Soil Survey of Iowa, Report No. 4—Webster County Soils

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

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

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

Recommended Citation
http://lib.dr.iastate.edu/soilsurveys/2

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

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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

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

CIRCULARS

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

RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*  
2 Some Bacteriological Effects of Liming.*  
4 Bacterial Activities in Frozen Soils.*  
5 Bacteriological Studies of Field Soils, I.*  
6 Bacteriological Studies of Field Soils, II.*  
8 Bacteria at Different Depths in Some Typical Iowa Soils.*  
9 Amino Acid and Acid Amides as Sources of Ammonia in Soils.*  
11 Methods for the Bacteriological Examination of Soils.*  
13 Bacteriological Studies of Field Soils, III.  
17 The Determination of Ammonia in Soils.  
18 Sulfonation in Soils.  
25 Bacterial Activities and Crop Production.  
34 Studies in Sulfonation.  
35 Effects of Some Manganese Salts on Ammonification and Nitrification.  
36 Influence of some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.  
39 Carbide Dioxide Production in Soils.

SOIL REPORTS

1 Bremer County  
2 Pottawattamie County  
3 Muscatine County  
4 Webster County  
5 Lee County  
6 Sioux County.
SOIL SURVEY OF IOWA
Report No. 1—WEBSTER COUNTY SOILS

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

Typical topography of Webster loam area in Webster County
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>General farm crops of Webster county</td>
<td>3</td>
</tr>
<tr>
<td>Miscellaneous crops</td>
<td>4</td>
</tr>
<tr>
<td>Livestock industry of Webster county</td>
<td>5</td>
</tr>
<tr>
<td>The Geology of Webster county</td>
<td>5</td>
</tr>
<tr>
<td>Physiography and drainage</td>
<td>6</td>
</tr>
<tr>
<td>Soils of Webster county</td>
<td>8</td>
</tr>
<tr>
<td>The fertility in Webster county soils</td>
<td>9</td>
</tr>
<tr>
<td>The surface soils</td>
<td>9</td>
</tr>
<tr>
<td>The subsurface soils and subsoils</td>
<td>11</td>
</tr>
<tr>
<td>Greenhouse experiments</td>
<td>13</td>
</tr>
<tr>
<td>Field experiments</td>
<td>15</td>
</tr>
<tr>
<td>The rotation experiments</td>
<td>16</td>
</tr>
<tr>
<td>The continuous corn experiment</td>
<td>19</td>
</tr>
<tr>
<td>Peat soils</td>
<td>20</td>
</tr>
<tr>
<td>Drainage and cultivation for peat soils</td>
<td>21</td>
</tr>
<tr>
<td>Alkali soils</td>
<td>22</td>
</tr>
<tr>
<td>Treatment for alkali soils</td>
<td>23</td>
</tr>
<tr>
<td>The needs of Webster county soils as indicated by laboratory and greenhouse tests</td>
<td>23</td>
</tr>
<tr>
<td>Drainage</td>
<td>23</td>
</tr>
<tr>
<td>Liming</td>
<td>24</td>
</tr>
<tr>
<td>Manuring</td>
<td>25</td>
</tr>
<tr>
<td>Commercial fertilizers</td>
<td>28</td>
</tr>
<tr>
<td>Crop rotations</td>
<td>29</td>
</tr>
<tr>
<td>Individual soil types in Webster county</td>
<td>30</td>
</tr>
<tr>
<td>Drift soils</td>
<td>30</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>37</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>38</td>
</tr>
<tr>
<td>Appendix: The soil survey of Iowa</td>
<td>39</td>
</tr>
</tbody>
</table>
WEBSTER COUNTY SOILS*

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

Webster county is situated in the north central part of Iowa entirely within the Wisconsin drift soil area. Almost 95% of its soils are drift soils, the remaining types being terrace and swamp and bottomland soils.

The county has a total area of 714 square miles, or 456,960 acres, of which 415,706 acres or 90.9% is in farmland. There are 2,438 farms with an average size of 171 acres. How the farm land of the county is used is shown in the following figures secured by the State Department of Agriculture in 1915.

Acreage in pasture .................................................. 90,000
Acreage in farm buildings, public highways and feed lots ....... 18,895
Acreage in orchards .................................................. 785
Acreage in gardens ................................................... 179
Acreage in waste land ............................................... 8,189
Acreage in crops not otherwise listed ................................ 241
Acreage in general farm crops ..................................... 392,855

These figures indicate that the type of agriculture followed in the county is mainly livestock farming combined to some extent with general farming. The raising and feeding of beef cattle and hogs are very important industries and they are steadily increasing in extent.

A large proportion of the grain produced on the farms is still being marketed, however, and the result is a constant removal of fertility from the soils. There is a very apparent need for the adoption of proper methods of management to keep the soils of the county permanently fertile.

The area of waste land in the county is rather large and the reclamation of all such unproductive land is very important. General recommendations along this line cannot be made, for the methods of treatment will vary with different conditions. The treatments necessary in the case of individual soil types will be considered later in this report. Definite advice for special cases is desirable and the Soils Section of the Iowa Agricultural Experiment Station will gladly offer suggestions regarding the best treatment for soils which are for any reason unproductive.

THE GENERAL FARM CROPS OF WEBSTER COUNTY

The general farm crops grown in Webster county in the order of their importance are corn, oats, hay, wheat, potatoes, alfalfa, barley and rye. The total acreage 1 of each of these crops, the percent of the total farm area in each crop, the yield per acre, the total yield, the average price, and the total value of the various crops are given in table I.

Corn is the chief crop and its total value is greater than the combined values of all the other crops. Formally good yields of corn were hard to secure, owing

---

*See Soil Survey of Webster County, Iowa, by J. O. Veatch of the U. S. Dep't of Agriculture and F. B. Howe of the Iowa Agricultural Experiment Station.

1 Iowa Yearbook of Agriculture, 1915.
TABLE I. ACREAGE, YIELD AND VALUE OF WEBSTER COUNTY FARM CROPS

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>% of total farm land in county</th>
<th>Bu. or tons per acre</th>
<th>Total Bu. or tons</th>
<th>Average Price</th>
<th>Total value crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>145,000</td>
<td>34.8</td>
<td>34</td>
<td>4,930,000</td>
<td>$0.45</td>
<td>$2,218,500</td>
</tr>
<tr>
<td>Oats</td>
<td>197,000</td>
<td>45.7</td>
<td>49</td>
<td>4,280,000</td>
<td>$0.62</td>
<td>1,299,200</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>2,300</td>
<td>0.5</td>
<td>14</td>
<td>32,200</td>
<td>$0.85</td>
<td>27,370</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>600</td>
<td>0.1</td>
<td>18</td>
<td>10,800</td>
<td>$0.83</td>
<td>8,964</td>
</tr>
<tr>
<td>Barley</td>
<td>450</td>
<td>0.1</td>
<td>23</td>
<td>10,300</td>
<td>$0.81</td>
<td>8,273</td>
</tr>
<tr>
<td>Rye</td>
<td>25</td>
<td>0.1</td>
<td>15</td>
<td>370</td>
<td>$0.77</td>
<td>285</td>
</tr>
<tr>
<td>Potatoes</td>
<td>530</td>
<td>0.1</td>
<td>19</td>
<td>51,400</td>
<td>$0.94</td>
<td>47,044</td>
</tr>
<tr>
<td>Tame hay</td>
<td>27,700</td>
<td>6.6</td>
<td>1.9</td>
<td>52,600</td>
<td>$0.94</td>
<td>47,044</td>
</tr>
<tr>
<td>Wild hay</td>
<td>19,000</td>
<td>4.5</td>
<td>1.8</td>
<td>34,200</td>
<td>$0.74</td>
<td>25,322</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>250</td>
<td>0.1</td>
<td>0.1</td>
<td>750</td>
<td>$1.18</td>
<td>8,935</td>
</tr>
<tr>
<td>Pasture</td>
<td>90,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Oats is the second crop of importance from the standpoint both of acreage and value. This crop is grown in practically all rotations and in most cases the yields are fairly satisfactory. Early maturing varieties of oats are grown to some extent and are preferred on new land, but the varieties more generally grown are those which ripen later. The greater part of the grain produced is sold, only the straw being utilized on the farm.

The chief hay crop in the county is mixed timothy and clover, and the average yields are good. Clover grows well on practically all the well drained soils and withstands the winters well. The acreage in wild hay is still considerable but the native grasses are gradually being replaced by tame hay and other crops. Practically all the hay produced is utilized on the farms.

In former years wheat was grown much more extensively than at present. Frequent unsatisfactory yields, due to continuous cultivation and to insect injuries and blights, are responsible for the decrease in acreage in this crop. Winter wheat has been grown recently to a small extent and the yields have been quite satisfactory. This crop may replace spring wheat and it may even be used in rotations in place of oats and prove more profitable.

MISCELLANEOUS CROPS

Potatoes are grown on only a small area with rather low yields. They are a valuable crop, however, on peat and muck soils not suited for cereal crops.

Alfalfa has been seeded on many of the soils in the county and in general the yields have been good. This crop will undoubtedly prove valuable for forage and may in part replace timothy and clover. Sweet clover has been grown only on small areas but it, too, may prove of value as a forage crop.

Barley and rye, flax and millet are grown only to a very small extent in Webster county and are of little importance economically. Millet is sometimes used on peat and muck soils and flax is valuable in reclaiming new, low-lying land.

Orcharding is carried on only on small areas and the fruits, chiefly apples and plums, are produced mainly for home consumption.
LIVESTOCK INDUSTRY OF WEBSTER COUNTY

The livestock industry is well developed, hogs and cattle being kept on practically every farm. Sheep raising is of minor importance. The following figures compiled in 1915 indicate the extent of the livestock industry:

<table>
<thead>
<tr>
<th>No. of head</th>
<th>Sen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses (all ages)</td>
<td>17,136</td>
</tr>
<tr>
<td>Mules (all ages)</td>
<td>725</td>
</tr>
<tr>
<td>Swine (on farms July, 1915)</td>
<td>65,394</td>
</tr>
<tr>
<td>Cattle (cows and heifers kept for milk)</td>
<td>12,223</td>
</tr>
<tr>
<td>Cattle (other cattle not kept for milk)</td>
<td>22,794</td>
</tr>
<tr>
<td>Cattle (total, all ages)</td>
<td>35,017</td>
</tr>
<tr>
<td>Sheep (all ages on farms)</td>
<td>688</td>
</tr>
<tr>
<td>Sheep (shipped in for feeding)</td>
<td>144</td>
</tr>
<tr>
<td>Sheep (total pounds wool clipped)</td>
<td>3,805</td>
</tr>
</tbody>
</table>

The livestock industry is extremely profitable and is proving the chief source of income in the county. Moreover, the livestock system of farming keeps the soil productive more readily because all farm produce is utilized on the farm.

Land values vary in Webster county but they are uniformly high. They range from $125 to $300 per acre, the selling price of most of the farm land being $175 to $200 per acre.

Crop yields in Webster county are fairly satisfactory but they may be increased thru proper soil management. The soils are not generally acid but in some cases the addition of lime is necessary for successful crop growth, particularly in the case of clover or alfalfa. Drainage is perhaps the most essential treatment for many of the soils. Ditches and tile drains have been installed in many areas, greatly increasing the productivity of the soil.

Altho organic matter is not low in most of the soils in the county, applications of manure are always valuable and other humus forming materials must also be used from time to time if the soils are to be kept well-supplied with this constituent. Phosphorus fertilizers are not always profitable now but they will be necessary on most of the soils at some time in the future. Complete commercial fertilizers, however, are not required for permanent fertility. Crop rotations are necessary in Webster county, just as elsewhere.

THE GEOLOGY OF WEBSTER COUNTY

The native rock materials underlying Webster county soils are of much interest both technically, and economically. The coal and gypsum deposits are rather extensive and have been a source of considerable income to the county. Information regarding these materials may be secured in the geological report mentioned in the footnote, or by application to the state geologist.

From the agricultural standpoint the character of the rock material is of little significance. Three great glaciers extended over the section of the state in which Webster county is located and deposited vast quantities of rock material gathered in their movement from the northwest. Practically all of the material left by the first and second glaciers was later removed by the action of streams and the third glacier. Small scattered beds of gravel are all that remain of these great glacial deposits. The gypsum, red shale, sandstone, coal and limestone of the geological eras preceding the glacial are all deeply buried under

---

1 See Geology of Webster County, Iowa, F. A. Wilder, Geol. Survey, Vol. XII, p. 67.
the great quantities of clay pebbles and boulders left by the most recent glacier. The variable material deposited by this great ice sheet has been modified by weathering, cropping and stream action, and now constitutes the soils of Webster county. This drift deposit is much more recent than the Iowan drift which makes up the soils to the east, and there has been much less loss of plant food than has occurred there. The soils are therefore generally richer in plant food and particularly in lime than the Iowan drift soils.

Altho there are some small stones and boulders present in the county, as is always the case in the more recent drift soils, they are not numerous enough to interfere with cultivation. The drift soils in the county are largely made up of similar rock material and do not vary widely in mineral characteristics, as is frequently the case in soils of glacial origin. They are largely loams, clay loams and silt loams and extend to a depth of 6 to 15 feet. The conditions have been extremely favorable for the growth of vegetation and this with the slower decomposition of organic matter in the soil which is characteristic of the area has led to soils generally rich in organic matter. Practically all the soils therefore, are dark brown to black in color.

Besides the drift soils which make up by far the largest group in the county, there are also small areas of terrace and swamp and bottomland soils, the result of action by the streams of the county on the glacial material. The swamp soils include small areas of peat and muck which were formed in shallow, undrained districts by the accumulation of organic matter from the luxuriant plant growth with which they have been occupied.

**Physiography and Drainage**

The topographic features of Webster county have been only very slightly influenced by the action of streams. Only in the vicinity of the Des Moines river and its tributaries is the effect of the action of water apparent.

The southern part of the county is remarkably level and constitutes a typical Wisconsin drift plain. Coon Mound, a knoll 50 feet in height, is practically the only elevation.

In the northwestern part of the county there are numerous hills and ridges, which are apparently not the result of erosion but were either formed naturally or by the weathering of the drift material. There are two groups of these hills and ridges. One of these, extending east and west, follows the northern county line thru Jackson and Deer Creek townships and across the river into Badger township. This broken region averages two miles in width and includes some extensive level areas. The second group of ridges is about three miles south of the first and extends across Douglas township and beyond the river into Badger township.

The topographic features of the county have been considerably modified by the Des Moines river and its tributaries. This river has cut thru the drift and rock material to a depth of 150 to 200 feet. The alluvial bottomlands are seldom more than 300 yards wide. The widest point occurs at the junction with the Boone river where the bottoms are a mile across. Terraces appear frequently, varying in width from 20 to 200 yards, the largest occurring south of Fort Dodge.

The tributaries of the Des Moines river generally rise in sloughs and follow the natural depressions in the surface soil and consequently have not materially al-
Fig. 1. Natural drainage system of Webster county

tered the topography of the county. Near the river these creeks have cut into the underlying material and have well-defined courses from 10 to 60 feet in depth.

The drainage of the county is effected by these streams and in general is rather incomplete, indicating the relatively recent formation of the soil area. The creeks have no well developed feeders and considerable areas of land are entirely dependent on artificial drainage. Sloughs and ponds are common throughout the county but the extensive drainage systems which have been installed in recent years have brought under cultivation large areas which were previously unproductive. A more complete drainage system is still needed in some cases and would result in increased productivity of many Webster county soils.

The Des Moines river crosses the county diagonally from northwest to south-east, and in the areas along this river and the creeks tributary to it, drainage
conditions are much more satisfactory. The level character of the topography, however, renders the use of drainage ditches as well as tile drains necessary in order to bring about the reclamation of swampy areas and of land which is too wet for the best crop growth.

THE SOILS OF WEBSTER COUNTY

There are three large groups of soils in Webster county, drift soils, terrace soils and swamp and bottomland soils.

There are no loess soils in the county and no residual soils. The entire county was covered by the Wisconsin drift glaciation and the soils are the result of that glacial deposit, the small areas of modified drift constituting the terrace and swamp and bottomland soils. The areas covered by these groups are given in table II. The drift soils cover 94.4 percent of the total area. The terrace soils, or accumulation of drift and alluvial material deposited on the banks of the streams and later raised above the flood plains of the rivers by the deepening of the river channels, cover 2.6 percent of the area of the county. The swamp and bottomland soils border the streams, and are subject to overflow or generally uncultivable because of lack of drainage. They occupy 3.0 percent of the area.

The individual soil types in Webster county together with the areas covered and the percent of the total area occupied by each type are shown in table III. There are six drift soils, two terrace soils and four swamp and bottomland soils including the peat and muck.

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acres</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>431,296</td>
<td>94.4</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>12,096</td>
<td>2.6</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>13,568</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>456,960</td>
<td></td>
</tr>
</tbody>
</table>

The Webster loam is the chief drift soil and covers over 46 percent of the area of the county. The Webster clay loam and the Carrington loam, including the...
WEBSTER COUNTY

steep phase of the latter, are also important soil types, occupying 22.1 and 23.0 percent of the total area, respectively. The other drift soils are of minor importance, especially the Carrington gravelly loam which covers only 0.1 percent of the total area of the county. The terrace soils are of minor importance, the Waukesha loam being the most extensive. The swamp and bottomland soils are likewise small in area, the largest being the Wabash fine sandy loam. The other types are of little value agriculturally.

Most of the soils are quite level, except the Carrington loam which occurs in the rolling phase and the steep phase. The Webster loam is likewise somewhat undulating in certain areas but the main portion of the type is level. The general need for drainage is clearly indicated by the topography of the county.

THE FERTILITY IN WEBSTER COUNTY SOILS

Samples of soil were drawn from all the soil types in Webster county except the peat and one minor drift soil and were analyzed for their plant food content. Three samples were secured from each of the main soil types and one from each of the minor types. At each sampling soil was secured from three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil. Analyses were made on all the samples for total nitrogen, total phosphorus, total organic carbon, total inorganic carbon and limestone requirement. The official methods were used for nitrogen, phosphorus and carbon and the Veitch method for limestone requirement. The results of the analyses given in the tables are the averages of duplicate determinations on all individual samples and where more than one sample of a soil was used they are the averages of the results for all samples of the same soil.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV and are expressed in pounds per acre of two million pounds of surface soil.

There is considerable variation in the amount of phosphorus in the soils in the different groups. No relation apparently exists between the soils within the groups in the content of this constituent. One drift soil is much lower than the others, and one terrace soil has a considerably smaller amount of phosphorus than the other. The muck is of course, rather high in phosphorus and the Wabash clay loam, a bottomland soil, is likewise higher in this element than the drift soils.

None of the soils in the county appear to be well supplied with this constituent and the drift soils, the most important group, are, on the average, quite low in phosphorus. There is no question but that this element must be added to these soils at some time in the future. The analyses show that there is still enough phosphorus present to support crop growth for a number of years, provided it is made available sufficiently rapidly to keep plants supplied. Sometimes, however, there may be a lack of phosphorus in an available form and then soils might respond profitably to phosphorus fertilizers at the present time. In any case, phosphorus must be considered in any system of permanent agriculture for these soils.

There is likewise no relation between the different groups of soils because of their nitrogen content. The same is true of the organic carbon content of the soils which is always closely related to the nitrogen content. The dark colored
TABLE IV. PLANT FOOD IN WEBSTER 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 Org. Carbon</th>
<th>Total Inorg. Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,160</td>
<td>5,366</td>
<td>67,229</td>
<td>280</td>
<td>3,147</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>1,353</td>
<td>4,686</td>
<td>81,353</td>
<td>4,473</td>
<td>Basic</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,298</td>
<td>5,333</td>
<td>66,452</td>
<td>127</td>
<td>6,817</td>
</tr>
<tr>
<td>57</td>
<td>&quot; (steep phase)</td>
<td>1,020</td>
<td>2,700</td>
<td>28,432</td>
<td>33,688</td>
<td>Basic</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>880</td>
<td>2,740</td>
<td>37,108</td>
<td>152</td>
<td>5,565</td>
</tr>
</tbody>
</table>

Drift Soils

Terrace Soils

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Total Org. Carbon</th>
<th>Total Inorg. Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>980</td>
<td>2,500</td>
<td>25,522</td>
<td>178</td>
<td>6,973</td>
</tr>
<tr>
<td>61</td>
<td>Hancock</td>
<td>1,480</td>
<td>4,110</td>
<td>45,041</td>
<td>138</td>
<td>8,074</td>
</tr>
</tbody>
</table>

Swamp and Bottomland Soils

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Total Org. Carbon</th>
<th>Total Inorg. Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>1,040</td>
<td>2,120</td>
<td>26,002</td>
<td>11,298</td>
<td>Basic</td>
</tr>
<tr>
<td>63</td>
<td>Wabash clay loam</td>
<td>1,760</td>
<td>5,440</td>
<td>55,448</td>
<td>112</td>
<td>Basic</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>1,860</td>
<td>21,290</td>
<td>262,146</td>
<td>5,540</td>
<td>Basic</td>
</tr>
</tbody>
</table>

Soils are richer in both constituents than the lighter colored soils, there being a definite relation between the depth of color in the soil and the amount both of nitrogen and of organic carbon.

The steep phase of the Carrington loam is much lower in these elements than the normal gently rolling soil of that type. These soils with subsoils of lighter texture are likewise lower in both nitrogen and carbon than those with heavier subsoils.

The nitrogen and carbon contents of the soils of this county do not average as low as in some other soil areas. The recent origin of the drift making up most of the soils, the poor drainage conditions and the consequent slowness of decomposition account for the higher amounts of these constituents. The amounts of these elements are not inexhaustible, however, and as the soils become better drained and more highly productive the need for organic matter will become more evident. Even at the present time applications of farm manure have proved of value and it should be used in as large quantities as available. On grain farms where manure is not produced green manures should be used. If this plan is followed, these soils need never become deficient in organic matter and extreme measures to build up their organic contents will not be necessary.

It is evident that the proportionate amounts of nitrogen and carbon in the soils are such that active decomposition of the organic matter is occurring in most cases. In several of the minor soils in the county the relations are not so satisfactory and farm manure would be especially valuable because of its effect in increasing decomposition and the production of available plant food.

The inorganic carbon content and the limestone requirement of the soils of the county vary widely. The swamp and bottomland soils are high in inorganic carbon and therefore not acid. Two of the drift soils are likewise well supplied with inorganic carbon and not in immediate need of lime. The other drift soils and the terrace soils are low in inorganic carbon and acid in reaction. It must be kept in mind that the need of lime is one of the most variable factors in soils and the results given here for these types are only indicative of field require-
ments. The needs of individual soils for this material can only be ascertained by tests of those particular soils.

While in a general way it may be said that the soils of Webster county are not in as great or widespread need of lime as in some other counties, there are soils in this county which are acid and which should be limed to produce the best crops. The more recent origin of these soils accounts for their higher content of inorganic carbon. Leaching and cropping remove lime and hence, under continued cultivation all soils tend to become acid. Webster county soils are evidently in the transition stage and if they are tested carefully now and lime applied as necessary, they need never become deficient in that constituent. Crop yields will not suffer to such an extent and the soils may be made and kept permanently fertile at a minimum of expense and difficulty. All the soils of the county should be tested from time to time to insure the best reaction for crop growth, and if they are acid lime should be applied.

THE SUBSURFACE SOILS AND SUBSOILS

The analyses of the subsurface soils and subsoils appear in tables V and VI and the amounts of the various constituents present are calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil. It is unnecessary to consider these results in detail as the amounts of plant food at these depths are of much less importance than the content in the surface soils. If the necessary elements for plant growth are not present in sufficiently large amounts in the surface soil, crops will suffer even tho they may draw some of the food that they need from the lower soil layers. The plant food in the soil below the surface seven inches merely serves to delay the time when the soils will become deficient in necessary constituents.

Figure 2. This view shows the typical topography of Carrington loam area in Webster county.
### TABLE V. PLANT FOOD IN WEBSTER COUNTY SOILS, IOWA

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Total Org. Carbon</th>
<th>Total Inorg. Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,813</td>
<td>7,000</td>
<td>87,305</td>
<td>228</td>
<td>Basic</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>2,213</td>
<td>6,160</td>
<td>80,732</td>
<td>15,601</td>
<td>Basic</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>2,000</td>
<td>7,140</td>
<td>88,053</td>
<td>133</td>
<td>10,943</td>
</tr>
<tr>
<td>57</td>
<td>&quot; &quot; (steep phase)</td>
<td>1,760</td>
<td>2,240</td>
<td>12,144</td>
<td>93,056</td>
<td>228</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>1,040</td>
<td>2,000</td>
<td>28,452</td>
<td>9,542</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,960</td>
<td>2,800</td>
<td>27,632</td>
<td>284</td>
<td>13,212</td>
</tr>
<tr>
<td>61</td>
<td>Hancock loam</td>
<td>2,800</td>
<td>5,740</td>
<td>68,344</td>
<td>276</td>
<td>13,112</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>2,640</td>
<td>3,880</td>
<td>18,440</td>
<td>22,600</td>
<td>Basic</td>
</tr>
<tr>
<td>63</td>
<td>Wabash clay loam</td>
<td>2,840</td>
<td>6,440</td>
<td>72,488</td>
<td>152</td>
<td>Basic</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>1,880</td>
<td>13,560</td>
<td>145,188</td>
<td>2,292</td>
<td>Basic</td>
</tr>
</tbody>
</table>

The phosphorus in the subsurface soils and subsoils is apparently not large in amount and will not materially alter the time when this element should be applied to these soils. The nitrogen and organic carbon, while not low in all these soils, are proportionately lower in every case than in the surface soils. These constituents always decrease in the underlying soil layers and the need for organic matter to keep them up to the optimum in the surface soil is not changed to any extent by the amount in the subsurface soils and subsoils.

The lime content is somewhat greater in the lower soil layers than in the surface soils but some of the subsoils are acid and the need for lime on these soils is particularly marked. Lime moves upward in the soil only in small amounts and the content of the subsurface soils and subsoils in this material has little influence on the acidity in the surface soil. Sufficient lime should be applied to neutralize all the acidity in the surface soil and about two tons additional to keep the soil in the best condition for plant growth; if this is done at regular intervals it is not necessary to give special attention to the needs of the lower soil layers for this constituent.
GREENHOUSE EXPERIMENTS

Two series of greenhouse experiments were carried out on two different soil types in Webster county. The first type was the Webster loam, the principal soil in the county. The experiment was planned to test the effects of manure, lime, acid phosphate and rock phosphate on wheat grown in pots in the greenhouse. The average yields of grain in grams from the duplicate pots and the plan of the experiment appear in table VII.

TABLE VII. POT EXPERIMENT — WEBSTER LOAM, WEBSTER COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Dry wt. grain, gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>10.75</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>11.75</td>
</tr>
<tr>
<td>3</td>
<td>Lime and Acid Phosphate</td>
<td>12.50</td>
</tr>
<tr>
<td>4</td>
<td>Lime and Rock Phosphate</td>
<td>11.00</td>
</tr>
<tr>
<td>5</td>
<td>Lime and Manure</td>
<td>16.75</td>
</tr>
<tr>
<td>6</td>
<td>Lime, Manure and Acid Phosphate</td>
<td>18.50</td>
</tr>
<tr>
<td>7</td>
<td>Lime, Manure and Rock Phosphate</td>
<td>17.50</td>
</tr>
</tbody>
</table>

Manure was applied 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. Sufficient lime was used to neutralize the acidity of the soil and supply two tons additional.

Examining the table it is apparent that lime brought about a slight increase in yield while phosphorus used with the lime increased the crop growth only very slightly; the acid phosphate showing a very small gain and the rock none at all. The differences in both cases were too small to be significant. Manure, however, markedly increased the crop yields. Phosphorus as acid phosphate used with the manure gave an increase in crop and the rock phosphate also showed a slight increase. Phosphorus was evidently of more value when applied with manure, but even in that case its use was not economical.

Fig. 3 shows the crop yields obtained in the experiment and the effects of manure used with and without phosphorus. Manure is evidently the most important fertilizer for this soil and the returns from its use are very satisfactory. Altho the color and the analyses of the soil indicated that it is well supplied with organic matter, manure is of value, probably because of its effect on the physical conditions in the soil, and because of the increase in decomposition processes and the greater production of available plant food which it causes.

The second experiment was carried out on the Carrington loam. The effects of lime, manure and acid phosphate were tested in this experiment and the results appear in table VIII. The applications of these materials were the same as in the preceding experiment.

TABLE VIII. POT EXPERIMENT — CARRINGTON LOAM, WEBSTER COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Dry wt. grain, gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>11.25</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>13.00</td>
</tr>
<tr>
<td>3</td>
<td>Lime and Acid Phosphate</td>
<td>13.75</td>
</tr>
<tr>
<td>4</td>
<td>Lime and Manure</td>
<td>16.75</td>
</tr>
<tr>
<td>5</td>
<td>Lime, Manure and Acid Phosphate</td>
<td>17.00</td>
</tr>
</tbody>
</table>
Figure 3. A greenhouse pot experiment on Webster loam showing the value of manure as a fertilizer on one of the main soil types in Webster county.

Figure 4. A greenhouse pot experiment with wheat on Carrington loam in which lime proved of considerable value and the combination of lime and manure of decided value in increasing yields.
The lime used on this soil brought about a decided increase in yield but the acid phosphate used with the lime showed only a slight gain. Manure with lime brought about a distinct increase in crop over that occasioned by the lime alone. The use of acid phosphate in addition to these two materials produced only a slight effect.

The results of this experiment coincide very closely with those of the preceding one on a different soil type. Manure is evidently the most effective fertilizing material on this soil. Lime should be used also in most cases to remedy the acidity of the soil. The effects of phosphorus are noticeable but are comparatively slight.

These greenhouse experiments show the value of applications of manure in increasing crop growth in both the soils tested. Even when the soils are apparently not deficient in organic matter, manure will increase crop production and keep the soils permanently fertile. Lime is always valuable on acid soils and should be used on these two soils in proper amounts whenever needed.

Phosphorus, either as acid phosphate or as rock phosphate does not give large increases in yield. There are indications, however, that the soils are so low in this element that the application of phosphorus fertilizers may prove quite profitable in the future. Tests along this line on individual soils are desirable.

FIELD EXPERIMENTS

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

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

The results of a ten year test of various means of maintaining fertility in this Carrington loam have already been published and will be referred to here only briefly to indicate the general needs of this soil.

The experiment was carried out on five series of plots, two of which contained 12 plots, one-tenth of an acre in size, two series contained 11 plots of the same size and the fifth series contained 12 plots, three-twentieths of an acre in size. These plots were laid out in the usual way with division strips of 6 1/2 feet wide around each series of plots.

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

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

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

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

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

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

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

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

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

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

THE ROTATION EXPERIMENTS

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

When phosphorus was added with the manure, almost the same yield was secured as with the manure alone but the cost of the phosphorus reduced the net returns considerably. Potassium applied with the manure and phosphorus brought about no appreciable increase in the yield and the cost of the material lowered the value of the treatment to an actual loss. The phosphorus and potassium together increased the yield of corn but to a less extent than the manure alone and again the applications proved uneconomical.
### TABLE IX. CORN YIELDS — CARRINGTON LOAM
#### Eight Years — 1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil Treatment</th>
<th>Av. Yield in Bu. per Acre</th>
<th>Inc. or Dec. in Bu. per Acre</th>
<th>Value of Increase per Acre</th>
<th>Cost of Treatment per Acre</th>
<th>Net Returns per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>60.2</td>
<td>-1</td>
<td>$-.05</td>
<td>$1.25</td>
<td>$-1.30</td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>60.1</td>
<td>-1</td>
<td>$-.05</td>
<td>$1.25</td>
<td>$-1.30</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>72.4</td>
<td>12.2</td>
<td>5.49</td>
<td>$.80</td>
<td>4.69</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>68.3</td>
<td>8.1</td>
<td>3.65</td>
<td>2.05</td>
<td>1.60</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>73.1</td>
<td>12.9</td>
<td>5.81</td>
<td>5.05</td>
<td>0.76</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>64.9</td>
<td>4.7</td>
<td>2.12</td>
<td>4.25</td>
<td>-2.13</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>72.1</td>
<td>11.9</td>
<td>5.36</td>
<td>3.80</td>
<td>1.56</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>72.1</td>
<td>11.9</td>
<td>5.36</td>
<td>3.80</td>
<td>1.56</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>72.7</td>
<td>12.5</td>
<td>5.63</td>
<td>6.30</td>
<td>-1.39</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>69.9</td>
<td>9.7</td>
<td>4.36</td>
<td>5.50</td>
<td>-1.14</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>59.1</td>
<td>-1.1</td>
<td>-.50</td>
<td>3.00</td>
<td>-3.50</td>
</tr>
</tbody>
</table>

Average gain for manure ................................................................. 8.8 Bu.
Average gain for phosphorus ....................................................... 6.2 Bu.
Average gain for potassium .......................................................... 0.4 Bu.

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

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

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

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

### TABLE X. OAT YIELDS — CARRINGTON LOAM
#### Eight-Year Period — 1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil Treatment</th>
<th>Av. Yield in Bu. per Acre</th>
<th>Inc. or Dec. in Bu. per Acre</th>
<th>Value of Increase per Acre</th>
<th>Cost of Treatment per Acre</th>
<th>Net Returns per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>55.0</td>
<td>1.4</td>
<td>$.49</td>
<td>$1.25</td>
<td>$-.76</td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>56.4</td>
<td>1.4</td>
<td>$.49</td>
<td>$1.25</td>
<td>$-.76</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>61.9</td>
<td>6.9</td>
<td>2.42</td>
<td>$.80</td>
<td>1.62</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>67.9</td>
<td>2.9</td>
<td>1.08</td>
<td>2.05</td>
<td>-1.02</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>62.5</td>
<td>9.1</td>
<td>3.18</td>
<td>5.05</td>
<td>-1.87</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>62.5</td>
<td>7.5</td>
<td>2.63</td>
<td>4.25</td>
<td>-1.62</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>62.4</td>
<td>7.4</td>
<td>2.59</td>
<td>3.80</td>
<td>-1.21</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>63.9</td>
<td>8.9</td>
<td>3.12</td>
<td>6.75</td>
<td>-3.63</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>65.3</td>
<td>10.3</td>
<td>3.61</td>
<td>6.30</td>
<td>-2.69</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>54.8</td>
<td>-2</td>
<td>-.07</td>
<td>3.50</td>
<td>-5.57</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>57.9</td>
<td>2.9</td>
<td>1.03</td>
<td>3.00</td>
<td>-1.97</td>
</tr>
</tbody>
</table>

Average gain for manure ................................................................. 5.0 Bu.
Average gain for phosphorus ....................................................... 3.9 Bu.
Average gain for potassium .......................................................... 0.4 Bu.
Greater increases in yields were obtained in several cases, from the combined treatments than were obtained from the manure alone, but the cost of the other fertilizers made the treatments uneconomical.

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

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

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

**TABLE XI. CLOVER YIELDS — CARRINGTON LOAM**

Eight-Year Period — 1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil Treatment</th>
<th>Avg. Yield in Tons per Acre</th>
<th>Inc. or Dec. in Tons per Acre</th>
<th>Value of Increase per Acre</th>
<th>Cost of Treatment per Acre</th>
<th>Net Returns per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>2.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>2.65</td>
<td>.40</td>
<td>$3.20</td>
<td>$1.25</td>
<td>$1.95</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>2.82</td>
<td>.57</td>
<td>4.56</td>
<td>.80</td>
<td>3.76</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>2.54</td>
<td>.29</td>
<td>2.32</td>
<td>2.05</td>
<td>4.37</td>
</tr>
<tr>
<td>5</td>
<td>Manure, cowpeas, phosphorus</td>
<td>3.11</td>
<td>.86</td>
<td>6.88</td>
<td>5.05</td>
<td>1.83</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas, phosphorus</td>
<td>2.71</td>
<td>.46</td>
<td>3.68</td>
<td>4.25</td>
<td>1.83</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>2.85</td>
<td>.60</td>
<td>4.80</td>
<td>3.80</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>3.35</td>
<td>1.10</td>
<td>8.80</td>
<td>6.75</td>
<td>2.05</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>3.06</td>
<td>.81</td>
<td>6.48</td>
<td>6.30</td>
<td>.18</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>2.90</td>
<td>.65</td>
<td>5.20</td>
<td>5.50</td>
<td>.30</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>2.45</td>
<td>.20</td>
<td>1.60</td>
<td>3.00</td>
<td>-1.40</td>
</tr>
</tbody>
</table>

Average gain for manure: 0.284 Tons
Average gain for phosphorus: 0.215 Tons
Average gain for potassium: 0.433 Tons
TABLE XII. CONTINUOUS CORN YIELDS — CARRINGTON LOAM

Eight-Year Period — 1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil Treatment</th>
<th>Avg. Yield in Bu. per Acre</th>
<th>Inc. or Dec. in Bu. per Acre</th>
<th>Value of Increase per Acre</th>
<th>Cost of Treatment per Acre</th>
<th>Net Returns per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>42.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>44.2</td>
<td>1.5</td>
<td>$.68</td>
<td>$1.25</td>
<td>$.57</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>53.9</td>
<td>11.2</td>
<td>5.94</td>
<td>.80</td>
<td>4.24</td>
</tr>
<tr>
<td>4</td>
<td>Manure, cowpeas</td>
<td>53.4</td>
<td>10.7</td>
<td>4.82</td>
<td>2.05</td>
<td>2.77</td>
</tr>
<tr>
<td>5</td>
<td>Cowpeas, phosphorus</td>
<td>56.4</td>
<td>13.7</td>
<td>6.17</td>
<td>5.05</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>Manure, cowpeas, phosphorus</td>
<td>46.5</td>
<td>3.8</td>
<td>1.71</td>
<td>4.25</td>
<td>-2.54</td>
</tr>
<tr>
<td>7</td>
<td>Manure, phosphorus</td>
<td>54.9</td>
<td>12.2</td>
<td>5.49</td>
<td>3.80</td>
<td>1.69</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas, phosphorus, potassium</td>
<td>55.5</td>
<td>12.8</td>
<td>5.76</td>
<td>6.75</td>
<td>-.99</td>
</tr>
<tr>
<td>9</td>
<td>Manure, phosphorus, potassium</td>
<td>54.2</td>
<td>11.5</td>
<td>5.18</td>
<td>6.30</td>
<td>-1.12</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus, potassium</td>
<td>49.2</td>
<td>6.5</td>
<td>2.93</td>
<td>5.50</td>
<td>-2.57</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>43.6</td>
<td>.9</td>
<td>.41</td>
<td>3.00</td>
<td>-2.59</td>
</tr>
</tbody>
</table>

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

THE CONTINUOUS CORN EXPERIMENT

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

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

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

Peat is partially rotted vegetable matter which consists either of swamp grasses, sedges, rushes, and flags, or of sphagnum moss; the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas, where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed, increase from year to year and with the long continuance of swampy conditions may become of considerable depth. When the glacier which once covered north central Iowa, retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area especially near the edges and in these places lakes, ponds and marshes were formed because of the heavy, impervious character of the subsoil, and the formation of peat followed. It is mainly in the Wisconsin drift soil area therefore that peat occurs in Iowa. Webster county is located in this soil area and has several peat areas, altogether making a total of 3,456 acres or 0.8 per cent of the total area of the county.

A complete discussion of peat soils in Iowa and a report of certain experiments which have been carried out to determine their needs have been given elsewhere and hence no extended consideration of these soils need be entered upon here. There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out. They are composed of fibrous, fairly dry vegetable matter extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer therefore only to the shallow peats and are not at all applicable to deep peats.

The peat in Webster county is generally from 6 to 20 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Hence practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

The analyses of numerous samples of peat soils reported in the bulletin referred to above showed that they contained not only an abundance of nitrogen and organic matter but also considerable amounts of lime. Their phosphorus and potassium content was rather low but these elements were abundant in the muck or clay which forms the subsoils of practically all the shallow peats in Iowa. In Webster county there are only a few extremely small areas where the subsoil under the peat is not a black to drab plastic clay. The character of the subsoil plays a very important part, as will be seen in the treatments which are advised for the reclamation of peat soils. On this account the heavy character of the subsoils underlying the peats in this county is emphasized.

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario in Webster, Wright and Story counties and these tests were considered at length in the bulletin mentioned above. The tests included the use of gypsum, limestone, phosphorus and potas-

sium, each applied alone or in combination, in the amounts in which such materials are generally applied to soils. *In no cases were there any profitable increases in crop yields from the use of any of these materials* and in most instances the variations in yields between the treated and the untreated soils were only such as might well occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Webster county do not need the addition of commercial fertilizing materials to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be profitable. The crop seems to be able to secure a sufficient amount of these plant foods from the subsoil which is well supplied with them. Furthermore peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria into the peat and increase the speed of decomposition. In general, manure should not be used on peat soils, but should be utilized on land in greater need of organic matter and nitrogen.

**DRAINAGE AND CULTIVATION FOR PEAT SOILS**

What the peats in Webster county *do* need to make them productive is the physical improvement resulting from drainage, cultivation, and the growing of the proper crops on them.

The drainage of peat soils is the most important step in their reclamation. Sufficient tile of ample size, and special drains to carry away flood waters and prevent the flooding of the lowlying peat areas at times of heavy rainfall are essential.

The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself as in the latter case the compacting of the peat would bring the tile too close to the surface and relaying would be necessary. The tile should not be laid too deeply in the subsoil as the heavy clay is quite impervious to the passage of water. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will allow for the ready passage of water into the drains.

Fall plowing is desirable for peat soils in order to expose the soil to the action of the frost, rain and snow during the winter and hasten the decay of the peat. Fall plowed peats may be worked earlier in the spring and hence the seed bed may be more thoroly prepared.

Deep plowing of peat soils is also of considerable value especially when the peat is very shallow and some of the underlying heavy clay, rich in phosphorus and potassium may be mixed with the peat. The physical and chemical conditions in the peat are both improved materially by such a mixing and crop production is increased. Even in the case of deeper peats where the subsoil is not reached by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of air and thus hasten decomposition.

Iowa peat soils which are not over sixteen inches in depth should not be rolled as such an operation may compact them too much and retard the decomposition of the peat. Where the peat is deeper than this, careful rolling may be of value.
in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening the decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivating the peat, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be quite luxuriant and interfere seriously with the production of crops.

Corn and small grain crops as a rule do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore it is not advisable to seed these crops on peat soils until several years after their reclamation when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay but it is better used as pasture as the trampling by the stock compacts the peat to an extent which aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes, and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit of the successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Webster county. With proper treatment and crop growth they can be reclaimed.

"ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of "alkali" soils in Webster county and while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots while other crops are affected to a less extent.

The origin of these spots has been discussed in another publication.¹ They occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned and more in detail in a later publication ² and it is apparent from the studies which have been carried out that the salts which occur are quite variable. The chief constituent is calcium bicarbon-

ate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amounts of these latter salts which make up the "alkali" content of Webster county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium bicarbonate which always occurs, may prove injurious.

The "alkali" problem in Webster county and in Iowa in general is therefore less serious than in the west and reclamation is more readily accomplished.

TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained but this does not mean that the drainage produces the "alkali" condition. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of "alkali" salts from the soil and in draining a slough or pond lines of tile should be laid around the low area as well as through the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be much more rapid. The lines of tile may be brought together again below the slough and if the area is rather wide, a third line of tile through the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully developed, as is frequently the case in Webster county, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available in sufficient amounts. In other cases green manures, or straw, may serve for the purpose but where such materials are used a small application of manure should be made along with them in order to hasten the decomposition processes which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming "alkali" soils as far as is known. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

NEEDS OF WEBSTER SOILS, INDICATED BY CHEMICAL, GREENHOUSE AND FIELD TESTS

DRAINAGE

Within the Wisconsin drift soil area one of the chief requirements for successful crop production is proper drainage. Thousands of acres of land in that area which were previously useless for agricultural purposes have been brought under cultivation during the last few years and made highly productive by the use of tile drains and drainage ditches. This soil area is
naturally poorly drained and ponds, lakes and swampy areas have been very common. With proper drainage the great natural fertility of the soil asserts itself and crop production becomes very profitable.

Adequate drainage is one of the first precautions necessary to bring about increased fertility in Webster county. The Webster clay loam, an upland soil, covering over 22 per cent of the total area of the county is particularly in need of proper tiling. The Wabash clay loam, a bottom soil is likewise in need of drainage as are also the areas of peat and muck. These three latter types together constitute only about 1 per cent of the total area in the county and are relatively unimportant. The Webster loam, the chief soil type in the county and the Miami silt loam, a minor soil type are generally well drained but in some places, small areas are found where drainage would be of value. Without adequate drainage no amount of care in the preparation of the soil or in fertilization in seeding will bring about good crop production.

Much of Webster county has been drained and the results secured are definite evidence of the value of the operation. If tile has not been laid in those soil types which have been listed above, they would be benefited by its use, and to a sufficient extent to warrant the expense involved. The method of installation of tile is quite generally understood but definite advice along this line will be given, if desired, by the Soils Section of the Agricultural Experiment Station.

**LIMING**

The soils in Webster county are not generally deficient in lime and only in certain soil types is its need apparent at present. The swamp and bottomland soils are not acid and that is true also of two of the upland soils. The Webster loam, the Carrington loam and the Miami silt loam are, however, distinctly acid in the surface soil and therefore in need of lime. The subsoils underlying all but one of these upland soils are well supplied with lime, but that is of little assistance to the surface soils. Lime does not move upwards in the soil except in very small amounts but is very largely carried down and out in the drainage water. Except in the case of deep-rooted crops, where the lime in the subsoil comes in contact with the plant roots, lime should be applied if the surface soil is acid, in order to put the soil in the proper physical and chemical condition for the best crop growth and to insure the best bacterial action in order that the proper production of available plant food will result.

The terrace soils in Webster county are distinctly acid at the surface and also at the subsurface and subsoil depths and the need of lime on them is very apparent.

Those soil types which are in need of drainage, or in which the natural drainage is poor, are usually much better supplied with lime than the better drained areas. Soils which are under more or less intensive cultivation lose their lime rapidly, if the drainage of the land is adequate, and it is only when this latter condition is met that crop growth becomes satisfactory on any land. The decomposition of organic matter leads to the production of organic and inorganic acids which act upon the lime and remove it from the soil, while
plants take up certain amounts as plant food. Therefore the losses of lime from soils, even those naturally well supplied, lead more or less rapidly to the occurrence of acid conditions. When poorly drained soils are tilled out and brought under cultivation, the loss of lime becomes rapid. Those soils in Webster county which are not now acid and not in need of lime will sooner or later, following proper drainage and cultivation, become acid and require the application of lime.

The proper method of avoiding infertility and unsatisfactory crop yields due to soil acidity, is to test the soil at regular intervals and determine its need of lime. The proper amount can then be applied and crop production will continue satisfactory. Farmers may test their own soils according to the method which has been described in another publication but they may secure more satisfactory results if they will send a sample to the Soils Section of the Agricultural Experiment Station and have it tested by a more accurate method. Many tests are made annually by the Soils Section and recommendations made regarding the application of lime.

The actual amounts of lime to apply to any acid soil must be determined for that particular soil and no general recommendations can be made which will fit all conditions. The average amounts needed by the soils in Webster county according to the analyses given earlier in this report range from 1½ to 4 tons of lime per acre of surface soil of 2,000,000 lbs. The amount of lime to apply will therefore be somewhere between 3½ and 6 tons. In most cases the former amount would probably prove ample as it allows of a sufficiently large application to neutralize the acidity in the surface soil and to supply 2 additional tons which will be especially worth while for the growth of alfalfa and clover.

The upland and terrace soils in Webster county should be tested for acidity from time to time and, when acid, lime should be applied. The value of lime even on slightly acid soils is shown in the results of both greenhouse experiments and field observations. This is particularly true where alfalfa, clover and certain other legumes are grown.

The kind of lime to apply, the method of application and other points of interest in this connection have been discussed elsewhere. Suffice it to say that limestone is the cheapest material to use in Iowa and it should be secured from that quarry where the best grade material can be obtained at the lowest cost with the smallest freight charges. Many times the freight cost is much greater than the cost of the lime itself. Lists of concerns prepared to supply lime for agricultural purposes are prepared from time to time by the Soils Section and will be furnished upon request.

MANURING

The soils of Webster county vary widely in content of organic matter but as a whole they are not noticeably deficient in that material. Some of the main upland soil types are very rich in organic matter, particularly the Webster loam and the Webster clay loam, the two main soil types in the county. It might seem therefore that the use of organic matter here would not be necessary or advisable but this is far from the case. Greenhouse and field

experiments and many unofficial field tests have shown large returns from the use of farm manure. In the experiments referred to earlier in this report, manure was the only fertilizing material which yielded economical returns. Increases in crop growth due to the use of manure on two of the main soil types in the county were very pronounced. Even tho soils are not actually deficient in organic matter additions of manure are valuable. Furthermore as soils high in organic matter content are brought under more intensive cultivation and particularly as the drainage conditions are improved, the removal of the organic matter will proceed more rapidly and the fact that the soils are well supplied now is no reason why they should be allowed to become deficient. Indeed it constitutes a very good reason why organic matter content should be kept up, when it can be done with small labor and expense.

Some of the minor soil types in the county would undoubtedly respond much more profitably to the use of manure than did the soils tested. Many of the minor types are much poorer in organic matter and show a marked need of the addition of some substance to build them up in that material.

There is no particular danger of applying too much manure to any of the soils of Webster county as the amount produced on the average farm is quite insufficient to permit of a larger application than ten tons per acre once in a four year rotation. There is no advantage, however, in using more than 16 to 20 tons per acre. The manure produced on the farm should be distributed over as much of the land as possible and not be applied in excessive amounts to one field.

Farm manure is one of the most important farm products for the maintenance of soil fertility. Because soils are rich in organic matter, manure should not be wasted but should be cared for and applied as carefully as where it is to be used on soils plainly lacking in organic matter. Manure may lose as high as 85 per cent of its value if improperly stored and allowed to remain in loose, open piles, exposed to the weather.¹ The importance of preventing such losses and of returning to the soil as large an amount as possible of the plant food contained in manure cannot be over emphasized.

If manure is properly stored its use may return to the soil a considerable portion of the elements removed from the soil by the crops which are fed to the live stock. Furthermore, the value of the manure is due in part to its effect on the physical condition of the soil and in part to the introduction of bacteria which stimulate the production of available plant food. The fertility of soils cannot be kept up practically nor profitably by commercial fertilizers alone but organic matter must be applied if soils are to be kept in the proper condition for plant growth. Furthermore the need of proper bacterial action to bring about the production of available plant food is well known. Hence manure serves a threefold purpose — to supply plant food, to keep the physical condition of the soil at the best and to add bacteria and thus bring about the best production of available plant food.

Many farmers partially keep up the organic matter content of their soils by turning under crop residues such as straw, and stover, but in other cases these materials are considered a waste product and are disposed of in some easier

¹ Circ. 9 Ia. Agr. Exp. Sta. — Farm Manures.
way such as by burning. The turning under of crop residues is a very im-
portant means of preventing the soil from becoming deficient in organic matter.
They also add some plant food but the chief value from these materials is
probably due to their effect on the physical conditions in the soil. The value
of the use of crop residues has not been shown in any experiments thus far
available but tests are now under way which it is hoped will give definite
data to show the effects on crop growth from the use of all crop residues on the
farm. The importance of such materials in keeping the soil in good physical
condition cannot be questioned as the general results of farm experience are
very definite along this line.

Webster county soils may be kept well supplied with organic matter pro-
vided these crop residues are utilized and farm manure is employed or if the
latter material is lacking, if green manures are employed.

THE USE OF GREEN MANURE

Green manure crops and preferably leguminous green manures may be used
to good advantage when farm manure is not available in sufficient amounts to
supply the entire farm. In livestock farming they are not so essential but
even there, the production of manure is rarely great enough to keep all the soil
on the farm properly supplied. Ten tons of manure per acre once in a four
year rotation is hardly sufficient to keep up the fertility in a soil and it is
not often possible to apply even that much regularly to all the soil on a farm.
Hence the use of a leguminous green manure crop must be resorted to, to make
up the lack of sufficient farm manure. On grain farms where the production
of farm manure is extremely small, the green manure crop becomes the chief
source of organic matter. There are many crops which may be employed for
green manuring purposes but well inoculated legumes are preferable because
they not only add organic matter to the soil but they also add nitrogen which
they secure from the air. Hence they not only replace manure but they
actually have the additional value that they become a nitrogenous fertilizer
and increase the nitrogen content of the soil. There are many legumes which
may be used as green manures and owing to the wide variation in needs, sea-
sons of growth and other characteristics some legume may be chosen to fit
almost any rotation and to be suitable under almost any conditions.

Green manuring then is an important farm practice, especially as a supple-
ment to the use of farm manure but it should not be considered as taking the
place of farm manure. The latter material is cheaper to use and if not added
to the soil would constitute a waste material. With leguminous crops, however,
there is need that the returns be large to offset the expense of seeding the crop.

General recommendations regarding the use of green manure crops cannot be
given but the Soils Section will be glad to answer any questions along this
line and make definite recommendations to fit special conditions in order that
the best results for individual farm conditions may be secured.

If legumes are used for green manures they should be thoroly inoculated in
order that they may secure their nitrogen from the air and thereby increase
the amount of that constituent in the soil. Information regarding inoculation
may be secured from Circular 43 of the Iowa Agricultural Experiment Station.
COMMERCIAL FERTILIZERS

The analyses of the Webster county soils given earlier in this report show no large amounts of phosphorus and nitrogen and it might seem that commercial fertilizers could be used to advantage. The greenhouse and field experiments, however, show no profitable returns from the use of phosphatic and potassic fertilizers and general experience indicates that economic returns are rarely secured from the use of nitrogenous fertilizers. No comparative experiments were carried out with any form of commercial nitrogen but it is a well-known fact that when soils are deficient in nitrogen, they are also usually lacking in organic matter and the cheapest and best method of treatment is the use of leguminous green manure crops which supply both nitrogen and organic matter to the soil. By turning under well-inoculated legumes the nitrogen content of soils may be maintained permanently. Nitrogenous fertilizers should be used only in special cases in small amounts as top dressings to encourage the rapid growth of certain crops. While the use of leguminous green manures is not necessary at the present time on the chief soil types it may be of considerable value on some of the minor, lighter colored soils of the county.

Furthermore, green manures should be used for the permanent fertility of all the soils. Farm manure returns a portion of the nitrogen removed by crops but there is always some loss of nitrogen from manure and with continued cultivation of all soils, a time will come when nitrogen must be added. Although the soils of Webster county are not rich in this element they are better supplied than many other soils in the state and if proper precautions are taken now to keep up the nitrogen content, the soils need never be brought to such a condition of infertility that long continued and expensive methods of treatment will be necessary to make them productive. The rational use of both farm manure and green manures is needed at the present time on the soils of Webster county to keep them permanently fertile.

Earlier analyses of the soils of the state showed very definitely that potassium is present in all the soils in such large amounts that there can be no need for the application of potassium fertilizers provided the soils are kept in the proper mechanical condition and well supplied with organic matter. Under such conditions bacterial action is so vigorous that there is a sufficiently rapid production of available potassium to keep the crops supplied. The field experiment described above showed very clearly that the use of potassium fertilizers is not profitable on the soils of this county.

Phosphorus fertilizers have been tested on several soils in Webster county and have not proven profitable. These tests have not been as extensive or as complete as desirable and it is hoped that the field experiments which are now in progress may give more definite results for a wider variety of conditions. However it is apparent that at present the use of phosphorus fertilizers cannot be recommended. The amount of the element in the soils is low and hence the permanent fertility of the soils of this county depends upon the use of phosphorus at some time in the future. On some soils, profitable returns might be secured at the present time. Farmers who are interested are urged to test the need of phosphorus on their own soils and determine the value of various

1 Bull. 150 la. Agr. Exp. Sta.
phosphorus fertilizers for their individual conditions. Directions for such tests are given in Circular 15 of the Iowa Agricultural Experiment Station and the Soils Section, upon request, will gladly offer advice and assistance in the carrying out of such tests. If phosphorus is necessary now or later the problem of the form in which it should be used immediately presents itself. Either rock phosphate or acid phosphate may be employed, the former being unavailable and the latter directly available. There is a wide difference in the price of these two materials and it is important to learn which is the most valuable economically. Experimental data is not available in sufficient amounts at the present time to warrant definite recommendations and all information which farmers may secure along this line by special tests on their own soils will be valuable.

Complete commercial fertilizers have no place in Webster county agriculture and the only fertilizing constituent which may possibly be used to advantage on some soils is phosphorus. Even this element is not of value now on all of the soils. But in the future the use of phosphorus fertilizers on the soils of Webster county must be considered an important factor in their permanent fertility.

CROP ROTATIONS

The value of the rotation of crops is well known. No specific rotation experiments have been carried out in Webster county but in general it is advisable that a definite rotation should be adopted for all conditions and the rotation should contain a regular legume crop and in some cases, one or more legume "catch" crops.

No particular rotation can be recommended as the best for all conditions owing to variations in the systems of farming, the size of the farm and other factors. The following rotations may, however, 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 rotation may be extended to five years. The last crop will consist principally of timothy)

2. Four-Year Rotation with Alfalfa.

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

3. Three-Year Rotation.

First year: Corn
Second year: Oats or wheat (with clover seeded in the grain.
Third year: Clover (Only the grain and clover seed should be sold; in grain farming most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)
INDIVIDUAL SOIL TYPES IN WEBSTER COUNTY

DRIFT SOILS

There are six types of soil in Webster county which are classed as drift soils; the Webster loam, the Webster clay loam, the Carrington loam, the Carrington loam (steep phase), the Miami silt loam, and the Carrington gravelly loam. These six types cover nearly ninety-five per cent of the total area of the county and include the most important soils in the county.

WEBSTER LOAM (55)

This soil covers 213,120 acres or 46.6 per cent of the total area of Webster county. The main body occurs in the southern part of the county but smaller areas are found in other parts of the county.

The surface soil to a depth of 10 inches consists of a black, mellow loam, containing a high percentage of organic matter. The underlying soil is a black, compact clay loam which at a depth of 6 to 8 inches merges into a black clay. This continues up to 24 inches where a drab to pale yellow or greenish-drab, plastic clay occurs.

The topography of the area covered by this soil is level to very gently undulating. For the most part drainage conditions are satisfactory. In some areas, however, the first treatment necessary to insure satisfactory crop production is the installation of an adequate drainage system.

As a whole this soil is highly productive and includes practically no waste areas. The main crops grown are corn, oats and hay. Corn yields on the average, 50 bushels per acre, oats, 40 bushels per acre and timothy and clover hay, 1 1/2 tons per acre.

Owing to its high organic matter content this soil holds moisture well and crops are rarely seriously injured by droughts. For the same reason the crops are usually somewhat later in maturing than on the lighter soils and the early maturing varieties of grains are to be recommended for this soil.

The subsoil frequently contains lime in the form of limestone pebbles or marl nodules. The analyses reported earlier show that the lower layers of this soil are rarely acid. The surface soil, however, has been found to be acid in many cases and applications of lime are necessary to bring about the best crop growth. The soil should be tested at regular intervals and if acid, lime should be applied in the amounts indicated as necessary by the tests.

Altho this soil is high in content of organic matter, the experiments mentioned above show very considerable increases in crop yields from the use of manure. In fact this material appears to be the most valuable fertilizer for the soil. Commercial fertilizers when used with manure give too small gains to make their use profitable at the present time. Phosphorus is low in this soil, however, and in the future, phosphorus fertilizers will be required. Potassium fertilizers are not needed and nitrogen may be supplied by the use of manure and leguminous green manure crops.

WEBSTER CLAY LOAM (56)

This soil is the second most extensive type in the county, occupying, however, a much smaller area than the Webster loam. It covers 101,120 acres or 22.1 per cent of the total area of the county, occurring in many small tracts, few of which occupy more than one-half section, mainly in the southern half of the county.

The surface soil to a depth of 10 to 12 inches consists of a black silty clay loam grading into black, rather compact, fine-grained plastic clay which at 20 to 24 inches becomes lighter in color. At a depth of 24 to 36 inches, much coarse sand and fine gravel is found which at 4 to 6 feet passes into the bluish-drab and mottled-drab and yellow drift.

1 The descriptions of individual soil types given in the Bureau of Soils report on Webster County, Iowa, have been rather closely followed in this section of the report.
Figure 5. Surface, sub-surface, and sub-soils of five of the individual soil types in Webster county.

1. Carrington loam.
2. Hancock loam.
3. Fargo loam.
4. Miami silt loam.
5. Fargo clay loam.
As a whole this soil is uniform in physical character. There are some local variations which consist mainly in the depth to which the black color extends. Some areas are slightly heavier in texture than the typical soil and others have a more sandy subsoil at a depth of 2 to 5 feet. These local differences do not affect seriously the character, needs, or productivity of the surface soil.

Corn yields ordinarily about 50 bushels per acre. Heavy yields of oats are secured and the straw is often so rank as to cause lodging. Wheat and barley give good yields. Clover is successfully grown and alfalfa should also prove a valuable crop where proper drainage conditions are established. The grain crops are later in maturing on this soil than on the Webster loam and hence it is especially necessary that early maturing varieties be used.

This soil occurs in low-lying and poorly drained areas, the larger of which are elongated and irregular in shape, while some of the smaller areas are roughly circular and represent the former location of ponds.

The first treatment required is adequate drainage. During the past few years much of this soil has been made cultivable by this means and on account of its high natural fertility it has proved highly productive.

The peat beds occurring in this county are usually associated with this Webster clay loam and like the latter are mainly in need of drainage.

In general this soil seems to be somewhat better supplied with lime than is the Webster loam. Analyses show it is generally not acid and not in need of lime. The subsoil is usually highly calcareous, containing many limestone particles, marl nodules, and lime aggregates while shells of mollusks and scattered pebbles of limestone sometimes occur in the surface soil. In certain areas, where this soil is associated with peat deposits, the salt or lime content sometimes becomes so large as to injure crops. These are called “alkali” spots and are in need of special treatment, primarily drainage, to make them productive.

As was the case with the Webster loam manure is the only fertilizing material which yields profitable returns on this soil at the present time. Phosphorus fertilizers will eventually be necessary but they are not profitable now and commercial potassium and nitrogen fertilizers need not be used.

CARRINGTON LOAM (1)

This soil occurs mainly on the gently undulating prairie and on the low, smooth-shaped hills or swells of the moraines. It also occurs on the gentle slopes down to the small stream valleys of the county. It covers an area of 86,784 acres or 19 per cent of the area of the county.

The surface soil, consisting of a dark-brown to black, mellow loam, extends to a depth of 12 to 15 inches where it passes into a brown, friable loam. At 18 to 24 inches a yellowish-brown or yellow gritty clay loam is found and at 4 to 5 feet the yellow glacial drift occurs. As a whole this soil is quite uniform in physical character, slight variations in the underlying material being insignificant. The surface soil is mellow and friable and fairly well supplied with organic matter. Drainage is good and there is practically no waste land. Corn, oats and hay are the chief crops. Corn yields 40 bushels per acre and oats, usually 35 to 40 bushels altho sometimes yields as high as 70 bushels of corn and 60 bushels of oats per acre are secured. Timothy and clover hay yield about 1½ tons per acre. Wheat and barley are grown to a small extent and are relatively unimportant. Yields of 20 to 25 bushels per acre of winter wheat have been secured and 15 bushels per acre for the spring varieties.

This soil type is very apt to be acid and in need of lime. As has been shown by the analyses which have been made from time to time, tests should therefore be made at regular intervals and lime applied as necessary in order to secure satisfactory crop growth. The actual amount of lime needed will vary with the different samples tested. The addition of lime is especially necessary on this soil if clover or alfalfa is to be grown.
Figure 6. Surface, sub-surface, and sub-soils of five of the individual soil types in Muscatine county.

6. Fargo loam.
7. Fargo loam.
8. Hancock loam.
10. Muck.
The beneficial effects of manure on this soil have been very definitely shown in the greenhouse and field experiments reported earlier in this report. Other fertilizing constituents seem to have little or no economic value at the present time. Potassium fertilizers are not necessary and nitrogen can be supplied by the use of leguminous green manure crops. Phosphorus fertilizers show only slight effects at the present time but will be needed in the future and under certain conditions they might be of value now.

**CARRINGTON LOAM (STEEP PHASE)** (57)

This soil occurs on the slopes and bluffs along the Des Moines river and its tributary ravines and creeks.

The surface soil is a black to brown friable loam, 6 to 12 inches deep, under-laid by a yellowish-brown compact gritty clay loam to clay. There is great variation in this soil owing to its generally steep topography. Along ravines the surface soil may be very largely removed by erosion and the underlying yellow clay loam exposed. At the bottom of some of the slopes the black loam may extend to a depth of 15 to 18 inches. All gradations may occur between these two extremes.

Originally this soil was in forest, bur oak, red oak, white oak, basswood and ash occurring most commonly. Over one-third of the type has now been cleared and is being used for pasture. Most of the land is too steep for general farm crops but on small areas on the lower, smother slopes, corn and oats are grown. Small fruits and berries might possibly be grown with profit with a good market. On the whole, however, the soil will be of value mainly for pasture.

**MIAMI SILT LOAM** (58)

This soil covers an area of 11,712 acres in Webster county or 2.6 per cent of the total area in the county. It occurs in narrow strips of level upland bordering the bluffs and steep slopes along the Des Moines river and its tributaries in the southern part of the county. These strips vary from 200 feet to about three-fourths of a mile in width. No areas of this soil large enough to be mapped occur north of Fort Dodge.

The surface soil is gray to light brown in color and extends to a depth of 15 to 18 inches. The subsoil is a brown, grayish-brown or dull-yellowish brown rather stiff clay. Between the surface and subsoil there usually occurs a layer of gray silty clay loam about 2 to 3 inches in thickness.

Some variations occur in the surface soil in different localities. For instance, in many places there is a very dark, almost black, surface layer 4 to 6 inches in thickness which is underlaid directly by a gray, ashy silt. In the flatter areas the subsoil is often drab or light-brown mottled.

This soil was originally forested but the greater part is now cleared and under cultivation. The forest growth consists mainly of bur oak and white oak, with some red oak, hickory, ash, elm, aspen and a few other hardwoods. Sumac and hazel are also common.

In favorable seasons good yields of corn are secured but the average yields are somewhat lower than on the prairie loams. Small grains, especially oats and wheat, and hay yield about the same as on other drift soils. During dry weather the soil becomes compact and hard which accounts for the average crop yields being lower than on some of the other soil types.

The drainage of the soil is usually adequate. In some cases tile drains would be of value and should be installed.

This soil is very apt to be acid and applications of lime are necessary to make it satisfactorily productive. The amount of lime needed is variable and applications should be made on the basis of individual tests for the particular soils.

The chief need of this soil is for organic matter. Farm manure should be applied in liberal amounts and in addition green manure crops should be grown. In this way and with the proper utilization of crop residues it is possible to
Figure 7. Surface, sub-surface, and sub-soils of five of the individual soil types in Muscatine county.
11. Wabash fine sandy loam.
12. Carrington loam (steep phase).
13. Waukasha loam.
14. Fargo clay loam.
15. Carrington loam.
build up this soil to a higher state of fertility than at present. Phosphorus is not present in any considerable amounts and applications of phosphorus fertilizers may be of value now and certainly will be in the rather near future.

CARRINGTON GRAVELLY LOAM (59)
This type covers but 192 acres or 0.1 per cent of the total area of the county. It occurs on the crests of low hills or swells in the northern part of the county. Many of the areas are too small to be mapped.

The surface soil to a depth of 8 to 10 inches consists of a brown to black friable gravelly loam or sandy loam. The subsoil is a yellowish-brown gravelly loam.

This type has a somewhat lower agricultural value than the typical Carrington soils and crops are apt to suffer from droughts as the soil is rather open and porous and low in organic matter.

The chief need of this soil is for the addition of organic matter as farm manure, leguminous green manures and crop residues. If the soil is acid in reaction lime should be applied. Phosphorus fertilizers may also be needed. With careful treatment this soil may be made quite as productive as the surrounding soil.
Two distinct soil types in Webster county are recognized as terrace soils and the total area covered by them amounts to but 2.6 per cent. The areas of the individual types are therefore quite small. The soils included are the Waukesha loam and the Hancock loam.

**Waukesha Loam (60)**

This soil covers 8,576 acres or 1.8 per cent the total area of the county. The soil is found mainly on the narrow terraces along the Des Moines river and Lizard creek, smaller strips occurring along Hardin and Deer creeks. The terrace plains are level or nearly level and vary in width from 100 yds. to about one mile. At no place does the plain extend for more than three or four miles.

The surface soil is a black friable loam extending to a depth of 10 to 15 inches. The subsurface soil is a dark-brown coarse, friable loam which grades into a brown to gray coarse unconsolidated sand and gravel at depths ranging from 20 inches to 4 feet. The subsoil material has a peculiar coffee-brown color and in many places contains large quantities of limestone particles ranging in size from sand to large pebbles.

Practically this entire type is under cultivation and in favorable seasons good yields of grain crops are secured. Crops are very apt to be injured by droughts as the subsoil is too open and porous to allow of the retention of moisture. With sufficient rainfall the yields of the ordinary farm crops are as good as those secured on the better upland soils.

The need of lime is apparent in many cases on this soil, and limestone should be applied in proper amounts to correct acidity. Manure should be employed in as large amounts as possible to keep the soil in good physical condition, particularly to aid in retaining moisture and also to add plant food. Green manures should be used for the same purposes and crop residues should all be turned under in the soil. Phosphorus is low in this soil and the use of a phosphorus fertilizer may be advisable. Tests along this line are desirable.

**Hancock Loam (61)**

This soil covers 3,520 acres in Webster county, or 0.8 per cent of the total area of the county. It occurs chiefly along the Des Moines river, occupying terraces, varying in width from 200 to 300 feet to one-fourth mile, and nowhere continuous for any great distance. Small areas occur also along Lizard creek.

The surface soil is a fine, friable, black loam to a depth of 20 inches and is underlaid by a loam or clay loam, more compact but lighter in color than the surface soil. There are some variations in this soil in the shape of occasional small patches of fine sandy loam but in general the soil is true to type.

Just east of Kalo there is a phase of the soil which deserves mention. There the soil is a black or nearly black fine loam to fine sandy loam underlain by a brown or yellow fine sandy loam which in places grades into yellow compact clay loam. This soil rests on a floor of rock at a depth 4 to 8 feet and it is this underlying rock material very largely which distinguishes this phase from the typical soil. Truck crops are grown on this phase of the soil near Kalo and Fort Dodge and fairly satisfactory yields are secured.

The typical soil of this type is as a rule quite productive and corn is the most successful crop. Oats also usually give satisfactory yields.

The soil needs include liming when acid, the use of farm manure, green manures and crop residues, and the use of phosphorus fertilizers at least sometime in the near future. The phase of the soil devoted to truck crops may also be benefited by the use of commercial fertilizers especially designed for the particular crop grown. The economic use of fertilizers in such cases must be determined by the value of the crop grown.
SWAMP AND BOTTOMLAND SOILS

There are two types of soil in Webster county which belong in this group and these, with the areas of peat and muck cover an area of 13,568 acres or 3 per cent of the total area of the county.

WABASH FINE SANDY LOAM (62)

This bottomland soil covers an area of 8,832 acres or 1.9 per cent of the total area of the county. It occurs mainly along the Des Moines river with smaller areas along the Lizard, Skillet, Brushy and other small creeks.

The surface soil is a black to brown, friable fine sandy loam 15 to 20 inches in depth. The color in the subsoil is a faint brown or dark-gray. There is little change in the texture of the subsoil from that at the surface to a depth of 3 feet altho the material becomes a little coarser in the lower part of the section.

There is considerable variation in the soil. In places it approaches a silt loam, and there are also areas of gray, loose, incoherent fine sand or fine sandy loam. In general the soil is rather dark in color and quite uniform in texture.

The greater part of the soil along the river has been cleared and the chief crop is corn. Small grains are produced to a slight extent but the yields are not as high as on upland soils. Along the creeks, less of this soil has been cleared and much of it is forested with elm, ash, box elder, hickory, walnut, butternut and hawthorn with some cottonwood, soft maple and willows. The areas along the creeks are small and irregular in shape and crop growth, after the soil is cleared, is not very satisfactory. The soil is all subject to overflow but floods are quite infrequent.

The needs of the soil include liming when acid, the use of manure, the turning under of green manure crops, the utilization of crop residues, and eventually the use of phosphorus fertilizers. With these treatments and protection against destructive floods the soil can be made to produce good crops.

PEAT (21)

The proper treatment of peat has been considered in an earlier section of this report and it need not be discussed here.

WABASH CLAY LOAM (63)

This soil covers 1,024 acres or 0.2 per cent of the total area of the county. The principal areas are along the south branch of Lizard creek near Barnum. Two small strips are mapped along the east and west branches of Buttrick creek near the southern boundary of the county.

The surface soil is a black slightly plastic, compact clay loam, 10 to 12 inches in depth. This is underlaid by black plastic clay which at 3 or 4 feet becomes sandy or gritty and dark drab or gray in color.

This soil occurs only from 4 to 6 feet above the stream level and consequently it is too wet or too poorly drained for cultivated crops. It affords good pastureage, however, and fair yields of hay. The chief need of the soil is for thorough drainage and with this and the other soil treatments generally recommended the soil could be made very productive.

MUCK (21a)

Only a few acres of this material are mapped in Webster county, the entire area covering only 256 acres. It consists of from 6 to 12 inches of intensely black loamy material which grades into a black plastic clay which in turn passes into drab or greenish-drab plastic clay at 30 to 40 inches.

The treatment needed for muck soil is not essentially different from that for peat. They are more easily reclaimed and with proper treatment can be made highly productive in a shorter time than is required for peat soils, from which the muck originated.

If this soil is well drained and properly cropped and handled satisfactory crops of corn and oats may be secured. Truck crops may also be grown successfully.
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
Fig. 9. Map of Iowa showing the counties surveyed

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>Corn crop</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
<td>17.76</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td>9.21</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats crop</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
<td>7.76</td>
</tr>
<tr>
<td>Barley grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley crop</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
<td>5.20</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
<td>6.62</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>65</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

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

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably the loss of plant food.

**REMOVAL FROM IOWA SOILS**

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

**PERMANENT FERTILITY IN IOWA SOILS**

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large,

* Bulletin 150 Iowa Agricultural Experiment Station.
there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements which are likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for crop production, largely because they help to control the moisture in the soil.

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought by thorough cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be more readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

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

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

THE ROTATION OF CROPS

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

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

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

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

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

**MANURING**

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

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

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

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

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

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

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

**THE USE OF PHOSPHORUS**

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

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports. Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

**LIMING**

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

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

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

**SOIL AREAS IN IOWA**

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

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

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

| Stones—over 32 mm.* |
| Gravel—32—2.0 mm. |
| Very coarse sand—2.0—1.0 mm. |
| Coarse Sand—1.0—0.5 mm. |

Inorganic Matter

| Medium Sand—0.5—0.25 mm. |
| Fine Sand—0.25—0.10 mm. |
| Very fine Sand—0.10—0.05 mm. |
| Silt—0.05—0.00 mm. |

SOILS GROUPED BY TYPES

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

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

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

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

Clays—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.

Silty Clay Loams—20 to 30 per cent clay and more than 50 per cent silt.

Clay Loams—20 to 30 per cent clay and less than 50 per cent silt and some sand.

Silt Loams—20 per cent clay and more than 50 per cent silt mixed with some sand.

Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

* 25 mm. equals 1 in.

1 Bur. of Soils Field Book.

2 C.
Sand 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.