>3,980</td>
<td>267</td>
</tr>
</tbody>
</table>

DRIFT SOILS

LOESS SOILS

TERRACE SOILS

SWAMP AND BOTTOMLAND SOILS

The actual content of plant food in the lower soil layers is of very much less importance than that in the surface soil. Only when the subsoil is very rich in some constituents, is there any appreciable influence on crop production. If the surface soil is deficient in any plant food, the amount present in the subsoil must be very large to obviate the need for that element in the surface soil. In most cases the amounts of plant food in the lower soil layers are sufficient only to delay for a short period the time when the soil will be deficient in plant food. There are no large amounts of any plant food elements present in the lower soil layers in Sioux county. The phosphorus and carbon content decreases in the subsurface soils and subsoils as would be expected and the organic carbon content is also smaller in the lower soil layers in nearly all cases. In one instance the amount of organic carbon in the subsoil is larger than that in the surface soil but that is in the case of a bottomland soil where the accumulation of organic matter is very large. In all cases the lower soil layers show a smaller lime re-

Fig. 5. First greenhouse experiment on Marshall silt loam. Immature wheat.
Fig. 6. First greenhouse experiment on Marshall silt loam. Mature wheat.

requirement than the surface soils and in the bottomland soils there are considerable amounts of lime present in the subsoils in several cases.

Thus in Sioux county the needs of the surface soils may be considered as indicating rather definitely the treatment which the soils should receive to make them satisfactorily productive.

GREENHOUSE EXPERIMENTS

Three greenhouse experiments were carried out on typical Marshall silt loam, the main soil type in Sioux county to attempt to learn something regarding the value of various fertilizer treatments in increasing crop production.

In the first experiment, lime was applied in sufficient amount to neutralize the acidity of the soil and supply two tons additional; manure was added at the rate of 10 tons per acre; acid phosphate at the rate of 200 pounds per acre and rock phosphate at the rate of 1,000 pounds per acre. The results of this experiment are given in table VII, the average dry weight in grams of the wheat crop being recorded.

The table shows some interesting data. The addition of lime apparently had no effect on the wheat crop. This does not mean that lime is of no use on this

| Table VII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, SIOUX COUNTY |
|-------------------------|-----------------|
| Pot No. | Treatment | Wt. grain in grams |
| 1 | Check | 13.00 |
| 2 | Lime | 13.00 |
| 3 | Lime+rock phosphate | 14.25 |
| 4 | Lime+acid phosphate | 12.50 |
| 5 | Lime+manure | 17.50 |
| 6 | Lime+manure+rock phosphate | 18.50 |
| 7 | Lime+manure+acid phosphate | 17.75 |
TABLE VIII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, SIOUX 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>Check</td>
<td>22.82</td>
<td>58.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>23.96</td>
<td>75.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>23.60</td>
<td>77.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>24.99</td>
<td>74.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>22.05</td>
<td>72.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+commercial fertilizer</td>
<td>22.56</td>
<td>72.0</td>
</tr>
</tbody>
</table>

soil, for wheat is not especially sensitive to acid conditions in the soil, unless they are extreme. Legumes are much more readily affected and might show profitable returns from the use of lime. Other samples of the same soil might also yield different results from the use of lime inasmuch as the extent of acidity in soils is very variable. Therefore, the results secured in this experiment should not be interpreted as indicating that the Marshall silt loam should not be tested before seeding to legumes. Experience shows that in all cases careful tests should be made for acidity and lime applied when necessary if such crops as alfalfa and clover are to give satisfactory yields.

The application of rock phosphate or acid phosphate brought about no appreciable increases in the yield of wheat when added with the lime. Manure, however, brought about a decided increase in crop, but phosphorus, either as the rock or acid phosphate, had practically no effect when used in addition to manure and lime. Evidently manure is the fertilizing constituent which will give the best results on this soil and phosphorus fertilizers do not at present prove profitable.

In the second experiment lime was applied as before, manure at the rate of 8 tons per acre, rock phosphate at the rate of 2,000 lbs. per acre, acid phosphate at the rate of 200 lbs. per acre and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 lbs. per acre. Wheat and clover were both grown on these soils, the clover being sown about one month after the wheat was up. The yields of both these crops in grams are given in table VIII. Manure brought about distinct increases in crop yields both of wheat and clover but the greatest gain was in the clover crop. Lime, in addition to the manure, had no effect on the wheat but did increase the clover to some extent. Rock phosphate had little effect on the wheat and none at all on the clover and both acid

Fig. 7. Clover in second greenhouse experiment on Marshall silt loam, Sioux county.
phosphate and the commercial fertilizer gave slightly smaller yields than the manure alone. The differences were too small to be distinct and it should merely be concluded that those materials had no beneficial influence either on the wheat or the clover. This experiment confirms the former results in showing the value of manure on this soil and the increase in clover shows clearly that lime should be applied when the type is acid and will prove profitable.

The third experiment on the same soil type was planned just like the second, the treatments being exactly the same. The only difference between the two experiments was that the soil was secured from another locality. It was, however, a typical Marshall silt loam. The results of this experiment are given in table IX.

Manure again showed a decided effect on both the wheat and clover crops. Lime brought about a slight increase in the clover but the rock phosphate, acid phosphate and commercial fertilizer had practically no effect. The differences among the yields with these latter treatments were too small to be definite. The results of this experiment show again that manure is the most profitable fertilizing material and that lime is necessary when the soil is acid.

**TABLE IX. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, SIOUX 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>Check</td>
<td>14.2</td>
<td>62.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>20.0</td>
<td>72.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>19.3</td>
<td>74.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>19.2</td>
<td>69.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>19.7</td>
<td>76.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+commercial fertilizer</td>
<td>20.5</td>
<td>66.5</td>
</tr>
</tbody>
</table>
These greenhouse experiments as a whole show rather definitely that manure should be used on the Marshall silt loam in as large quantities as are practicable and available. Lime should be applied when the soil is acid in order to provide for the best growth of legumes. Phosphorus fertilizers and commercial fertilizers do not seem to be necessary at the present time. Phosphorus will be necessary on this soil in the future, however, and tests with acid and rock phosphate on individual farms are quite desirable. The field tests which are now under way in Sioux county will give interesting data regarding the use of phosphorus. They will be published later when several years results are available.

FIELD EXPERIMENT

The soil upon some of the more hilly portions of the Missouri loess area in Sioux county has sometimes become rather thin and occasionally outcrops of the underlying drift material occur. The removal of organic matter from the loess soils, which is generally rapid, is increased in such a topographic situation.

A field experiment was conducted during the seasons of 1905, 1906, and 1907 to ascertain the needs of such rather poor areas of Missouri loess soil. The experiment field was located at Leeds, in Woodbury county, near the Plymouth county line. The general situation and the conditions are very similar to those in Sioux county so that the results of that experiment may well be considered here.

The complete data secured in the experiment were presented in Bulletin 95 of the Iowa Agricultural Experiment Station published in 1908 and hence only summarized data and conclusions will be given here.

This experiment was carried out on an infertile hilltop, the field being situated on a divide and the road between the two series of plots being in the center of the ridge. The plots sloped east or west and the general slope of the area was north. The soil was a true loess, the underlying glacial material appearing only in a few places in the vicinity. The field had been under cultivation for only two years. Prior to that time it was in native pasture.

On the top of the divide the organic matter content was very low due to the constant removal of the surface soil by erosion as well as to rapid decomposition. The organic matter content of the soil increased toward the lower part of the

Fig. 9. Clover in third greenhouse experiment on Marshall silt loam, Sioux county.
slopes and the growth of crops was much better in these portions of the plots. This hilltop was probably less fertile than the most of the area covered by the Missouri loess, but it was typical of a large number of unproductive areas which occur through the region.

The field was laid out into 44 one-twentieth acre plots, each 1 rod wide and 8 rods long, with a border 6 feet, 10 inches wide separating it from the next plot.

A regular four-year rotation was followed, consisting of corn, corn, oats, and clover. The clover yields were not secured separately so there are no results for this crop. The oats were not threshed and hence the grain and straw yields were not secured separately. The total oats yield is given, however, for the two years 1905 and 1906 and the yield of corn for the years 1905, 1906, and 1907 is likewise given. Only the weight of grain was secured in the case of the corn.

The treatments of the plots consisted in the application of manure at the rate of 8 tons per acre, bone meal at the rate of 200 lbs. per acre annually, and cowpeas for a green manure by seeding the crop in the corn at the last cultivation and turning it under in the spring.

The yields of oats are given in table X and the average yields of corn for the three years appear in table XI together with the average increase and value of

### TABLE X. FIELD EXPERIMENT — OATS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1905 Average Weight Crop</th>
<th>1906 Average Weight Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>91</td>
<td>156</td>
</tr>
<tr>
<td>Manure</td>
<td>126</td>
<td>228</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>99</td>
<td>186</td>
</tr>
<tr>
<td>Manure + Phosphorus</td>
<td>126</td>
<td>231</td>
</tr>
<tr>
<td>Potassium (KCl)</td>
<td>89</td>
<td>...</td>
</tr>
<tr>
<td>Manure + Potassium</td>
<td>126</td>
<td>197</td>
</tr>
<tr>
<td>Phosphorus + Potassium</td>
<td>103</td>
<td>193</td>
</tr>
<tr>
<td>Manure + Phosphorus + Potassium</td>
<td>134</td>
<td>251</td>
</tr>
</tbody>
</table>

### TABLE XI. FIELD EXPERIMENT — CORN

<table>
<thead>
<tr>
<th></th>
<th>1905 Aver. yield bu. per acre</th>
<th>1906 Aver. yield bu. per acre</th>
<th>1907 Aver. yield bu. per acre</th>
<th>Average for 3 years</th>
<th>Increase</th>
<th>Value of increase*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>26.7</td>
<td>35.1</td>
<td>25.5</td>
<td>29.4</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Manure</td>
<td>38.1</td>
<td>61.5</td>
<td>39.7</td>
<td>46.4</td>
<td>17.0</td>
<td>$0.43</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>44.0</td>
<td>66.9</td>
<td>46.1</td>
<td>52.3</td>
<td>22.9</td>
<td>7.56</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>26.4</td>
<td>44.9</td>
<td>31.1</td>
<td>34.1</td>
<td>4.7</td>
<td>1.55</td>
</tr>
<tr>
<td>Manure</td>
<td>42.4</td>
<td>64.9</td>
<td>47.3</td>
<td>51.5</td>
<td>22.1</td>
<td>7.29</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>41.6</td>
<td>64.0</td>
<td>49.2</td>
<td>51.6</td>
<td>22.2</td>
<td>7.33</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>22.2</td>
<td>41.9</td>
<td>28.3</td>
<td>30.8</td>
<td>1.4</td>
<td>0.46</td>
</tr>
<tr>
<td>Potassium (K₂SO₄)</td>
<td>34.4</td>
<td>58.2</td>
<td>44.7</td>
<td>45.8</td>
<td>16.4</td>
<td>5.41</td>
</tr>
<tr>
<td>Manure</td>
<td>32.3</td>
<td>50.5</td>
<td>34.9</td>
<td>39.2</td>
<td>9.8</td>
<td>3.23</td>
</tr>
<tr>
<td>Potassium</td>
<td>53.1</td>
<td>68.5</td>
<td>49.3</td>
<td>57.0</td>
<td>27.6</td>
<td>9.11</td>
</tr>
</tbody>
</table>

* Value calculated on basis of 33 cents per bushel.
Little value can be attached to the oat results inasmuch as it is quite impossible to determine how much of the increase in total crop was in the grain and how much was in the straw.

It is apparent from the results as a whole, that the plots to which manure was applied produced approximately one-third more grain and straw than did the plots which received no manure. This is a significant fact, and its importance accounts for the inclusion of the data at this place. It should be kept in mind in considering the results secured by the growth of corn for three years under the same treatments.

The effects of the various treatments on the corn crop are clearly shown in Table XI by the increases calculated for the average yield for the three years. The cowpeas gave a very slight increase, which might be expected since the crop turned under was rather small. Manure gave a larger increase in the yield of corn and when cowpeas were applied with the manure, a further gain was shown.

Bone meal with the cowpeas had practically no effect but with manure showed a small gain over the plot treated with manure alone. Potassium sulfate exerted little influence on the crop when used with cowpeas or with manure. A slight gain was noted, both when it was applied with bone meal and cowpeas and when it was used with bone meal and manure.

The beneficial effect of the manure is the most prominent fact brought out by the results as a whole. It shows its influence distinctly in each crop, as well as in the general average. The calculation of the value of the increases due to the various treatments shows a large value for the manure.
Evidently, altho phosphorus was not abundant in these infertile hill tops, the use of sufficient organic matter encouraged decomposition processes and the production of available phosphorus to such an extent that the addition of a phosphate fertilizer did not give large increases. The same is true of potassium sulfate. The large increase in crop brought about by the manure may have been due in part to the plant food supplied in the material, but by far the greatest effect was probably due to the organic matter introduced which brought about an improvement of the physical condition of the soil. The ability to retain moisture, less extensive aeration and consequently better bacterial action, with the more economic production and utilization of plant food, are the direct results of the application of manure to this soil.

The system of management recommended for the improvement of the hilltops in the Missouri loess area involves, therefore, the maintenance of a sufficient supply of organic matter. This may be accomplished by the use of manure and by the proper rotation of crops. The rotation used should include the growing at frequent intervals of a crop which leaves a large portion of its material on the land and clover is the best crop for this purpose.

When this crop is grown and the seed only is removed, or even where the first crop is cut and fed, there is considerable value in clover from the standpoint of maintaining the organic matter content of the soil. It is a valuable addition to farm manure which so often is not produced in large enough amounts to keep up all the soil on a farm.

THE NEEDS OF SIOUX COUNTY SOILS INDICATED BY CHEMICAL, GREENHOUSE AND FIELD TESTS

MANURING

The tests of Sioux county soils reported here and the chief need of the soils of the county is for farm manure. The main upland soils and many of the terrace and bottomland soils are not abundantly supplied with organic matter and the use of manure results in more profitable increases in crop yields than any other fertilizing material. This is undoubtedly due in large part to the addition of organic matter but the plant food constituents contained in the manure are also of value in keeping up the content of nitrogen, phosphorus and potassium in the soils.

If manure is properly stored and applied, the return to the soil of the plant food in the crops grown may amount to 75 to 80 percent. These figures show the effect of manure in lengthening the "life" of the soil from the standpoint of the various plant food elements.

Manure should never be stored in a loose pile exposed to the weather as in that way the greatest losses occur especially if, as so often happens, the soluble portion is allowed to wash away. The losses in some cases due to improper storage have been found to amount to 75 to 90 percent of the plant food originally present in the manure. Some method should be adopted on every farm to keep the manure compact and moist and protected from the weather, until it is applied to the soil. No one method of storing applicable to all conditions can be recom-
mended but further information along this line is given in Circular 9 of the Iowa Agricultural Experiment Station.

Manure contains large numbers of bacteria and the result of introducing them into the soil is to increase to a large extent the production of available plant food. When applied to soils in which the decomposition processes are not proceeding sufficiently rapidly to keep the crops supplied with plant food, manure is of especial value because of the bacterial effects which it induces.

Because of the limited production of manure on the average farm there is no particular danger of applying too much to any soil, provided the amount produced is uniformly applied to the soils of the farm but 16 to 20 tons per acre usually bring about the largest increases and greater applications do not prove as profitable.

Under systems of grain farming where the production of manure is not large enough to keep up the supply of organic matter in the soils green manuring must be practiced. Many crops are available for use as green manures but the legumes are particularly desirable as when well inoculated, as they always should be, they add nitrogen to the soil as well as increase the organic matter content.

The number and variety of legumes is so great that some one may be chosen which will be adapted to almost any conditions. Growing and turning under such crops meets the lack of farm manure and maintains the organic matter content of the soil at the best point for crop production. Green manuring should be practiced with care and the proper precautions, however, or it may not prove profitable. General information regarding green manures is given in Circular 10 of the Iowa Agricultural Experiment Station and suggestions regarding the practice for specific conditions may be secured by writing the Soils Section.

Crop residues such as straw and stover return to the soil considerable amounts of the plant food removed by the crop but their main value lies in the organic matter which they supply. They should never be burned, or otherwise destroyed as their value to the soil is considerable. On the livestock farm they should be utilized for feed and bedding and returned to the soil in the manure and on the grain farm they should be stored and allowed to decompose partially or applied to the soil directly. Crop residues alone are insufficient to keep up the organic matter in soils but they aid materially in that direction.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of Sioux county soils is not very large and it might be concluded that phosphorus fertilizers would prove of value. The greenhouse experiments, however, did not show any marked gains either from the use of rock phosphate or of acid phosphate on the main soil type at the present time. Field tests are now under way with both of these materials and also a complete commercial fertilizer and it is hoped that in a few years definite information along this line will be available. The data secured in these experiments will be reported at a later date as a supplement to this report.

Phosphorus fertilizers are not profitable now on the main soil type of the county. They will undoubtedly be necessary in the future and on some of the other types they might be profitable even now. Tests under a variety of soil
conditions are desirable and farmers who are interested are urged to determine the needs of their own soil for phosphorus and the kind of fertilizer which should be employed. Specific directions for carrying out such tests are given in Circular 51 and the Soils Section is always ready to aid in planning such experiments. The more tests which are carried out under a wide variety of conditions the sooner it will be possible to gather definite information regarding the needs of the soil and the materials which can be used with the greatest profit.

Nitrogen is not present in large amounts in Sioux county soils but nitrogenous fertilizers cannot be recommended for general use at the present time. The use of leguminous green manures well inoculated, is a much cheaper method of increasing and maintaining the nitrogen in the soil. Except as top dressings or in small amount to encourage the early growth of certain crops, commercial nitrogenous fertilizers will probably not prove of value.

Potassium fertilizers are probably unnecessary on Sioux county soils at the present time. The amount of that element present in all the soils of the state is so great that a sufficient amount is probably produced in an available form to keep crops supplied. If the soil is kept in proper physical condition by drainage, cultivation and other treatments, there should be an abundant production of available potassium and so far as is now known potassium fertilizers will probably not yield profitable returns.

Complete commercial fertilizers are not expected to prove profitable in Sioux county soils inasmuch as the nitrogen and potassium present is either unnecessary, or may be supplied in a cheaper form. The comparative tests which are being carried out with the use of phosphorus fertilizers and a standard brand of a complete fertilizer will show whether or not the use of these materials pay. If tests have shown them to be of value, complete fertilizers may be used without fear of injury to the land. The need of tests of these materials on various soils is evident and farmers are urged to determine the needs of their own soils by field tests carried out according to a definite plan.

**LIMING**

None of the Sioux county soils are strongly acid in reaction but several of them are in need of lime in small amounts to put them in the best condition for crop growth. The underlying soil layers in several instances are well supplied with lime but this does not obviate the need of lime in the surface soil as lime moves upward in the soil only in small amounts. The soils of Sioux county are evidently just at the transition stage from a basic to an acid condition and if lime is applied now in the amounts necessary the soil will never become as acid as in many other counties. Acid soils prevent the best growth of crops, especially clover, alfalfa and other legumes. Large increases in the production of corn and small grain crops from the use of lime should not be expected, however, unless the soils are extremely acid. The chief beneficial effect of the lime is exerted on the legume grown in the rotation and its influence on that crop is sufficient to warrant its use. All the soils of Sioux county should be tested and when acid, lime should be applied. Farmers may test their own soils but it is more satisfactory to send a sample of soil to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.
In that way the amount of lime needed by the soil will be determined and the
farmer may apply what is necessary avoiding an excessive amount or too small
a quantity, either of which is undesirable economically. General recommenda­
tions for the application of lime cannot be made as soils vary widely in their
need for that material. Each soil must be tested and its individual need deter­
mined. Further information regarding the kind of lime to use, method of
application, and other points connected with liming are given in Bulletin 151
of the Iowa Agricultural Experiment Station.

DRAINAGE

Most Sioux county soils are fairly well drained but there are three minor
types which would be benefited by better drainage. These are the Lamoure
silt loam, colluvial phase, the Wabash silt loam and the Wabash silty clay loam.
All other methods of soil treatment are practically useless if the drainage of the
soil is inadequate and the first step necessary to make soil properly productive
is to insure thorough drainage. Tile should be installed and proper outlets provided
and even if the expense of the installation is considerable, it will be more than
offset by the increased crop returns. Indeed, in extreme cases the use of tile
has changed a totally unproductive soil into a highly productive one.

It is easy to determine the need for drainage, and the method of establishing
an efficient drainage system is too well known to need special attention here.

ROTATION OF CROPS

No specific experiments have been carried out in Sioux county to show the
value of the rotation of crops, but many tests on a variety of soils and much
farm experience has thoroughly demonstrated the importance of such a practice.

It does not pay to grow one crop continuously on any soil as this practice de­
creases yields very rapidly. A rotation of crops should always be followed on
all soils and the rotation should contain a regular legume crop and in some types
of rotations, one or more legume "catch" crops.

No particular rotation can be recommended as the "best" because of variations
in the systems of farming, capital, size of farm and other factors. The follow­
ing rotations, however, may be 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 rota­
tion may be extended to five years. The last crop will consist principally of timothy).

2. FOUR-YEAR ROTATION WITH ALFALFA

First year: Corn.
Second year: Oats.
Third year: Clover.
Fourth year: Wheat.
Fifth year: Alfalfa. (This crop may remain on the land five years. This field should then
be used for the four-year rotation outlined above).
3. THREE-YEAR ROTATION

First year: Corn.

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

Third year: Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil).

THE PREVENTION OF EROSION

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

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner to the detriment of the land.

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

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

There are some areas in Sioux county where gullying occurs to an injurious extent. The bluffs extending from the upland to the alluvial bottoms are frequently very badly dissected as a result of erosion. The Marshall silt loam, the Carrington loam and the Sioux loam are all subject to erosion, and especially in the case of the Marshall silt loam the injury to the land may be considerable.

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

EROSION DUE TO DEAD FURROWS

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

"Plowing In."—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In."—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three to four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some

Fig. 11. Bottomland with adjoining bluffs. It is on these bluffs that erosion is active.
brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

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

### SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

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

**The Straw Dam.**—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use 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
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 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 drainages may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The concrete dam.

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

Straightening and tiling.—The straightening of the larger streams in bottomland 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 bottomland 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 gullies the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.
Use of organic matter.— Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

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

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

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

INDIVIDUAL SOIL TYPES IN SIOUX COUNTY

DRIFT SOILS

There is one drift soil in Sioux county, the Carrington loam and an area of unclassified material called rough, broken land.

CARRINGTON LOAM (1)

The Carrington loam covers an area of 15,488 acres, or 3.2 per cent of the total area of Sioux county. It occurs chiefly in the western part of the county along the south and east slopes leading to the bottoms along the Big Sioux and Rock rivers. Small areas occur in other parts of the county where the slopes are more or less abrupt.

The surface soil to a depth of 8 or 10 inches is a dark grayish-brown to

1 The descriptions of individual soil types given in the Bureau of Soils report have been rather closely followed in this section of the report.
dark-brown loam to silty loam. This is underlain by a light-brown to yellowish-brown heavy loam to light silty clay which extends to a depth of 24 inches. At that point the subsoil material becomes a yellowish-brown sandy loam, or clayey sand. Fine sand occurs in rather large amounts throughout the soil section. Sometimes a layer of yellowish-brown sand occurs below 27 inches. These layers appear on the steeper slopes while on the more gradual slopes the subsoil is often practically free from sand as is the case near Hawarden.

Much lime appears in the subsoil in the form of concretions or small bowlders of limestone. On the rougher areas, pebbles and bowlders of various kinds are frequently found thruout the soil and in some instances they are so abundant that cultivation is seriously hindered.

The drainage of the Carrington loam is usually satisfactory altho on some of the more abrupt slopes it is excessive. As a general rule, however, this soil is able to retain a good supply of moisture and only in very dry years is it inclined to be drouthy.

Most of the soil is under cultivation, only the rougher portion being used for pasture. The common crops usually give satisfactory yields, the largest crops being secured where the heavier subsoil occurs. Where the subsoil is sandy the yields are apt to be small. Corn, wheat, oats and barley are the main crops grown altho alfalfa and clover are being grown more extensively at the present time than previously.

The main need of this soil at the present time to make it productive is for organic matter. It is not well supplied with this material and hence farm manure should be used on the soil in as large quantities as practicable. It has a special value on that portion of the soil which has a sandy subsoil in that it aids in the retention of moisture in the soil. Phosphorus fertilizers will certainly be necessary in the future if they are not profitable at the present time. Tests of these materials are very desirable. Lime is not necessary at the present time, but with more intensive cultivation it will be needed and the soil should be tested before seeding to legumes such as alfalfa and clover.

ROUGH BROKEN LAND (78)

There are areas along the Rock and Big Sioux rivers where the slopes are too steep and broken for cultivation. They are made up of a variety of materials ranging from coarse sand to stony or gravelly clay containing some bowlders. These areas are called rough broken land inasmuch as they can hardly be considered as containing a definite soil type. There are three small irregular strips of this rough broken land varying from one-eighth to one-half mile in width. The area included in this land is 2,368 acres or 0.5 percent of the total area of the county.

LOESS SOILS

There are two loess soils in Sioux county, the Marshall silt loam and the smooth phase of the same type. Together they cover over 80 percent of the total area of the county.

MARSHALL SILT LOAM (9)

This is the second most extensive soil type in the county covering 151,232 acres or 30.8 percent of the total area. It is developed in the western part of the
county in the drainage basins of the Big Sioux and Rock rivers. Smooth, distinctly V-shaped valleys are characteristics of the areas of this soil type.

The surface soil is a dark grayish-brown to dark-brown heavy silt loam, 8 to 12 inches deep. This is underlain by a yellowish-brown to brownish-yellow rather compact, friable, heavy silt loam to light silty clay loam. In some areas the subsoil becomes grayish in color and loose and friable in texture.

The surface soil is variable in depth, in some places being very thin. The underlying brown to yellowish-brown heavy silt loam is exposed in some instances, as in the region south of Hawarden where erosion has been extensive. On the rather level divides the surface soil is somewhat heavier than the typical soil and resembles the smooth phase altho it is not so deep.

The topography of the soil is usually rolling, being more steeply rolling near the larger streams and less rolling between the Big Sioux and Floyd basins. The soil is for the most part well drained and in some instances it is in danger of considerable injury by erosion.

Corn, oats, hay, barley and wheat are the principal crops grown. Alfalfa is also produced to some extent. Corn yields ordinarily from 32 to 42 bushels per acre, altho in some cases the yields are very large. Oats yield 30 to 40 bushels, wheat 14 to 18 bushels and potatoes 100 bushels per acre. Clover and timothy yield $1\frac{1}{2}$ to $2\frac{1}{2}$ tons of hay per acre, red clover alone about 2 tons, timothy alone 1 to $1\frac{3}{4}$ tons and alfalfa $2\frac{1}{2}$ to 3$\frac{1}{2}$ tons.

The need of this soil is mainly for the application of manure. It is not rich in organic matter and the increases in yield secured from the use of farm manure are always large. It is sometimes acid in reaction and when this is the case lime should be applied to insure the best crops of clover and alfalfa. The soil should always be tested for acidity when such crops are to be grown. It is not very well supplied with phosphorus and phosphorus fertilizers if not needed at the present time will certainly be necessary in the future. Field tests are now under way to ascertain the value of their use. The greenhouse tests on the soil showed no great increases in yields at the present time from their use but field tests are desirable to check the greenhouse results and it is urged that farmers determine the needs of their own soils.

This soil is in danger of erosion and care should be taken to prevent its washing away. Some one of the methods listed in the previous section of this report should be chosen to control erosion selecting that one which is adapted to the particular condition.

**MARSHALL SILT LOAM (SMOOTH PHASE) (74)**

This is the most extensive soil type in Sioux county, covering over two-thirds of the upland areas. It occurs in a large continuous area in the eastern half of the county, covering nearly all the upland.

The surface soil is a dark-brown heavy silt loam extending to a depth of 12 to 15 inches. This is underlain by a layer of brownish-yellow to dark-yellowish-brown, heavy, compact silt loam. At a depth of about 22 inches there is a gradation into a yellow to brownish-yellow rather compact, heavy silt loam, or light silty clay loam. This continues rather uniform down to the underlying drift, reddish-brown or rusty-brown iron stains frequently occurring below 30 inches.
Fig. 12. Surface, subsurface and subsoils on five of the individual soil types of Sioux county.
1. Wabash loam.
2. Wabash silty clay loam.
3. Wabash silt loam.
4. Wabash fine sandy loam.
Small lime concretions are sometimes found in the lower part of the 3 foot section.

On the flatter areas the subsoil sometimes becomes grayish in color and crumbly in character while the surface soil becomes somewhat heavier. In general there occurs between 15 and 22 inches a layer of compact clay. This disappears in the steeper slopes. The surface soil is usually quite uniform in depth altho on the slopes, it sometimes becomes shallower, rarely however, becoming less than 6 to 8 inches in depth.

In topography this soil is generally undulating to very gently rolling. In some places it is almost flat, as for instance near Granville, Hull and Boyden. The drainage is adequate in spite of its rather level topography and tiling is not needed. Erosion does not occur to any extent.

Corn, oats, hay, barley and wheat are the main crops grown on this soil. The yields of corn are somewhat greater than on the typical Marshall silt loam but the other crops give very similar average yields. Corn and oats are the most important money crops. Alfalfa is being grown to a considerable extent and is very well suited to this soil. Its yields are very satisfactory.

The needs of the smooth phase of the Marshall silt loam are very similar to those of the typical Marshall silt loam. Manure brings about the greatest increase in crop yields and should be used in as large amounts as practicable. Green manuring may also be of value. Lime is needed in some cases for the growth of legumes and the soil should be tested before growing such crops, especially alfalfa. Phosphorus fertilizers have not shown profitable returns in the few tests available at the present time, but they will undoubtedly be necessary in the future. Field tests are urged with these materials, as they may prove profitable in some cases even now.

TERRACE SOILS

There are two terrace soils in Sioux county, the Waukesha silt loam and the Sioux loam. These two soils together cover over 5 percent of the total area of the county.

WAUKESHA SILT LOAM (75)

This soil covers 14,720 acres or 3.0 percent of the total area of Sioux county. It occurs along both large and small streams, the areas along the rivers being rather narrow while those along the creeks are larger. The soil is almost entirely above overflow, occupying a typical terrace position. Along the Big Sioux river above the mouth of the Rock river the terraces are higher than elsewhere in the county lying 20 to 50 feet above the flood plains.

The surface soil to a depth of 12 to 15 inches is a dark-grayish-brown to dark-brown moderately heavy silt loam. This is underlain by a brown, rather compact silt loam to light silty clay loam, which at 22 inches passes into a yellowish-brown to brownish-yellow, very heavy silt loam to light silty clay loam, extending to a depth of 5 to 20 feet. At that depth there occurs light gray or yellowish-gray stratified sand and gravel which is sometimes exposed where this type grades into the Wabash soils on the bottoms. In the more undulating areas the intermediate brown layer is absent, the subsoil being a brownish-yellow heavy silt loam.
Altho the topography of this soil is nearly flat the drainage is good. The main crops grown are corn, oats and hay with some barley and wheat. The yields are very satisfactory and compare very favorably with those secured on the upland soils. About 85 percent of the type is under cultivation, the remaining portion being in pasture.

The treatments necessary to make this soil more productive are the application of manure, the use of phosphorus fertilizers now, or in the future, the addition of lime to remedy acidity and the proper rotation of crops. The soil is not unproductive now, but with proper treatment, especially the use of manure, greater crop yields may be secured. Lime would be valuable where legumes are to be grown.

**SIoux Loam (76)**

The Siouxs loam covers 10,752 acres or 2.2 percent of the total area of Sioux county. It occurs mainly along the Big Siouxs and Rock rivers but a few smaller areas are found along the other larger streams.

The surface soil is a dark-grayish-brown to dark-brown loam extending to a depth of 8 to 12 inches. This is underlain by a yellowish-brown to brown silty clay loam. Much sand occurs both in the surface and subsoil material and at a depth of about 30 inches a bed of stratified gravel and sand is encountered. This layer of sand and gravel may be as much as 40 feet in thickness. Sometimes this underlying material is a brownish mixture of coarse and medium sand while in other cases it is mostly gravel.

A sandy variation of this soil occurs along the Big Siouxs river occupying narrow, rather flat ridges about 10 to 15 feet above the typical soil. It is a grayish-brown to dark-grayish-brown sandy loam to a depth of 10 or 12 inches underlain by a light-brown or yellowish-brown mixture of fine, medium and coarse sand with some gravel and a small amount of clay. This soil is subject to excessive drainage and crops are more apt to suffer in dry seasons than is the case on the typical soil.

The typical Siouxs loam is rather flat in topography, occurring generally on terraces 10 to 20 feet above the streams. One area north of the mouth of the Rock river is 20 to 50 feet above the bottomland.

The soil is well drained and where the layer of coarse material occurs near the surface, the drainage is apt to be excessive and the soil drouthy. Erosion occurs to a considerable extent in some areas.

Most of the Siouxs loam is under cultivation, corn being the principal crop grown. Winter wheat is produced to a considerable extent and oats, spring wheat, barley, clover, timothy and alfalfa are other important crops. In normal seasons the yields of corn average 35 to 45 bushels, oats 35 to 40 bushels, winter wheat 25 to 30 bushels, and spring wheat 14 to 18 bushels. In favorable seasons the yields may be much higher while in dry years they are seriously reduced.

The application of farm manure is the treatment most needed to make this soil more productive. This material not only adds the organic matter and plant food in which the soil is deficient but what is particularly necessary makes it more retentive of moisture. Green manuring may probably also be followed with profit on this soil either as a substitute or supplement for farm manure.

The soil is slightly acid in reaction and lime should be applied at regular in-
tervals especially if legumes are to be grown. The lime has an additional value in that it improves the physical condition of the soil. Phosphorus is low on this soil and phosphorus fertilizers would probably be of value in many cases now. Tests in the field of these materials are desirable for if their use is not distinctly profitable now it is certain that it will be in the future.

SWAMP AND BOTTOMLAND SOILS

There are five swamp and bottomland soils in Sioux county belonging to the Wabash and Lamoure series and an area of riverwash. These soils together cover 50,752 acres or 10.3 percent of the total area of the county.

WABASH SILT LOAM (26)

This soil covers 32,000 acres or 6.5 percent of the total area of Sioux county and is the most important bottomland soil. It occupies nearly all the bottomland of most of the smaller streams, occurring in strips ranging from a few hundred feet to one-half mile in width. Along the Big Sioux, Rock and Floyd rivers it occurs in small isolated areas.

The surface soil consists of a very dark-brown to nearly black heavy silt loam, extending to an average depth of 18 or 20 inches. It is underlain by a brownish-gray heavy silt loam to light silty clay loam. The change from the surface soil to the subsoil is usually very gradual and frequently there is very little difference in color, or texture throughout the 3 foot section.

A variation of the typical soil occurs along some of the larger streams and adjacent to areas of the Wabash loam where much fine sand may be present. South of Hawarden and near Chatsworth another variation from the typical soil is found where the subsoil is a very stiff, compact, silty clay loam.

In topography the Wabash silt loam is nearly flat. It lies only 2 to 10 feet above the normal water level of the streams and is practically all subject to overflow. Except for the higher-lying areas the type as a whole is poorly drained.

About 30 percent of this soil is under cultivation, the remaining area being in native grasses. On the higher areas, corn is the principal crop and may yield as high as 50 bushels per acre. Small grains and alfalfa are not grown to any considerable extent except where the land is higher and protected from overflow. In those places the yields secured are satisfactory.

The soil is used mainly for pasture and as a rule the pasturage is excellent. The chief need of this soil is for protection from overflow and where it is diked as at Chatsworth it is very productive. Where flooding is prevented the soil should receive applications of farm manure; lime, if necessary; and phosphorus at some future time to make and keep it productive.

WABASH LOAM (49)

This bottomland soil covers 12,800 acres or 2.6 percent of the total area of the county. It occurs chiefly along the Rock, Big Sioux and Floyd rivers and is usually found in long narrow strips altho in some places the areas are rather wide. The soil occupies the lowest part of the bottoms, lying only 2 to 10 feet above the level of the streams and it is more or less subject to overflow. Some higher areas are overflowed only very infrequently.
The surface soil to a depth of 15 to 18 inches consists of dark-grayish-brown to nearly black friable loam, underlain by a brownish-gray, heavy loam which extends to a depth of 40 inches.

In the poorly drained areas, the subsoil is a light silty clay loam. The surface soil varies somewhat in texture, being quite sandy in places and approaching a sandy loam and in other areas having a high silt content and becoming a rather heavy loam.

In one area of this type south of Hawarden the soil varies from the typical being underlain by a layer of yellowish-gray fine sand at a depth of 27 inches.

In topography the Wabash loam is nearly flat to slightly undulating. Drainage is usually fairly good altho in wet seasons the lower lying areas are apt to be too wet.

In the eastern part of the county the type is devoted to hay and pasture. In the western part probably 70 percent is under cultivation, the remainder supporting either a growth of grass or a stand of timber, chiefly willow, box elder, ash and cottonwood.

Corn is the most important crop grown on this soil and when not damaged
by flooding yields 45 to 60 bushels per acre. Winter wheat may yield 25 to 35 bushels. Oats are seldom grown on this soil because of the tendency to lodge. Clover and timothy do well, ordinarily yielding 2 to 2 1/2 tons of hay per acre. Alfalfa yields 3 to 4 tons per acre in good seasons. Potatoes average 90 bushels per acre.

When this soil is protected from flooding good crop yields are secured. Farm manure would be of value and phosphorus will be necessary in the future. Altho the soil is not strongly acid at the present time it is becoming more and more in need of lime and should be tested at regular intervals and lime applied in order to insure proper crop production.

LAMOURE Silt Loam (Colluvial Phase) (77)

This soil covers 3,264 acres or 0.7 percent of the total area of Sioux county. It occurs in small patches within the smooth phase of the Marshall silt loam and is found in narrow strips along some of the streams and near the heads of drainage ways. The chief areas are in the vicinity of Hull, Boyden and Granville and north of Orange City.

The surface soil is a dark-brown to nearly black, heavy silt loam to light silty clay loam extending to a depth of 12 inches. The subsoil is a dark yellowish-brown, heavy silt loam or light silty clay loam, containing some grayish-yellow spots and grading at a depth of 20 to 24 inches into a grayish-yellow silty clay loam. There is much lime in the subsoil and it is marked with dark-brown or rusty-brown iron stains. In some of the smaller areas the subsoil at 30 inches is a brownish-yellow, rather friable, heavy silt loam.

The surface of this soil is nearly flat and the drainage is rather poor. Water is apt to stand on the surface of many of the undrained areas for some time after each heavy rain.

Probably 75 percent of the soil is utilized for hay or pasture land. Where the land is not drained, it supports a growth of slough grass which furnishes good hay and pasturage. This slough grass yields from 1 to 2 tons of hay per acre. Corn is the principal grain crop grown on the soil when it is drained.

The main need of the soil to make it more productive is the installation of tile drainage. When that is accomplished good crop yields are secured. Farm manure is of value in increasing the fertility of the soil and phosphorus will be necessary as it is brought under cultivation.

RIVERWASH (53)

Small areas of riverwash occur along the Rock and Big Sioux rivers, the material consisting of a mixture of yellowish-gray fine, medium and coarse sand with small gravel particles. It lies but a few feet above the river and is frequently overflowed. Riverwash is practically valueless agriculturally. When not barren a growth of willow occurs.

WABASH Fine Sandy Loam (62)

This is a very minor type in Sioux county, covering only 832 acres or 0.2 percent of the total area of the county. It occupies first bottomland along the Big Sioux and Rock rivers and usually occurs in bends or old loops of the streams.
The surface soil is a dark-grayish-brown to dark brown fine sandy loam extending to a depth of about 20 inches. The subsoil is a brownish-gray heavy fine sandy loam to light loam and extends to a depth of 3 feet or more. There is some variation in the character both of the surface soil and subsoil. In the lower lying areas the content of coarse sand is rather high. In some places the subsoil consists of a grayish-yellow fine sand.

In topography this soil is level to gently undulating and drainage is satisfactory becoming excessive in places where the surface soil and subsoil are loose and open.

This type is not important agriculturally. Probably three-fourths of it has never been cultivated and it supports a growth of native grasses for pasturage. A few willow, box elder, cottonwood and ash trees are found on these areas. When it is cultivated corn is the main crop grown.

This soil when brought under cultivation needs farm manure, or green manuring. Phosphorus will also be necessary in the future and may be of value now. Liming would also prove of value in many cases, especially for the growth of legumes, and the soil should be tested and lime applied as necessary.

WARASH SILTY CLAY LOAM (48)

This is a minor soil type in the county covering only 704 acres, or 0.1 percent of the total area of the county. It occurs only in the vicinity of Hawarden.

The surface soil is a very dark brown to nearly black, heavy silty clay loam and extends to about 15 inches. The subsoil is a brownish-gray stiff, waxy, silty clay to clay and continues for 36 inches. There are usually numerous brown or reddish-brown iron stains thruout the subsoil. In places there may occur considerable sand which has washed in from surrounding sandy soil.

The topography of this soil is nearly flat, drainage is poor and the run-off after heavy rains is slow. It is not subject to overflow since the railroads were built and Dry Creek was diked.

The soil is all under cultivation and general farm crops give satisfactory yields. It is difficult to work being sticky when wet and cracking when dry. Cultivation should be carried on when the soil is fairly moist and the clods should be broken up as soon as they are turned up.

To increase crop production this soil should be adequately drained and farm manure applied in liberal amounts. Phosphorus will be necessary in the future and lime should be applied in many cases to remedy the acid conditions which frequently occur.
APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied are problems which are met constantly on the farm today.

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

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

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

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

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

PLANT FOOD IN SOILS

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

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

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

THE "SOIL DERIVED" ELEMENTS

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

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

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

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

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

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

**REMOVAL OF PLANT FOOD BY CROPS**

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

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

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

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

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil there is a large loss of fertility, and if the entire crop is removed and no return made, the
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>......</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats crop</td>
<td>......</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Barley grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley crop</td>
<td>......</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>......</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>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 amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop, if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

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

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

But, whatever the reason for the bad effects of continuous cropping, it is evident that for
all good systems of farming some definite rotation should be adopted, and that rotations should
always contain a legume, because of the 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 satis­
factory crops are to be secured. Humus not only keeps the soil in the best physical condition
for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus
may always be considered a reliable indication of the presence of much nitrogen. This nitro­
gen does not occur in a form available for plants, but with proper physical conditions in the
soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus,
is made usable by numerous bacteria and changed into soluble and available nitrates.

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

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

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

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

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

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

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

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

SOIL AREAS IN IOWA

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

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

Organic Matter

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

Inorganic Matter

| Stones—over 32 mm.* |
| Gravel—32—2.0 mm. |
| Very coarse sand—2.0—1.0 mm. |
| Coarse Sand—1.0—0.5 mm. |
| Medium Sand—0.5—0.25 mm. |
| Fine Sand—0.25—0.10 mm. |
| Very fine Sand—0.10—0.05 mm. |
| Silt—0.05—0.00 mm. |

SOILS GROUPED BY TYPES

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

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

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

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

Clays—Soils with more than 30 per cent clay, usually mixed with much silt and some silt.

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 Ill. 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.