Soil Survey of Iowa, Report No. 16—Buena Vista County Soils

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

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SOIL SURVEY OF IOWA
BUENA VISTA COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 16
October, 1920
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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161 Soil Acidity and the Liming of Iowa Soils (Abridged).
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18 Sulphification of Soils.
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44 The Effect of Certain Alkali Salts on Ammonification.
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BUENA VISTA COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman and H. W. Warner

Buena Vista county is located in northwest Iowa in the third tier of counties south of the Minnesota state line and the third tier east of the Sioux river, which forms the South Dakota state line. It is entirely in the Wisconsin drift soil area and the soils are mainly glacial in origin.

The total area of the county is 574 square miles or 365,440 acres. Of this area, 341,271 acres, or 93.4 percent, is farm land. The total number of farms is 1,923 and the average size of the farms is 177.5 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1918 show the utilization of the farm land of the county:

- Acreage in general farm crops: 248,701
- Acreage in pasture: 70,419
- Acreage in farm buildings, feed lots and public highways: 18,641
- Acreage in waste land: 881
- Acreage in crops not otherwise listed: 779

Agriculture in Buena Vista county consists mainly in the production of corn, oats and hay and the raising and feeding of hogs, cattle, horses and sheep. It is estimated that about one-half of the farm land is used for livestock farming and the remaining half for grain farming. There are of course many farmers who keep some stock and hence are not strictly grain farmers, but neither are they livestock farmers. A large group, therefore, should be considered as practicing general farming.

The area of waste land in the county is not particularly large, but it is quite desirable that some method of treatment be followed to reclaim any soils which are not producing profitable crops. General methods of treatment cannot be recommended to fit all conditions, inasmuch as infertility is usually due to a wide variety of causes. The special treatments necessary for individual soil types will he considered later in this report. Advice regarding treatment in special cases may be obtained from the Soils Section of the Iowa Agricultural Experiment Station upon request.

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

Corn is by far the most important crop both in acreage and value. It is grown in all parts of the county on practically every farm. The greater portion of the crop is fed to stock on the farm, the remainder being sold locally. Average yields of corn are estimated at 42.7 bushels per acre, but under many conditions the yields are much higher than this.

Oats is the second crop in acreage and value and is also produced on practically every farm. Average yields of 43.8 bushels per acre are secured, while
TABLE I. ACREAGE, YIELDS AND VALUE OF CROPS GROWN IN BUENA VISTA COUNTY*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm land of county</th>
<th>Bu. or tons per acre</th>
<th>Total bu. or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>120,665</td>
<td>35.30</td>
<td>42.7</td>
<td>5,151,634</td>
<td>$1.23</td>
<td>$6,336,510</td>
</tr>
<tr>
<td>Oats</td>
<td>93,247</td>
<td>27.30</td>
<td>43.8</td>
<td>4,080,346</td>
<td>0.64</td>
<td>2,611,431</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>3,276</td>
<td>.95</td>
<td>23.9</td>
<td>75,408</td>
<td>1.99</td>
<td>150,062</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>71</td>
<td>.02</td>
<td>14.2</td>
<td>1,010</td>
<td>2.02</td>
<td>2,042</td>
</tr>
<tr>
<td>Barley</td>
<td>1,827</td>
<td>.53</td>
<td>35.3</td>
<td>64,456</td>
<td>0.89</td>
<td>57,366</td>
</tr>
<tr>
<td>Rye</td>
<td>408</td>
<td>.11</td>
<td>15.4</td>
<td>6,298</td>
<td>1.48</td>
<td>10,521</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,064</td>
<td>.31</td>
<td>72.1</td>
<td>76,713</td>
<td>1.32</td>
<td>101,361</td>
</tr>
<tr>
<td>Tame hay</td>
<td>20,738</td>
<td>6.07</td>
<td>1.3</td>
<td>24,069</td>
<td>19.57</td>
<td>482,772</td>
</tr>
<tr>
<td>Wild hay</td>
<td>6,892</td>
<td>2.01</td>
<td>1.1</td>
<td>7,309</td>
<td>16.00</td>
<td>116,944</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>573</td>
<td>.17</td>
<td>2.2</td>
<td>1,813</td>
<td>23.93</td>
<td>31,420</td>
</tr>
<tr>
<td>Pasture</td>
<td>70,419</td>
<td>20.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1918.

in favorable seasons the yields are very much greater. A small part of the oats raised is fed on the farm, the remainder being sold and largely shipped out of the county.

Of the hay crop produced, by far the larger portion is made up of tame hay, less than one-fourth of the total acreage in hay being in wild grasses. The tame hay consists chiefly of clover and timothy and average yields of 1.1 tons per acre are secured. The average yields of wild hay are somewhat smaller. Some timothy is grown alone and in some places clover is grown alone, but in general the hay crop consists of a mixture of the two.

The acreage in winter wheat is small, but there is a rather considerable area in spring wheat, average yields of 23 bushels per acre being secured. The value of this crop is considerable.

Potatoes are an important special crop and average yields of 72.1 bushels per acre are secured. The total value of this crop in the county is estimated at over $100,000. Barley is produced on a somewhat larger acreage than potatoes, but the value of this crop is only about $57,000.

Alfalfa is grown on a small acreage and has given satisfactory results. Average yields of 2.2 tons per acre are recorded and the total value of this crop amounts to a large sum. Undoubtedly the acreage in alfalfa will increase during the coming years as the methods for securing a satisfactory stand become more generally recognized. There is no reason why this crop should not prove entirely satisfactory in Buena Vista county.

Rye is produced on only a small acreage, with a correspondingly small value. Sweet corn is grown to some extent in the neighborhood of Storm Lake to supply a canning factory which utilizes from 800 to 1,200 acres of sweet corn each year.

Gardens and orchards form a part of practically every farm. The vegetables and fruits produced are almost entirely consumed locally. The vegetables grown include chiefly root crops, peas and beans. The orchards are made up largely of apple trees but there are also a good many plum and cherry trees and some peach trees. The production of these fruits is considerable. Raspberries, gooseberries, blackberries and strawberries are also grown and good yields are secured.
The livestock industries of the county, in the order of their importance, include the raising of hogs, the feeding of beef cattle, dairying, the raising of horses and mules and sheep raising. The following figures from the Iowa Yearbook of Agriculture for 1918 show the character and extent of the livestock industry in Buena Vista county:

- Horses (all ages) ........................................................... 15,143
- Mules (all ages) ..................................................................... 536
- Swine (on farms January 1, 1918) ........................................... 97,887
- Cattle (cows and heifers kept for milk) .............................. 10,459
- Cattle (other cattle not kept for milk) .................................. 26,565
- Cattle (total all ages) .......................................................... 48,052
- Sheep (all ages, on farms) ................................................... 4,205
- Sheep (total pounds wool clipped) ....................................... 13,070

The raising of hogs is particularly important and in 1918 there were over 97,000 hogs on the farms of the county. The feeding of beef cattle is practiced quite extensively, large numbers of cattle being purchased from the markets of Sioux City, Omaha and Chicago, and to some extent from the western ranges. These cattle are fed usually for short periods ranging from 60 to 90 days, corn, hay and, in some cases, silage and concentrates, being used for feed. Few cattle are raised on the farms. Dairying is of some importance, altho only a few farmers are engaged in dairying exclusively. The value of the dairy products is considerable, a large number of farmers producing sufficient for their own use and some excess for sale locally. Creameries are located at Storm Lake, Alta, and Albert City.

Poultry raising is carried on mainly to supply the home demands, but increasing attention is being paid to this industry and there is a considerable sale of poultry products out of the county. The raising of horses is practiced to some extent, but only a few are sold off the farms. Only a comparatively few farmers keep sheep and these are mainly bought from the large markets, not many being raised on the farms. The total wool produced in 1918 was somewhat over 13,000 pounds.

The value of the land in Buena Vista county varies considerably, depending upon topographic conditions, location with reference to towns and railroad facilities, and improvements. The average price of farm land is about $325 per acre, while the range in selling price is from $200 to $650 per acre.

Crop yields in Buena Vista county are quite satisfactory, but in many cases larger yields might readily be secured by following better methods of soil treatment. There are many cases where the drainage is poor and crop production on these areas is likely to be considerably below the average. Much land has been drained successfully and the value of the crop increases secured has more than offset the expense involved. Wherever drainage is poor, the first treatment necessary is the proper installation of tile.

Many of the soil types are acid in reaction and in these cases lime should be added to secure the best crop growth, particularly of legumes. The soils should always be tested for lime requirement before seeding to clover or alfalfa, and the amount of lime needed should be applied. The supply of organic matter is not low and in some instances it is very high, but on most of the soil types the addition of farm manure or leguminous green manures would be highly desirable. This is particularly true of the O'Neill soils and the Carrington loam. Even on the darker-colored types, however, the application of
small amounts of farm manure is very desirable and usually results in profitable increases in crop yields.

The amount of phosphorus in the various soils is rather low and additions of phosphorus fertilizers will be needed in the near future, even if they do not prove profitable at present. Tests now under way on several fields in the county indicate that such materials may be used with profit in many cases. These tests include a comparison of rock phosphate, acid phosphate and a complete commercial fertilizer, and it is hoped that definite conclusions regarding the relative merits of these materials will be obtained in the course of the next few years. At present no comparisons can be made and no definite recommendations can be given regarding the application of phosphorus fertilizers. Farmers are urged to test them on small areas on their own soils and thus determine for their specific conditions the relative value of the various materials. Complete commercial fertilizers are not now generally recommended for use in the county, but if tests such as are suggested above prove any particular brand to be of value, there is no reason why that brand should not be used. It should be emphasized, however, that tests of any fertilizing material should be carried out on a small area before applications are made to a large area.

There is some erosion on the Carrington loam and particularly in the case of the steep phase of this type. Where this washing occurs, care should be taken in the handling of the soil and in the method of cropping in order to prevent the complete removal of the surface soil. In places, the steep phase is suitable only for pasture.

THE GEOLOGY OF BUENA VISTA COUNTY

The original rock material in Buena Vista county is buried deeply under thick coverings of drift or glacial till. The county was invaded by at least two great ice sheets during the glacial age and each of these left behind, upon its retreat, a thick deposit of debris, collected in its forward movement over the land. This drift material is composed of a complex mixture of rock debris, some of which is finely divided and some of which is rather coarse material. In general, it consists of mixtures of clay, silt, sand and boulders of all sizes, accumulated by the glaciers from large areas over which they passed, and bearing no relation to the rock material upon which they now rest. It is unnecessary, therefore, to consider the character of the underlying rock formations in Buena Vista county, as they have no effect upon the soil conditions.

The two glaciations which are represented in Buena Vista county are the Kansan and the Wisconsin. The Wisconsin drift, which is the more recent deposit, extends from the eastern side of the county over nearly two-thirds of its area. The remainder of the county is within the Kansan drift area. The boundary between these two drift areas coincides almost exactly with the boundary between the Carrington loam of the Wisconsin drift and the Carrington silt loam derived in part from the Kansan drift and in part from an overlying deposit of silty loessial material. This layer of silt has covered the Kansan drift to a considerable depth in most of the western part of the county and it is so much like the well weathered silty Kansan material that it is a
question how much of the Carrington silt loam mapped is due to the silt layer and how much is derived from long weathering of the Kansan drift.

The Kansan drift in general, before weathering, consists of a blue clay which, when weathered, becomes brown or yellow. It contains numerous pebbles, boulders, shale fragments and frequently considerable sand or gravel. It ranges from 20 to 50 feet in depth.

The Wisconsin drift material is very similar to the Kansan, the chief difference being that it is less weathered; hence, the soil derived from it is somewhat darker in color. It also contains more pebbles and boulders, the latter varying in size up to 3 or 4 feet in diameter. The unweathered Wisconsin drift is a bluish-drab to bluish-gray in color. The depth of this drift deposit in the county is uncertain, but it is sufficient to prevent any of the underlying materials having any effect upon the soil conditions.

Thruout the central portion of the county, there occurs what is known as the moraine or terminal deposit of the Wisconsin glacier. The drift material here

Fig. 1. Map of natural drainage system of Buena Vista county
is somewhat variable in composition; there are pockets of sand, gravel and boulders occurring on knobs or kames and at the tops of slopes. Some of these areas are very close to the surface, or even exposed. Exposed areas are generally roughly circular in shape and a few feet in diameter.

**PHYSIOGRAPHY AND DRAINAGE**

The upland of Buena Vista county is in general a gently rolling plain, cut by the stream channels. In places, particularly in Brooke township, the topography is broken by the Little Sioux river and Brooke creek, and here the slopes are steep and the small drainageways are almost gulches. In the remainder of the well drained part of the county, the topography is gently rolling, the slopes are gentle and the streams are separated by long, low ridges, some of which are almost flat. In the larger part of the county, where stream valleys are practically lacking, the topography shows a confusion of irregular mounds, some of which are low swells and some rather sizeable hills. The smaller mounds have a gentle slope, while the larger are often rather steep. The general trend of these mounds is northwest and southeast.

Many depressions occur throughout the county, especially in the central portion. Before tile drainage was practiced, these depressions were sloughs or ponds during the greater part of the year. Some of these sloughs are long and winding and they range from one acre to hundreds of acres in size. Narrow strips of bottomland are found along the principal streams and in some places there are small areas of terrace or second bottomland.

A divide runs across the county, passing through Storm Lake and Alta. It separates the drainage tributary to the Missouri river and that tributary to the Mississippi. Most of the county north of Alta has a general slope to the north, while east of the divide the prevailing slope is to the south. The area west of Alta extending to the northwest has a gradual slope to the west. The drainage of that part of the county east of the divide is almost entirely through the Coon river. The Little Sioux river drains a narrow area in the north central portion, and also a narrow area extending from the river just west of Linn Grove south almost to Storm Lake. The western part of the county is drained by Maple creek. A small area south of Storm Lake drains into Boyer river in Sac county.

The Little Sioux river has a valley from one-half to one mile in width, in most places bounded by steep bluffs which rise 120 to 125 feet above the bottomland. Brooke creek, the chief tributary of the Little Sioux river, rises just north of Storm Lake, and joins the Little Sioux in the northwest part of the county. From its source to a point about six miles north of Alta, this creek formerly consisted of a series of marshes or sloughs, thru which an artificial channel has now been cut. The valley becomes deeper and the slopes steeper as the creek approaches the Little Sioux. The width of the valley never exceeds one-eighth of a mile. The valleys of the tributaries of Maple creek, Boyer river and other streams are characterized in most cases by gentle slopes. Occasionally the slopes may be steep, as in the case of one of the tributaries of the Boyer river. The streams east of the divide are all small, with few tributaries. They drain a strip of country very little wider than the flood plains. The Coon river is the only important stream and much of the upper part of this river
BUENA VISTA COUNTY SOILS

consists of a series of narrow sloughs. There are three lakes in the county, Storm lake, which is by far the largest, Pickerel lake, and Pleasant lake.

The accompanying map indicates the extent of the natural drainage of the area and shows clearly that artificial drainage is necessary over a considerable portion of the county. Much of the land in Buena Vista county has been reclaimed and made highly productive by the installation of tile and drainage ditches, and the expense of this operation has been well warranted by the value of the crop yields secured.

THE SOILS OF BUENA VISTA COUNTY

The soils of Buena Vista county are grouped into three classes, according to their origin and location. These classes are drift soils, terrace soils, and swamp and bottomland soils.

Drift soils are formed from the debris deposited by glaciers upon their retreat and contain material from various sources and sometimes pebbles and boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams, and they are subject to more or less frequent overflow. The areas of these three groups of soils in Buena Vista county are shown in table II.

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN BUENA VISTA COUNTY

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>344,256</td>
<td>94.2</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>1,920</td>
<td>0.5</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>19,264</td>
<td>5.3</td>
</tr>
<tr>
<td>Total</td>
<td>365,440</td>
<td></td>
</tr>
</tbody>
</table>

Practically all of the county is covered by the drift soils, over 94 percent of the total area being included in this group. Swamp and bottomland soils cover only about 5 percent of the total area, and the terrace types are very minor in importance, covering only one-half of one percent of the total area.

Fig. 2. View across the Sioux river bottoms near Sioux Rapids
There are 12 individual soil types in Buena Vista county and these, with the steep phase of the Carrington loam, make a total of 13 separate soil areas. There are six drift soils, two terrace types, and five areas of swamp and bottomland which include an area of muck and one of peat. These various soil types are distinguished by characteristics which are described in the appendix to this report, and their names denote certain group characteristics. The areas of the various soil types are shown in table III.

The Carrington loam is the most extensive individual soil type in the county, covering 48.6 percent of its total area with the steep phase, which is minor in extent. The Carrington silt loam is second, covering 27.8 percent. The Webster silty clay loam is the third and is found on 15.7 percent of the more level upland. The Webster silt loam is rather minor in area, covering only 2 percent of the total area, and the Clyde sand, the remaining drift soil, is found on only 64 acres in the county.

The two terrace types in the county are both very small in extent, the O’Neill loam covering only 0.4 percent and the O’Neill fine sandy loam 0.1 percent of the total area.

The Wabash silt loam is the most extensive bottomland soil and is found on 3.1 percent of the total area. The Wabash silty clay loam is second in extent, covering about one-half as large an area as the silt loam. There are very small areas of Lamoure silty clay loam, muck and peat, covering 0.2 percent, 0.3 percent and 0.2 percent of the total area, respectively.

The upland types belonging to the Carrington series are in general gently undulating to rolling, with the exception of the steep phase Carrington loam found on the slopes, which is too steep for cultivation, and may be termed sharply rolling to broken in topography. The soils of the Webster series are found in those portions of the county which are poorly drained and level to gently undulating in topography. They are also often found in flat or depressed areas. The need for drainage of the Webster soils is very definitely evidenced by their topographic position. The terrace types, belonging to the O’Neill series, are found on the rather level terraces, but owing to the sandy

### TABLE III. AREAS OF DIFFERENT SOIL TYPES IN BUENA VISTA COUNTY

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>188,448</td>
<td>57.6</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>9,216</td>
<td>2.6</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>101,760</td>
<td>28.3</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>57,556</td>
<td>15.7</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>7,232</td>
<td>2.0</td>
</tr>
<tr>
<td>114</td>
<td>Clyde sand</td>
<td>64</td>
<td>0.1</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>1,600</td>
<td>0.4</td>
</tr>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>28</td>
<td>Wabash silt loam</td>
<td>11,328</td>
<td>3.1</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>5,312</td>
<td>1.5</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>1,216</td>
<td>0.3</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>768</td>
<td>0.2</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>640</td>
<td>0.2</td>
</tr>
</tbody>
</table>
character of the subsoil, drainage is more than adequate and the soils are apt to be drouthy. The bottomland types are all level in topography and subject to overflow. If these types are to be successfully used for the growth of general farm crops, they must be tiled and protected from flooding.

**THE FERTILITY IN BUENA VISTA COUNTY SOILS**

Samples were taken for analyses from each of the soil types and also from the areas of muck and peat. The more extensive types were sampled in triplicate, while one sample only was secured from each of the minor types. The samples were all taken with the greatest care that they should represent accurately the soil types and that all variations due to local conditions or special treatments should be eliminated. The samplings were made at three depths, 0-6 2/3", 6 2/3"-20", and 20"-40", representing the surface soil, the subsurface soil and the subsoil, respectively.

These samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were employed in the determination of phosphorus, nitrogen and carbon, and the Veitch method was used to determine the limestone requirement. The figures given in the tables are the averages calculated from duplicate determinations on all samples of each type that were analyzed. Thus, where more than one sample of a type was taken, the figures represent the averages of four or six determinations.

**THE SURFACE SOILS**

The result of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre. The phosphorus content of the soils of the county is somewhat variable, ranging from 1266 up to 2,000 pounds per acre. The variation in the amount of phos-

**TABLE IV. PLANT FOOD IN BUENA VISTA COUNTY, IOWA, SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,267</td>
<td>3,839</td>
<td>47,150</td>
<td>0</td>
<td>4,663</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,580</td>
<td>5,764</td>
<td>79,933</td>
<td>0</td>
<td>1,076</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,613</td>
<td>5,706</td>
<td>71,713</td>
<td>0</td>
<td>6,636</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,506</td>
<td>8,577</td>
<td>99,644</td>
<td>13,962</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam*</td>
<td>1,347</td>
<td>17,426</td>
<td>196,820</td>
<td>0</td>
<td>2,002</td>
</tr>
<tr>
<td>114</td>
<td>Clyde sand</td>
<td>1,582</td>
<td>4,280</td>
<td>43,010</td>
<td>36,280</td>
<td>Basic</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>1,500</td>
<td>4,733</td>
<td>59,890</td>
<td>0</td>
<td>3,766</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>1,266</td>
<td>2,522</td>
<td>28,560</td>
<td>0</td>
<td>2,690</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,680</td>
<td>5,824</td>
<td>72,100</td>
<td>0</td>
<td>2,152</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,876</td>
<td>7,508</td>
<td>103,144</td>
<td>636</td>
<td>1,614</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>2,000</td>
<td>22,134</td>
<td>371,614</td>
<td>1,646</td>
<td>538</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>1,710</td>
<td>9,730</td>
<td>108,712</td>
<td>9,193</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>1,700</td>
<td>29,200</td>
<td>378,960</td>
<td>0</td>
<td>400</td>
</tr>
</tbody>
</table>

*This sample was somewhat mucky at the surface, hence the organic carbon and nitrogen contents are abnormally high
phorus present is quite as great between soils in the same group as it is between types in the different groups, hence no relation can be traced between the phosphorus supply and the soil group. The bottomland soils may in general be a trifle higher in phosphorus, as might be expected from the fact that these types have been cultivated to a less extent and there has been less removal of phosphorus from the store originally present in the soil. However, there seems to be a more definite relation between the soil type and the phosphorus supply, the silty clay loams and silt loams being better supplied with this element than the loams and sandy loams. The phosphorus supply in the soils as a whole is evidently not very large. While not actually deficient, in many cases the amount is inadequate to keep up the best crop growth for many years. It will be only a short time until phosphorus fertilizers will be needed. Tests now under way in the county will show within the next few years whether or not phosphorus fertilizers are profitable for use on the main soil types. Such materials may prove profitable at the present time, but tests should be first made on small areas, and, if the fertilizer shows value, applications may be made on a large scale.

The nitrogen supply of the various soil types is sufficient in most cases for a large number of crops; in the case of the Webster silt loam, the muck and the peat, the amount of nitrogen present is extremely large. In one or two cases, however, it is evident that nitrogen will need to be supplied in the immediate future. There is no relation, apparently, between the nitrogen content and the soil group, altho the terrace soils are lower than the upland or bottomland types. This is largely due to the fact that the terrace types are both of the O'Neill series, which is characteristically low in organic matter and nitrogen. Again, as in the case of phosphorus, the soil type seems to bear an important relation to the nitrogen supply, and silty clay loams and clay loams are much better supplied than are the loams and sandy loams. While nitrogen is not actually lacking, this does not mean that nitrogen should be disregarded in systems of permanent fertility. The supply of this element must be maintained by the regular application of nitrogenous materials. Farm manure and crop residues return to the soil much of the nitrogen removed by crops, but in spite of this return, there is a constant loss of nitrogen. Leguminous crops turned under as green manures are the best means of building up the nitrogen content. When well inoculated, a part of the nitrogen which they contain is taken from the atmosphere. They also add organic matter and hence have a double value.

There is always a rather definite relation between the nitrogen content of the soil and the supply of organic carbon. The latter furnishes a measure of the amount of organic matter present. When there is a large amount of organic matter in the soil, there is usually also an abundant supply of nitrogen. Furthermore, the relation between these two constituents gives some evidence of the rate at which plant food is being made available. The amount of organic carbon and nitrogen in a soil is in general rather definitely shown by the color of the soil. Those types which are darker in color are richer in organic carbon and nitrogen, while the light colored types are apt to be deficient in both constituents. The amount of organic matter in Buena Vista county soils is extremely variable, but in no case is it very low. The terrace types are the
poorest, as was noted in the case of nitrogen, and the bottomland types are in general the highest, owing to the accumulation of plant residues and the lack of decomposition and disappearance of these materials in poorly drained soils. In general, the heavier types are the richer in organic matter, especially when they are dark in color, as is usually the case. Thus the silty clay loams and the silt loams show the largest amount of organic matter, as well as of nitrogen. The samples of muck and peat are, of course, extremely high in both organic matter and nitrogen, as would be expected from the nature of their formation. The organic matter supply in Buena Vista county soils, while not extremely low, must be maintained if satisfactory crop yields are to be secured, and this can be done by the use of farm manure, green manures and crop residues. On the sandy types, these materials should be used extensively, and even on the heavier soils, the application of farm manure, at least, should be practiced. The value of farm manure as a means of increasing crop production has been evidenced by much farm experience and the soils of Buena Vista county should receive regular applications of this material.

Five of the soil types show a considerable amount of inorganic carbon present, while in the other types this constituent is not found, and those types are therefore acid and show a lime requirement. The Webster silty clay loam, the Clyde sand and the Lamoure silty clay loam are the only soil types which the test show to have a basic reaction or to be non-acid. The amount of lime present in the Wabash silty clay loam and the muck is insufficient to give the soils a basic reaction. With the exception, therefore, of the three basic types mentioned above, the soils of the county should be tested for lime requirement and the amount needed should be applied. While most of the soils do not show a large lime requirement according to the figures given in the table, the acidity or lime requirement will gradually increase as crop production continues. Furthermore, these tests are merely indicative of the needs of the soil types in general and should not be considered as showing the needs of all soil of the same type. Every soil should be tested before lime is applied; then the proper application may be made to insure the best growth of crops. One application will not serve indefinitely, but the soils must all be tested from time to time if crop growth, particularly of legumes, is to be kept at its best.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of sub-
surface soil and 6,000,000 pounds of subsoil. No analysis was made of the subsoil of the Clyde sand, as is indicated in the table.

The amount of plant food in the lower soil layers has very little influence on the fertility of the soil, unless an unusually large amount of some constituent is present. The supply of the various plant food elements is not extremely high in the lower layers of the soils of this county; hence it will not be necessary to enter into any extended discussion of the analyses given in the table.

### TABLE V. PLANT FOOD IN BUENA VISTA COUNTY, IOWA, SOILS

**Pounds per acre of four million pounds of subsurface soil (6 2/3 - 20")**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,720</td>
<td>5,129</td>
<td>62,653</td>
<td>0</td>
<td>7,173</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>2,500</td>
<td>8,408</td>
<td>113,184</td>
<td>3,736</td>
<td>1,076</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>2,573</td>
<td>7,872</td>
<td>97,616</td>
<td>0</td>
<td>10,760</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>2,560</td>
<td>7,872</td>
<td>113,585</td>
<td>23,188</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>2,120</td>
<td>21,416</td>
<td>234,960</td>
<td>0</td>
<td>4,004</td>
</tr>
<tr>
<td>114</td>
<td>Clyde sand</td>
<td>2,120</td>
<td>3,984</td>
<td>50,000</td>
<td>74,320</td>
<td>Basic</td>
</tr>
</tbody>
</table>

### TERRACE SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>2,440</td>
<td>6,648</td>
<td>89,740</td>
<td>0</td>
<td>8,071</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>2,000</td>
<td>2,321</td>
<td>25,232</td>
<td>288</td>
<td>1,076</td>
</tr>
</tbody>
</table>

### SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,440</td>
<td>7,974</td>
<td>104,160</td>
<td>0</td>
<td>6,456</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,640</td>
<td>7,974</td>
<td>110,312</td>
<td>488</td>
<td>3,228</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>2,120</td>
<td>21,096</td>
<td>305,768</td>
<td>19,322</td>
<td>Basic</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>3,220</td>
<td>10,254</td>
<td>144,466</td>
<td>20,154</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>1,920</td>
<td>26,228</td>
<td>356,160</td>
<td>8,040</td>
<td>800</td>
</tr>
</tbody>
</table>

### TABLE VI. PLANT FOOD IN BUENA VISTA COUNTY, IOWA, SOILS

**Pounds per acre of six million pounds of subsoil (20" - 40")**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>2,160</td>
<td>3,491</td>
<td>43,740</td>
<td>0</td>
<td>11,288</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>3,180</td>
<td>4,320</td>
<td>50,820</td>
<td>112,380</td>
<td>Basic</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>3,760</td>
<td>5,149</td>
<td>61,520</td>
<td>0</td>
<td>11,837</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>3,540</td>
<td>6,712</td>
<td>76,504</td>
<td>58,076</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>3,090</td>
<td>12,066</td>
<td>227,658</td>
<td>1,182</td>
<td>6,006</td>
</tr>
<tr>
<td>114</td>
<td>Clyde sand (not analyzed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TERRACE SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>3,150</td>
<td>4,627</td>
<td>49,329</td>
<td>291</td>
<td>8,877</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>2,580</td>
<td>1,933</td>
<td>20,538</td>
<td>25,002</td>
<td>Basic</td>
</tr>
</tbody>
</table>

### SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limest'n requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,300</td>
<td>12,066</td>
<td>237,658</td>
<td>1,182</td>
<td>8,006</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>3,300</td>
<td>5,358</td>
<td>104,928</td>
<td>732</td>
<td>1,614</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>2,300</td>
<td>12,180</td>
<td>214,080</td>
<td>70,500</td>
<td>Basic</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>3,300</td>
<td>8,916</td>
<td>191,550</td>
<td>6,870</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>2,520</td>
<td>9,624</td>
<td>123,420</td>
<td>58,444</td>
<td>Basic</td>
</tr>
</tbody>
</table>
The needs of the soils which were indicated by the analyses of the surface soil, are very largely confirmed by the data secured for the lower layers. Phosphorus will certainly be needed in the future and phosphorus fertilizers may prove profitable at the present time. The organic matter and nitrogen supply must be maintained by the proper use of farm manure, leguminous green manures and crop residues. In several instances, the lower soil layers are better supplied with lime than is the surface soil, but with the exception of the three types which were basic in the surface and whose basic condition persists thru the subsoil, all the soil types of the county should be tested for acidity. There is very little movement of lime upward in the soil and if the surface soil shows an acid reaction, lime should be applied regardless of the content of the subsoil.

**GREENHOUSE EXPERIMENTS**

One greenhouse experiment was carried out on the Webster silty clay loam from Buena Vista county. Two other experiments on Clay county soils are included here, inasmuch as the types are the same and the conditions practically identical. These latter experiments were carried out on the Carrington silt loam and the Webster silty clay loam.

The arrangement of all the experiments was the same. Lime was added in amounts sufficient to neutralize the acidity of the soils and supply two tons additional. Manure was supplied at the rate of 8 tons per acre, rock phosphate at the rate of 2000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Both wheat and clover were grown in all these tests, the clover being seeded in the pots after the wheat had been up about

**TABLE VII. GREENHOUSE EXPERIMENT**

Webster silty clay loam—Buena Vista county

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>26.56</td>
<td>29.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>29.46</td>
<td>36.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>31.71</td>
<td>44.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>28.85</td>
<td>46.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>35.80</td>
<td>45.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>31.13</td>
<td>46.0</td>
</tr>
</tbody>
</table>
one month. The average yields of the two crops from the duplicate pots are given in the tables.

Table VII gives the results obtained on the Webster silty clay loam from Buena Vista county. It will be noted that the application of manure brought about a distinct increase in the yields both of wheat and of clover, the gain being more pronounced in the case of the latter crop. The addition of lime with manure brought about a small increase over the manure alone in the case of the wheat, while with clover, the increase was considerable. Rock phosphate showed no effect on wheat and a very slight influence on clover. Acid phosphate gave a considerable gain in the yield of wheat, but only a slight effect on the clover. The commercial fertilizer showed only a small effect in the case of both crops. Manure is evidently a very valuable fertilizer for use on this soil, in spite of the fact that it is well supplied with organic matter. Lime, also, evidently should be applied when the soil is acid. There is evidence of value from the use of a phosphate fertilizer, but the results do not permit of very definite conclusions along this line.

The results secured on the Carrington silt loam from Clay county are given in table VIII. The manure brought about a distinct increase in the yield of wheat and an even greater gain in the clover. The lime showed little influence on either crop and the rock phosphate showed practically no effect. The acid phosphate and the commercial fertilizer gave very slight gains on the wheat crop, but on the clover both materials brought about distinct effects, the
TABLE VIII. GREENHOUSE EXPERIMENT
Carrington silt loam—Clay county

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>19.54</td>
<td>25.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>23.40</td>
<td>41.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>23.55</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>23.16</td>
<td>40.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>23.60</td>
<td>52.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>24.27</td>
<td>56.5</td>
</tr>
</tbody>
</table>

Manure is evidently the most valuable fertilizing material for use on this soil and it should be applied in as large amounts as practicable. There are indications of value from the use of a phosphorus fertilizer and also from the use of a complete commercial fertilizer, although the latter case the influence of the material was probably due to the phosphorus content, and the effect was very little greater than that of the acid phosphate.

The results obtained on the Webster silty clay loam from Clay county are given in table IX. Again, as was noted in the experiment with the same type from Buena Vista county, manure brought about increases in the case of the wheat and clover, showing the greatest effect on the clover. Lime had little influence on either crop and the rock phosphate, acid phosphate and commercial fertilizer showed no effect on the wheat and only a small influence on the clover. These results very largely confirm those obtained in the first greenhouse experiment on this type and show the value of manure as a fertilizing material and the possibility of value from the use of a phosphate fertilizer. Tests of phosphorus carriers in the field are evidently necessary in this county in order to arrive at definite conclusions regarding the value from such materials. The field tests given later in this report throw some light upon this question, but they have not been under way long enough and the results are not sufficiently definite to permit of general conclusions.

FIELD EXPERIMENTS

Several field experiments are now under way in Buena Vista county and while results have been secured for only two seasons, a portion of the data is given in this report for the purpose of showing the direction in which the results are tending. The experiments are far from complete, however, and

TABLE IX. GREENHOUSE EXPERIMENT
Webster silty clay loam—Clay county

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>26.24</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>29.56</td>
<td>51.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>30.44</td>
<td>44.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>29.31</td>
<td>53.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>28.97</td>
<td>53.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>29.12</td>
<td>54.5</td>
</tr>
</tbody>
</table>
general conclusions cannot be drawn from the results so far obtained. Data should be secured over a period of at least five years before conclusions are warranted. More complete results from these experimental fields will be published later in a separate report.

These field tests were all laid out on land which is thoroughly representative of the more extensive soil types. They are located on the Carrington loam and the Webster silty clay loam. The location of the various series of plots is made permanent by the installation of corner stakes and care is taken in the application of fertilizers and in the harvesting of crops to be certain that the results secured are accurate. On each field there are one or more series of plots, so arranged as to include tests under the livestock system and under the grain system of farming. In the livestock system, manure is applied, while, in the grain system, crop residues are utilized as a source of organic matter. The other applications tested are limestone, rock phosphate, acid phosphate, and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four year rotation. Limestone, when needed, is added in a sufficient amount to neutralize acidity and supply two tons additional. Rock phosphate is used at the rate of 2,000 pounds per acre once in the rotation, while acid phosphate is applied at the rate of 200 pounds per acre annually. A 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually. In the grain system, where crop residues are employed in place of manure, the second crop of clover is plowed under on all plots. Corn stalks are cut with a disc and plowed under and the threshed straw from the small grain is returned to the soil.

There are thirteen plots in each experiment, three of which are untreated or check plots and are numbered 1, 7, and 13. Plots 1 to 7 inclusive are considered in the livestock system, while plots 7 to 13 are in the grain system.

THE TRUESDALE FIELD

This field was laid out in the fall of 1917 and the plots are 155' 6" by 28', or 1/10 of an acre in size. There are two series on this field, both of which are on the Carrington loam. The first applications of fertilizing materials were made in the fall of 1917 to the clover on Series I, and in the spring of 1918 to
TABLE X. FIELD EXPERIMENT—TRUESDALE FIELD

Series I

Carrington loam—Buena Vista county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre corn—1918</th>
<th>Bu. per acre corn—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>38.9</td>
<td>56.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>44.3</td>
<td>57.1</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>46.4</td>
<td>58.1</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>54.4</td>
<td>58.7</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>49.6</td>
<td>58.7</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>49.6</td>
<td>58.7</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>38.4</td>
<td>58.1</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>49.1</td>
<td>61.9</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+Lime</td>
<td>51.2</td>
<td>66.6</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+Lime+Rock phosphate</td>
<td>58.9</td>
<td>68.8</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+Lime+Acid phosphate</td>
<td>57.6</td>
<td>67.2</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+Lime+Complete commercial fertilizer</td>
<td>62.9</td>
<td>66.1</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>47.5</td>
<td>64.0</td>
</tr>
</tbody>
</table>

Series II. The results obtained for the years 1918 and 1919 on Series I are given in table X. It will be noted that the manure brought about an increase in the crop of corn in 1918. The lime showed some effect when added with manure, rock phosphate brought about a considerable increase and acid phosphate and the commercial fertilizer also increased the crop, but to a less extent than did the rock. In the case of the crop residue plots, there was some influence from the use of lime; the rock phosphate increased the yields considerably; acid phosphate showed a slightly smaller effect, and the commercial fertilizer gave a distinct increase, larger, in fact, than that brought about by any of the other materials.

The yields for 1919 were much less definite than those for 1918. This is particularly true of the livestock system plots, where the yields were almost identical on all of the plots. On the grain system plots, however, there was again an effect from the use of lime and from the use of rock phosphate, acid phosphate, and commercial fertilizer. These results, however, show much smaller influence from these materials than in the previous year.

In table XI appear the results obtained for 1918 and 1919 on Series II on the same field. The yield of oats in 1918 showed a distinct increase as a result of the application of manure and additional applications of the other fertilizer materials brought about no further increases. In the case of the grain system plots, there is evidence of the value of the various phosphates, acid showing up a little better than rock, and commercial fertilizer better than either phosphate. The yield on plot IX was evidently somewhat abnormal. In 1919 the yields of clover on the first four plots of the series were not secured. From the data obtained, however, it seems that the acid phosphate and commercial fertilizer, applied with lime and manure, increased the clover yield considerably over the check. Unfortunately, the loss of the data from the four plots prevents any conclusion regarding the value of the phosphate materials over manure alone. In the crop residue plots, lime seemed to have some effect, and rock phosphate, acid phosphate and commercial fertilizer all brought about distinct increases in yield, the two phosphates showing practically identical effects and the commercial fertilizer slightly higher results.
TABLE XI. FIELD EXPERIMENT—TRUESDALE FIELD
Series II
Carrington loam—Buena Vista county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre oats—1918</th>
<th>Tons per acre Clover*—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>69.9</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>94.2</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>91.2</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>88.2</td>
<td>...</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>91.2</td>
<td>1.89</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>88.2</td>
<td>2.00</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>89.7</td>
<td>1.59</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>97.3</td>
<td>2.07</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+Lime</td>
<td>91.2</td>
<td>2.19</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+Lime+Rock phosphate</td>
<td>92.7</td>
<td>2.22</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+Lime+Acid phosphate</td>
<td>95.8</td>
<td>2.37</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+Lime+Complete commercial fertilizer</td>
<td>85.1</td>
<td>1.91</td>
</tr>
</tbody>
</table>

*The clover on plots 1, 2, 3 and 4 winter killed, and no yield was secured.

THE NEWELL FIELD

The experiment on this field was laid out as in the preceding case, the experiment being started in the spring of 1918. The soil type in this case is the Webster silty clay loam. The particular type was not acid in reaction and no limestone was added. Hence plots 2 and 3 are duplicates.

The yields obtained on the livestock plots in Series I on this field are given in table XII. The grain system plots are not included, as they showed considerable abnormality in several cases, and furthermore, no crop residues have yet been available to turn under and the effects of treatment on these plots can hardly be determined until later. Beneficial effects from the use of manure and rock phosphate are evident in the yields for 1918, but acid phosphate and complete commercial fertilizer showed little influence. Rock phosphate gave a decided increase in the yield of corn. The following year, manure brought about an increase and additional increases were caused by the application of the other three fertilizing materials. Commercial fertilizer seemed to give somewhat greater effects, but it will be noted that the soil evidently becomes better in going from the first to last check, plot 7 giving a very much larger yield than plot 1.

TABLE XII. FIELD EXPERIMENT—NEWELL FIELD
Series I
Webster silty clay loam—Buena Vista county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre corn—1918</th>
<th>Bu. per acre corn—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>69.0</td>
<td>44.8</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>70.9</td>
<td>48.1</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Rock phosphate</td>
<td>71.4</td>
<td>54.4</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Rock phosphate</td>
<td>74.1</td>
<td>61.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Acid phosphate</td>
<td>66.9</td>
<td>65.1</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Complete commercial fertilizer</td>
<td>66.4</td>
<td>70.9</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>60.9</td>
<td>62.4</td>
</tr>
</tbody>
</table>
TABLE XIII. FIELD EXPERIMENT—NEWELL FIELD

Series II
Webster silty clay loam—Buena Vista county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre oats—1918</th>
<th>Bu. per acre corn—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>80.7</td>
<td>58.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>89.2</td>
<td>68.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>87.1</td>
<td>75.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Rock phosphate</td>
<td>85.0</td>
<td>69.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Acid phosphate</td>
<td>88.0</td>
<td>74.4</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Complete commercial fertilizer</td>
<td>85.0</td>
<td>74.7</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>76.5</td>
<td>62.7</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>76.5</td>
<td>66.4</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues</td>
<td>72.2</td>
<td>61.1</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+Rock phosphate</td>
<td>89.2</td>
<td>61.1</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+Acid phosphate</td>
<td>93.5</td>
<td>65.1</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+Complete commercial fertilizer</td>
<td>93.5</td>
<td>68.0</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>80.7</td>
<td>62.9</td>
</tr>
</tbody>
</table>

The results obtained on series II on this field are given in table XIII. Manure showed a large increase in the oats crop in 1918, but there was no additional effect from any of the fertilizing materials. The yield on plot 5, where acid phosphate was used, was evidently abnormal and should not be considered. In the crop residue system, plots 8 and 9 should be considered as checks and taking the average of the three check plots, it will be noted that the rock phosphate, acid phosphate and commercial fertilizer all gave distinct increases in crop yields. These materials showed an effect on oats when not applied with manure, but when the latter material was used, the effect was not evidenced. The yields of corn for 1919 very largely confirm those of the preceding year with oats. Again manure brought about a distinct increase, while the use of the other fertilizing materials had no additional value. On the grain system plots, the addition of acid phosphate and commercial fertilizer showed some effect, while none was evidenced with the rock.

THE STORM LAKE FIELD

This field was laid out in 1917 and the first treatments were made in the spring of 1918. The soil type on the field is the Webster silty clay loam. The results obtained on this field on Series I are given in table XIV. This soil was not acid in reaction, and no lime was applied. It is high in organic matter and manure causes the oats to lodge; hence, no manure was applied in 1918.

TABLE XIV. FIELD EXPERIMENT—STORM LAKE FIELD

Series I
Webster silty clay loam—Buena Vista county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre oats—1918</th>
<th>Bu. per acre corn—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>73.0</td>
<td>54.7</td>
</tr>
<tr>
<td>2</td>
<td>Manure*</td>
<td>73.0</td>
<td>54.1</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>73.0</td>
<td>57.6</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Rock phosphate</td>
<td>80.6</td>
<td>61.1</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Acid phosphate</td>
<td>74.5</td>
<td>66.4</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Complete commercial fertilizer</td>
<td>82.0</td>
<td>61.1</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>70.0</td>
<td>61.1</td>
</tr>
</tbody>
</table>

*No manure applied in 1918 to any of the plots. Regular application made in 1919.
yields of the first three plots are therefore checks. Rock phosphate gave an increase in the oats crop, acid phosphate showed little effect, and the commercial fertilizer showed a somewhat larger effect than the rock. In 1919, manure was applied to the proper plots, but showed slight influence on the corn. Rock phosphate, acid phosphate and commercial fertilizer gave distinct increases in corn yields, the acid phosphate showing up somewhat better than the other materials. These field experiments as a whole show the value of manure as a fertilizing material and the value of lime when soil is acid and they indicate distinctly that phosphorus fertilizers may be used to advantage on some of the soils of the county.

**PEAT SOILS**

Peat is partially rotted vegetable matter, which consists either of swamp grass, sedges, rushes and flags, or of sphagnum moss; the former variety is 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, because of the heavy, impervious character of the subsoil, lakes, ponds and marshes were formed and the formation of peat followed. It is mainly in the Wisconsin drift soil area, therefore, that peat occurs in Iowa.* Buena Vista county is located in this soil area and has several peat areas, altogether making a total of 640 acres or 0.2 percent of the total area of the county.

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 Buena Vista county is generally from 10 to 14 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

Analyses of numerous samples of peat soils 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 clay which forms the subsoils of practically all the shallow peats in Iowa. In Buena Vista county, there are no areas where the subsoil under the peat is not a black to drab, plastic clay. The char-

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acter 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 potassium, 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 easily occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Buena Vista county do not need the addition of commercial fertilizing materials to make them productive. Although they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be necessary and crops seem 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 Buena Vista county need to make them productive is the physical improvement resulting from drainage, cultivation and the growing of proper crops.

Drainage is the most important step. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying 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 re-laying 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, hence, the seed bed may be more thoroughly prepared. Deep plowing is also valuable, 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 of the peat are both much improved 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 the air and thus hasten decomposition.

Iowa peat soils which are not over 16 inches in depth should not be rolled, as such an operation may compact them too much and check 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 decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivation, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be 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 and 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 pro-
dutive and it is certainly advisable to attempt the utilization of the peat areas in Buena Vista county. With proper treatment and crop growth, they can be reclaimed.

THE NEEDS OF BUENA VISTA COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The field experiments in Buena Vista county reported in the preceding pages have not been under way long enough to permit definite conclusions regarding the real merits of various fertilizing materials. The results given however, are strongly indicative of the soil needs, especially as they are confirmed by the laboratory and greenhouse tests. The suggestions made relative to desirable treatments are based upon these indications and cannot at the present time be made absolutely definite. As soon as further data is secured in the field experiments, a more complete supplementary report will be made and definite recommendations will be given. The recommendations in the following pages are based not only upon the various tests reported in this bulletin, but also upon the practical experience of farmers. No definite suggestions are made which have not been proved to be of value by practical experience.

MANURING

The soils of Buena Vista county, with a few exceptions, are well supplied with organic matter and hence it would seem that manuring would not be of as great value as in some other counties. The experiments reported, however, and much practical experience indicate that the use of farm manure is very profitable. Even those types which are particularly well supplied with organic matter seem to respond to small applications of manure. In the case of the Carrington loam, the largest individual soil type, manure has shown special value, and the same is true in the case of the minor sandy soils. In some instances, manure proves of value when used at certain places in the rotation, while it may be injurious if applied at another time, for example, preceding the oats. In the Webster silty clay loam, manure often causes the oats to lodge. It should be used on this type following this crop and its value will be evidenced on the succeeding crop of corn. On newly drained land, the application of small amounts of manure proves especially valuable, in spite of the fact that such land is usually rich in organic matter. The influence of the manure in such cases is undoubtedly due to the stimulation of bacterial action and the consequently greater production of available plant food. Manure is evidently one of the most valuable fertilizing materials that can be used in Buena Vista county, and the proper preservation and application of all the manure produced on the farm is strongly to be urged if the fertility of the soils of the county is to be kept at the best.

Manure exerts a three-fold effect when applied to soils, due to its influence on their physical, chemical, and bacteriological conditions. It makes light, open soils more retentive of moisture, less open and porous and less apt, therefore, to lose valuable plant food by leaching. It improves the physical condition of heavy soils, opening them up and making them less impervious, less
retentive of excess moisture, and better aerated. In both cases, therefore, the physical condition of the soils is improved and this improvement is reflected in a greater production of available plant food and in greater crop yields.

The chemical effect of manure is due to the addition of plant food constituents. It contains a large portion of the elements removed from the soils by crops and subsequently supplied to the animals in their feed. The addition of these elements to the soil increases the total supply considerably, and exerts an important effect in lengthening the "life" of the soil. Manure contains large numbers of bacteria and, when these are introduced into the soil, there is an immediate increase in the production of available plant food, which is the result of bacterial activities. The large amount of organic matter in manure also has an effect on the bacterial activities in the soil, stimulating the development of these organisms and causing a greater production of available plant food. Manure may prove of value on soils because of any one of these effects, but in most cases, increased crop production resulting from its use is probably due to all three effects.

The value of manure in increasing crop production is so great that every care should be taken to prevent its losing any of its valuable properties before application to the soil. When stored in loose piles and exposed to the weather, there is a washing away of the liquid portion, which may remove 75 to 90 percent of the valuable constituents, and thus reduce the effect of the manure on crop growth. Manure may be stored in a covered yard or pit to keep it protected from the weather, or it may be cared for in some other way particularly adapted to individual farm conditions. No one method of handling manure is applicable to all conditions, but some one method should be chosen which will keep the manure moist, compact, well protected from the weather and as nearly unchanged as possible until it is applied to the soil. It is sometimes practicable to apply manure to the soil as it is produced, and then there is practically no loss. When manure is applied as produced or when it is properly stored before application, it may return to the soil 75 or 80 percent of the plant food removed by the crops grown.

The production of manure on the average farm is insufficient to permit of the application of excessive amounts, provided there is a uniform distribution over the farm. The usual application is about 8 to 10 tons per acre and while larger applications may be made in some cases, it is not advisable to apply more than 16 to 20 tons per acre for general farm crops.

Manure alone is insufficient, even on the livestock farm, to keep up the supply of organic matter and nitrogen, and some other means must be resorted to in order to provide these constituents. On the grain farm, very little manure is produced, and in such cases some substitute for farm manure must be employed. Green manuring is a practice which may be followed as a supplement to or a substitute for manuring. Legumes are usually employed as green manures, inasmuch as they have the ability when well inoculated of drawing a part of their nitrogen from the atmosphere. While they supply just as much organic matter as non-legumes, they also act as a nitrogenous fertilizer. Non-legumes may be used in special cases when the addition of organic matter is of chief importance, but usually, if organic matter is needed, nitrogen is also needed and some leguminous crop should be employed. Many legumes are
available for use under a wide variety of conditions and some one may be chosen which will fit almost any rotation. Green manuring may prove profitable on some of the lighter soil types in Buena Vista county, but it should not be practiced blindly or carelessly and it may not prove profitable on the heavier types. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The use of crop residues, such as straw and stover, is a third means by which the organic matter content of soils may be kept up. Often these materials are burned or otherwise destroyed. They may be used for feed or bedding in livestock farming and returned to the soil mixed with the manure, thus giving the greatest effect on the soil. On the grain farm, it is even more important that the residues be applied to the soil, as there is little addition of manure. They may be applied directly, as is now being practiced in some cases, or they may be allowed to decompose partially before application. In any case, however, the crop residues should be carefully returned to the soil, as they form a valuable supplement to the manure or a partial substitute for that material. They not only add organic matter, but they supply considerable plant food. The physical and chemical effects of these materials frequently bring about considerable increases in crop production.

THE USE OF COMMERCIAL FERTILIZERS

Analyses of the soils of Buena Vista county show that the supply of phosphorus is not large and hence it might be expected that phosphorus fertilizers would prove of value in many cases now. At all events, they will undoubtedly be needed in the future.

The greenhouse experiments and the field experiments reported in the preceding pages on the three most important upland types, indicate that phosphorus fertilizers may be used profitably at the present time. These experiments are not sufficiently complete, however, to permit of very definite conclusions. Thus it is not possible to choose the phosphorus carrier which should be used where there is evidence of need for that element. In some instances, acid phosphate gives the best results, while in others rock phosphate has some advantages, and sometimes the complete commercial fertilizer gives the largest crop increases. The differences in most cases between the results secured with these materials are not great enough so that a selection can be made. It may be safely concluded, however, that much of the soil in Buena Vista county would probably respond to phosphorus fertilization and farmers are urged to test the value of phosphorus fertilizers on their own soils.

Acid phosphate is more expensive than rock phosphate, but it contains phosphorus in an available form, and gives a much larger immediate supply. Rock phosphate, on the other hand, must be used in considerably larger amounts and the rate of availability is rather low. In determining the real value of these two materials, therefore, the expense involved in the application should be taken into account and the actual economic return on the money invested should be determined. It is a comparatively simple matter to test these materials on the farm. Directions which any farmer may follow are given in Circular 51 of the Iowa Agricultural Experiment Station. If one of these phosphorus fertilizers shows profit on a small area, then that material may be
used on a large area with assurance of economic returns and without fear of injury to the soil.

The nitrogen content of Buena Vista county soils is not in general especially low. In most cases, indeed, the soils seem well supplied with this constituent. The amount present, however, is not sufficient to warrant disregarding this element in planning systems of permanent fertilization. Farm manure and crop residues return large amounts of this element to the soil, but in spite of their use, the nitrogen content will gradually decrease unless some nitrogen-containing fertilizer is employed.

Well-inoculated legumes used as green manures serve most efficiently in supplying nitrogen. No rotation is satisfactory unless it contains a legume and the growth of such a crop is never of most use unless it is well inoculated. To increase the nitrogen content of the soil by means of legumes, either the entire crop must be turned under as green manure, or else a large portion must be plowed under, only a part of the crop being removed. For example, removing of the seed only from a clover crop which has been well inoculated, still leaves some nitrogen for addition to the soil. Well inoculated legumes may be used as catch crops in almost any rotation.

Commercial nitrogenous fertilizers are very expensive and their use can hardly be recommended at the present time for ordinary crops. They may be used in small amounts as top dressings to encourage early growth, but as a general rule it is not believed that their application in Buena Vista county would yield economic returns. If such materials prove of value, however, according to small scale tests, they may be used without fear of injury to the soil.

The potassium content of the soils of the state has been found by previous analyses to be high and it seems hardly likely that this element will be needed on Buena Vista county soils for many years to come. If the soils are kept in the best physical condition, if they are well drained and cultivated and if the supply of organic matter is adequate, bacterial activities should go on at a satisfactory rate and available potassium should be produced rapidly enough to keep crops supplied. Small amounts of potassium fertilizers may be used as top dressings to stimulate the early growth of some crops, but the use of extensive applications for general farm crops cannot be recommended at the present time. As noted in the case of nitrogenous materials, however, if a potassium fertilizer proves of value on a small area, that material may be applied to a large area without fear of injury to the soil.

Complete commercial fertilizers are being tested in the field experiments reported earlier and it will be noted that increases are secured in some cases from the use of these materials, but in general, the phosphorus fertilizers show quite as satisfactory results. It would seem, therefore, that complete brands of fertilizers which supply not only phosphorus, but also nitrogen and potassium, would hardly prove as profitable as the phosphate materials, especially if leguminous crops are employed to supply nitrogen and the soil treatment is such that the best production of available potassium is kept up. Complete brands of commercial fertilizers may easily be tested on the farm and such materials may readily be compared with phosphorus fertilizers. If any particular brand gives profitable increases on a small area, it may then
be used satisfactorily on a large area. It should be emphasized that there is no objection to the use of complete commercial fertilizers if they prove more profitable than a phosphorus carrier.

LIMING

Some of the soils of Buena Vista county are acid and therefore in need of lime. In most cases, the acidity in the surface soil is not large, but in a few cases the soils are apparently rather acid. The lower soil layers of the acid types in the county are in general acid in reaction also. There are one or two exceptions to this rule, as for example, the steep phase of the Carrington loam, the O'Neill fine sandy loam and in some areas in the Carrington loam. In most cases the needs of the surface soil indicate quite definitely the lime requirements of the soils to a depth of 40 inches. Even where lime is present in the lower layers, the material should be applied if the surface soil is acid, inasmuch as there is very little movement of lime upward in the soil. The soils of Buena Vista county should evidently all be tested for acidity.

Soils vary widely in reaction and the average needs of the soils of the county as given in the tables should not be taken to show definitely the type needs. Tests should be made on every farm and the need of the particular soil for lime accurately determined. Farmers may test their own soils for acidity, but it will probably be more satisfactory if they will send a small sample to the Soils Section and have it tested free of charge.

Practically all crops make the best growth when the reaction of the soil is basic and lime should be used whenever the reaction has become acid. Furthermore, when cultivated, all soils tend to lose their supply of bases and lime must be applied at regular intervals if the supply is to be kept up. Legumes are particularly sensitive to acid conditions and the beneficial effects of liming are usually very evident on such crops.

The influence of liming in increasing crop growth has been shown in some of the experiments given in the previous pages and there is abundant evidence from the practical experience of many farmers showing profit from the use of lime on acid soils. Corn and small grain crops ordinarily are not expected to be influenced to any large extent by liming, but in many cases the yields of these crops are increased considerably. Liming is profitable, however, even if its effect is shown only on the legume crop in the rotation.

DRAINAGE

Many of the soils in Buena Vista county are in need of drainage. Among the upland types, the Webster silty clay loam and the Webster silt loam are both poorly drained. The bottomland types, with the exception of the Wabash silt loam, are all very much in need of thorough drainage if crop production is to be satisfactory. These latter types are subject to overflow and are not only in need of drainage, but of protection from overflow, if they are to be made satisfactorily productive. The installation of tile drains and ditches is very necessary on these poorly drained types. It is the first treatment needed to make the soils productive and to insure satisfactory crop yields. In those cases where tile has been installed, the value of the crop increases has more than paid for the cost of installation, for these soils are naturally highly pro-
ductive. It may be said in general that any soil in Buena Vista county which is not properly drained should be tiled if the best crop yields are to be secured.

THE ROTATION OF CROPS

The results of many experiments and of much farm experience have clearly demonstrated the fact that the continuous growing of any one crop is much less profitable in the long run than the rotation of crops. The decrease in yields from year to year under continuous cropping is so great that the actual income from the land is less than when a rotation is followed, even tho the crop grown is a so-called money crop, such as corn. If the soil is to be maintained in a continuously fertile condition, it is absolutely necessary that a rotation of crops be followed.

While no special rotation experiments have been carried out in Buena Vista county, several rotations may be listed here which have proved quite satisfactory throughout the state and from among these, one may be chosen which will be suitable for use in the county. Modifications of these rotations may be made as seems desirable and, indeed, almost any rotation will be satisfactory, provided it contains a legume and includes the most profitable crops.

1—FOUR OR FIVE-YEAR ROTATION

First year—Corn.
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).

Fig. 8. Natural grass on peat land
THE PREVENTION OF EROSION

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

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

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

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

In Buena Vista county, erosion is not of great importance, most of the upland having a rather level topography, not subject to much washing. The steep phase of the Carrington loam is the only type which is badly eroded, and much
of this type is so steep that it should undoubtedly be kept in pasture. In the
cultivated portion, however, precautions are very necessary to prevent the
extensive washing away of the soil. The formation of gullies in any of the
other types, particularly the typical Carrington loam, should also be prevented
and while these do not occur to any considerable extent, when they are found,
some one of the methods described should be employed to reclaim the eroded
area.

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

EROSION DUE TO DEAD FURROWS

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

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

"Staking In." The method of "staking in" is better as it requires less work
and there is less danger of washing out. The process consists of driving in
several series of stakes across the gully and up the entire hillside at intervals of
from 15 to 50 yards, according to the slope. The stakes in each series should be
placed three to four inches apart and the tops of the stakes should extend
well above the surrounding land. It is then usually advisable to weave some
brush about the stakes, allowing the tops of the brush to point up-stream. Ad­
titional brush may also be placed above the stakes, with the tops pointing up­
stream, permitting the water to filter thru, but holding the fine soil.

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

SMALL GULLIES

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

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

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

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

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

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

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

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

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

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tilling may be the only method necessary for reclaiming useless bottomland.

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

HILLSIDE EROSION

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

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and for this reason it proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw, corn stalks, etc., may also be

Fig. 9. The steep phase of the Carrington loam is often subject to serious erosion
turned under to increase the organic matter content. Any means employed to increase the organic matter content of soils will usually have an important influence in preventing erosion.

Growing of Crops. The growing of perennial crops, such as alfalfa, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable in such locations. The root system of such crops holds the soil together and the washing action of rainfall is reduced to a marked extent.

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

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

INDIVIDUAL SOIL TYPES IN BUENA VISTA COUNTY*

DRIFT SOILS

There are five drift soil types in Buena Vista county and these, with the steep phase of the Carrington loam, make up six drift areas in the county.

CARRINGTON LOAM*

The Carrington loam is the largest individual type, as well as the largest drift soil. It covers 168,448 acres or 46.0 percent of the total area of the county. It occurs extensively on the better drained upland in the eastern three-quarters of the county. The line of separation between the Carrington loam and the silt loam runs diagonally across the county from the northwest to the middle southern boundary, following the course of Brooke creek a large part of the way, then passing just east of Storm Lake and south to the county line. It is largely broken into small areas by the level, poorly drained, Webster silty clay loam and there are no individual extensive areas of the type. Within this type there are included small areas of what is now known as the Clarion loam, a soil very much like the Carrington, except that there is some lime in the subsoil. These areas are too small to show on the map.

*The descriptions of the individual soil types given in the Bureau of Soils report have been rather closely followed in this section of the report.
The surface soil of the Carrington loam is a dark brown to black, mellow, friable loam, extending to a depth of 12 to 14 inches. The subsoil to a depth of 36 inches is a heavy loam to light silty clay loam, yellowish-brown to light brown in color, occasionally mottled with rusty brown and gray. Gravel occurs throughout the three foot section, generally to a greater extent in the subsoil than in the surface soil. In places, large boulders are found on the surface. The surface soil of the type varies somewhat in texture, ranging from almost a silt loam to a loam so sandy as to constitute almost a fine sandy loam. On the more gradual slopes, it is closer to a silt loam in texture, varying but slightly from the Carrington silt loam. East of the Coon river in the eastern parts of Lincoln and Grant townships and the western parts of Fairfield and Coon townships, there are several areas of a fine sandy loam, varying in size from a fraction of an acre to about three acres. Owing to their small extent, these areas are not separated from the Carrington loam. In the southwest corner of Lee township, the type is so closely associated with the Webster silty clay loam that small areas rather heavy in texture, approaching a clay loam, are included. In the central portion of Fairfield and Grant townships, the boundary lines between the Carrington and the Webster soils were located with considerable difficulty and must be considered more or less arbitrary.

In topography, the Carrington loam is gently rolling to rolling, occupying in some places almost steep slopes. The drainage of the type is entirely adequate; in fact, in some small areas the soil is inclined to be somewhat drouthy. Occasionally the soil on the more rolling areas is subject to considerable washing.

About 85 to 90 percent of the Carrington loam is under cultivation, the remainder being occupied by farm buildings, wind-breaks and feed lots or temporary pasture. Corn is the chief crop grown and yields of 25 to 55 bushels per acre are secured. Oats are also grown extensively, yielding from 30 to 50 bushels per acre. Timothy and clover are the chief hay crop and yield 1 to 1 1/2 tons per acre. Alfalfa is produced to a small extent and yields 2 1/2 to 3 1/2 tons per acre.

The needs of the Carrington loam to make it more productive and keep it in the highest state of fertility, are the addition of organic matter, the application of lime and probably in most cases, the use of a phosphorus fertilizer. The soil is generally rather acid in reaction and should always be tested, especially before seeding to a legume, and if acid, the proper amount of lime should be applied. The supply of organic matter in the soil is not extremely low, but neither is it high, and the application of farm manure in as large amounts as practicable is extremely desirable. The tests given in this report and the results of much farm experience show very clearly the value of farm manure on this type. No other fertilizing material proves as profitable and, indeed, it is probable that other materials would not prove of value unless proper applications of farm manure were made. Where the production of manure is inadequate, green manuring should be practiced and leguminous crops should be used in order to supply not only the needed organic matter but also to keep up the nitrogen content, which is not high. For the latter purpose, legumes in the rotation are desirable. Crop residues should be utilized as a means of maintaining the organic matter content of the soil. The experiments
on the Carrington loam have indicated the value of phosphorus fertilizers and, while it is not yet possible to choose the particular material which should be applied, farmers are urged to test the value of rock phosphate on their farms. Any areas of this type which are poorly drained should be tiled, if crop production is to be satisfactory. In many places where gullies have been formed, some method should be employed to prevent their extension and also to fill them.

CARRINGTON LOAM (Steep phase) (57)

This phase of the Carrington loam is of minor importance, occupying 9,216 acres or 2.6 percent of the total area of the county. It occurs chiefly in the northwest part of the county, along the slopes to the Little Sioux river and its tributaries. There is one small, isolated area along Boyer creek.

The surface soil of this type is a dark brown to black, friable loam, extending to a depth of 10 to 14 inches. The subsoil is a yellowish-brown loam, becoming mottled with gray and rusty brown in the lower depths and grading gradually into a clay loam, which at 32 inches becomes a silty clay loam to silty clay. Numerous pebbles are found in the soil and boulders are of frequent occurrence on the surface. Lime is sometimes present in the subsoil, in which case the soil is really Clarion loam (steep phase). In some areas where the erosion has been excessive, the surface soil is very thin and even entirely removed in places.

The topography of this type, as indicated by the name, is sharply rolling to broken and the soil is subject to considerable washing. The drainage is ordinarily adequate. Less than 5 percent is under cultivation. About one-half of it is forested, principally with bur oak, soft maple, elm, basswood and red oak. Corn is the crop usually grown on the cultivated portion and the yields are about the same as those secured on the typical Carrington. Most of the type is used for pasture and provides a satisfactory growth of pasture grass. The needs of this type to make the cultivated portions more productive, are practically the same as those mentioned for the typical Carrington. The topography is so steep that the greater portion must inevitably remain in pasture. When cultivated, however, the chief precaution to be observed in securing good crop growth is the prevention of erosion.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the second most extensive individual soil type, occupying 101,760 acres, or 27.8 percent of the total area of the county. It covers the greater portion of the upland in the western one-fourth of the county and is also found in the north central portion along the gentler slopes to the Little Sioux river.

The surface soil is a dark brown to black, friable silt loam to a depth of 12 to 16 inches. The subsoil is a yellowish-brown, friable silt loam, becoming somewhat lighter in color and heavier in texture in the lower portions. The lower subsoil is frequently a silty clay loam, but in some areas it is very different from the upper subsoil. Grayish mottlings are usually found below 20 inches. Some gravel is found in the three-foot section and boulders are occasionally found on the surface. A few gravel pockets occur, but they are of no practical importance. The occurrence of gravel and boulders is very much less than in the Carrington loam. In some places lime occurs in the subsoil
and the soil is Clarion silt loam. The areas of this nature, however, are too small to separate.

In topography, the Carrington silt loam is undulating to gently rolling. Drainage is ordinarily entirely sufficient and the soil is not drouthy.

About 90 to 95 percent of the type is under cultivation, the chief crops grown being corn, oats, timothy and clover. Corn yields 40 to 55 bushels per acre, oats, 40 to 50 bushels, timothy and clover, 1½ tons per acre. Potatoes are grown to some extent in local areas, as for example near Alta, and highly satisfactory yields are secured. Alfalfa is well suited to this soil and yields of four tons per acre are secured. The acreage devoted to this crop is small at present, however.

The Carrington silt loam is measurably productive, but proper soil treatment will undoubtedly bring about larger crop growth. The soil is generally acid in reaction and should be tested and the proper amount of lime needed should be applied. While the soil is not low in organic matter, applications of farm manure are distinctly profitable and this material should be applied in as large amounts as practicable. The nitrogen supply should be maintained by the proper use of legumes and the application of phosphorus fertilizers will undoubtedly prove of value in most cases.

WEBSTER SILTY CLAY LOAM (107)

This is the third largest soil type, covering 57,556 acres or 15.7 percent of the total area of the county. It is distributed over practically all of the county, being associated with the Carrington loam and with the silt loam, the two largest upland types. It occupies the level to undulating, flat or depressed areas and, these areas being less common in the Carrington silt loam, there is a smaller occurrence of the Webster silty clay loam in the western part of the county.

The surface soil is a black, silty clay loam, extending to a depth of 12 to 14 inches, then passing into a dark brown to black silty clay loam to silty clay. Below 18 to 20 inches, gray, yellowish-brown and rusty brown mottlings are of frequent occurrence. Gravel and boulders are occasionally found throughout the soil. The subsoil is calcareous. Within this type there are areas of Webster silt loam and Carrington loam which are too small to show on the map. Occasionally in some of the smaller areas and along the boundaries of other areas, the typical gray color of the subsoil is replaced by a drab color and the yellowish-brown and rusty brown are lighter. Below 24 inches in these areas, the color is generally mottled yellowish-brown and gray.

The topography of the type is gently undulating to flat and formerly it was under water for a considerable part of the year. The drainage is very poor and the installation of tile and the providing of open drainage ditches are absolutely essential to make the soil suitable for crop production.

About 75 percent of the Webster silty clay loam has been drained and is now under cultivation, the remainder of the type being in pasture. Corn, hay and oats are the chief crops grown, corn yielding 30 to 50 bushels, hay 1½ to 2 tons and oats 20 to 40 bushels per acre. This soil is highly productive when thoroughly drained and the careful and thorough installation of tile is the most important treatment needed. It is high in organic matter and nitrogen, but will
respond to small applications of farm manure. It is well supplied with lime in most cases and does not need the use of this material. The phosphorus content, however, is rather low and phosphorus fertilizers will undoubtedly prove of value.

**WEBSTER SILT LOAM (113)**

The Webster silt loam is of small occurrence in the county, occupying 7,232 acres or 2 percent of the total area. It is found mainly in the eastern part in numerous more or less isolated level areas of irregular shape and varying size. The greatest development of the type is in the southern part of Lee township. Evidently before the installation of drainage ditches and tile, this type was often under water for a portion of the year. By drainage, however, practically all of it has been brought under cultivation.

The surface soil is a black, friable, silt loam, 12 to 14 inches in depth. The subsoil is a black, silty clay loam, which at 18 to 20 inches becomes a silty clay, mottled with gray and in some cases with yellowish-brown and rusty brown. Gravel is frequently found throughout the soil and subsoil, and the subsoil usually contains lime. Within this type there are included very small areas of the Webster silty clay loam, Carrington loam and muck, which cannot be shown separately.

The topography of the Webster silt loam is level to depressed and the drainage is very poor. Artificial drainage is the first treatment needed to bring this soil under cultivation.

The greater part of the type is now cultivated, common farm crops being grown. Corn yields 25 to 50 bushels per acre, clover and timothy 1 to 2 tons and oats 35 to 60 bushels. The remainder of the type is in pasture.

This soil is well supplied with organic matter and nitrogen, and it is usually not acid in reaction. The particular sample tested in this work, however, showed acidity, indicating that the type should be tested for acidity and lime should be applied as needed. As the phosphorus supply is low, phosphorus fertilizers will undoubtedly yield profitable returns in the future and there is strong probability that they will be of value at present. When this soil is properly drained, it is highly productive and with the application of small amounts of farm manure and the use of phosphorus fertilizers, no difficulty should be experienced in keeping it permanently fertile.

**CLYDE SAND (114)**

This type is of very minor importance, covering only 64 acres or approximately 0.1 percent of the total area of the county. Three small areas of this type are mapped near Storm Lake, the largest occurring on the west side of the lake, separating the lake proper from the marsh to the west. The second area occurs between the lake and the small marsh just west of Casino. The third area is an island southwest of the city of Storm Lake.

The surface soil is a brown, medium sand, mixed with some gravel, and extends to a depth of 10 to 14 inches. The subsoil is of the same texture and slightly lighter in color. None of the land is under cultivation.

**TERRACE SOILS**

There are two terrace types in the county, both belonging in the O'Neill series, together covering only 1920 acres or 0.5 percent of the total area.
The O'Neill loam is the largest of the two terrace types, occupying 1600 acres or 0.4 percent of the total area of the county. It occurs on the terraces of the Little Sioux river in the northern part of the county, the largest area being found across the river, west of Sioux Rapids.

The surface soil is a dark brown, loose, friable loam, extending to a depth of 12 to 14 inches. The subsoil is a brown loam, which, at about 18 inches, changes to a yellowish-brown, fine, sandy loam. At 28 to 30 inches it becomes a sandy loam. Gravel occurs throughout the surface and subsoil. Within this type there are included two small areas of O'Neill silt loam which are too small to be mapped separately. The surface soil in this included area is a dark brown, friable silt loam, extending to a depth of 16 inches. The subsoil is a brown, heavy silt loam to silty clay loam, the color in the lower subsoil becoming a yellowish-brown. Some gravel is found throughout the three-foot section, but the typical gravel layer of the O'Neill series is found below the three-foot section and the type is therefore less subject to drought. The total acreage of this silt loam amounts to about 70 acres and it occurs on the higher level terraces adjoining the upland.

In topography this type is level to gently rolling. It occurs on the level terraces and also on the slope between terraces, or between the first bottom and the terraces. The soil is apt to be dry, owing to the open character of the subsoil.

Practically all of the O'Neill loam is under cultivation, corn being the chief crop grown. Yields of 25 to 45 bushels per acre are secured. Some hay and oats are grown also. This soil is in need of organic matter, nitrogen, phosphorus and lime to make it more productive. The use of organic matter is particularly desirable in order to permit of the retention of moisture. The soil is acid and needs lime; it is low in phosphorus and should receive applications of phosphorus fertilizers. The nitrogen supply is not abundant and the use of leguminous green manures would be very desirable.

The O'Neill fine sandy loam is of very minor importance, occupying only 320 acres or 0.1 percent of the total area. It occurs in five small areas in the northern part of the county along the Little Sioux river.

The surface soil is a brown, sandy loam extending to a depth of 9 inches, below that point grading into a yellowish-brown, fine sandy loam. Below 16 inches, the subsoil becomes more sandy and the color somewhat lighter.

In topography this type is level to gently rolling and the drainage is thorough; in fact, in dry seasons crops are subject to injury by drought.

All of the soil is under cultivation, the ordinary farm crops being grown. Corn yields 25 to 40 bushels per acre, oats, 20 to 30 bushels and timothy and clover, 1 to 1½ tons.

This type is in need of the application of organic matter and nitrogen, the use of phosphorus and the addition of lime, to make it more productive. Farm manure should be used in as large amounts as practicable and leguminous green manures would be of value. The application of phosphorus fertilizers would also probably yield profitable returns.
SWAMP AND BOTTOMLAND SOILS

There are five swamp and bottomland types, belonging to the Wabash and Lamoure series, and including areas of muck and peat. The total area occupied by these soils is 19,264 acres or 5.3 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland type, covering 11,328 acres or 3.1 percent of the total area. It occurs in all parts of the county along the bottoms of the larger streams. The largest development is along the Little Sioux river, but there is considerable bottomland of this type along the Coon river and also in the southwest part of the county.

The surface soil is a black, friable, silt loam 14 inches in depth. The subsoil is a black, heavy, silt loam which at about 28 inches becomes a silty clay loam. In topography the type is level, but the drainage is generally good.

Areas of the type along the Little Sioux river are under cultivation, but elsewhere the type is used almost entirely for pasture. Some of the uncultivated portions along the Little Sioux river are forested with red oak, soft maple, and elm. Corn is the chief crop grown in the cultivated areas and yields 35 to 50 bushels per acre. Hay is produced to some extent, yielding 1 to 2 tons per acre, and some small grains are grown. This type is chiefly in need of protection from overflow to make it more satisfactorily productive. It is acid in reaction and needs liming. It is low in phosphorus and some phosphorus fertilizers should undoubtedly be applied. The application of farm manure or the use of leguminous green manures will be needed from time to time to keep up the supply of organic matter and nitrogen.

WABASH SILTY CLAY LOAM (48)

This is the second most extensive bottomland type, covering, however, less than one-half as large an area as the silt loam. It is found on 5,312 acres or 1.5 percent of the total area. It occurs in the first bottoms of many of the smaller streams, the greatest development of the type being in Elk township along Maple creek and Brooke creek. It is also found near Storm Lake and in small areas in other parts of the county.

The surface soil is a black, silty clay loam to a depth of 11 inches. The subsoil is a black, heavy clay loam to silty clay, which becomes heavier with increasing depth. The type is level in topography and the drainage is fair. It is subject to overflow. Practically all of the soil is used for pasture or hay land, the native grasses or timothy being the important hay crops. Yields of 1 to 1½ tons per acre are secured. This type, too, is in need of better drainage and protection from overflow to make it more productive. It is also acid and in need of lime. Phosphorus fertilizers would be of value and small applications of farm manure or the use of green manures should be employed to keep up the nitrogen and organic matter supply.

MUCK (21a)

There is a small acreage of muck in the county, amounting to 1,216 acres or 0.3 percent of the total area. It occurs chiefly in the eastern part, altho there
BUENA VISTA COUNTY SOILS

are three small areas in the northwest corner and one area about five miles southwest of Rembrandt. The largest area is what was known as Grassy Lake, about 5 miles southeast of Sioux Rapids.

The surface soil of this muck is a black, light, fluffy material, extending to a depth of about 10 inches. It is composed of 15 to 35 percent of organic matter, a small amount of very fine sand and the remainder is silt and clay. At about 12 inches the soil becomes a dark brown to black silty clay loam which changes at 30 inches to a silty clay. At the same depth, yellowish-brown and gray mottling becomes prominent. A few areas of the Webster silt loam and silty clay loam, too small to be mapped separately, are included within this type. Muck occupies level to slightly depressed areas.

Practically all of the area in this soil is now drained and in cultivation. Corn is the chief crop grown, yields of 25 to 50 bushels per acre being secured. It is chiefly in need of adequate drainage to make it productive.

LAMOURE SILTY CLAY LOAM (111)

This is a minor soil type, occupying only 768 acres or 0.2 percent of the total area. It occurs on the bottoms along a few of the smaller streams. The largest area is found along the Coon river just above the southern county line. Smaller areas are found scattered throughout the county.

The surface soil is a black, silty clay loam and the subsoil is also a black, silty clay loam, changing at 16 inches to a silty clay. Lime is present in both the surface and subsoil in considerable amounts. A few areas of Lamoure silt loam, Wabash silt loam and Wabash silty clay loam, too small to be mapped separately, are included in this type. In the areas along Coon river, the subsoil is somewhat mottled with gray and resembles the Webster silty clay loam.

The largest area of the type along Pleasant Lake is the only one under cultivation and it is devoted to corn. The remainder of the type is used for hay or pasture. The soil is well supplied with organic matter and nitrogen and is high in lime; hence, the only treatment needed might possibly be phosphorus. It must be thoroughly drained and protected from overflow before crop production will be satisfactory.

PEAT (21)

Peat occurs to a small extent, covering 640 acres or 0.2 percent of the total area. It is found only in three areas, the largest covering what was formerly known as Grassy Lake. The second area, much smaller in extent, is found along the southern edge of the county, south and east of Juniata, and the third area is found five miles southwest of Rembrandt. There are several areas on the map which are indicated as peat, but include swamp symbols. These areas are at present under water and the character of the material is supposed to be peat.

The surface soil of peat to a depth of 10 to 14 inches is composed of over 35 percent of black organic matter, much of which is undecomposed. The remainder is made up of a mixture of very fine sand, silt and clay. The surface soil grades into a silty clay, which gradually becomes heavier. Below 24 inches, yellowish-brown and gray mottlings occur, and below 30 inches the gray color predominates.
Practically all of the typical peat mapped is under cultivation, corn being the chief crop grown. Yields of 25 to 50 bushels per acre are secured. Oats are grown only to a small extent and do not prove very satisfactory.

The chief need of these peat areas, as indicated in the section of this report dealing with peat soils, is for thorough drainage. This must be accomplished before any crop production can take place. Following drainage, some little time is necessary before satisfactory yields of corn and small grains can be secured. Fall plowing and deep plowing are recommended to aid in the decomposition of peat soils. Frequent cultivation is also of value. Timothy and alsike clover is probably the best crop to grow on newly reclaimed peat land. This crop may be used for hay or pasture. Vegetables such as onions, celery, tomatoes, etc., also give excellent yields on peat soils. With thorough drainage and proper plowing and cultivation, the growth of these crops for several years will put the soil in satisfactory condition to permit of the growing of corn and small grains.
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

Fig. 10. Map of Iowa showing the counties surveyed
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 fer­
tility and the character, needs and treatment of Iowa soils, gathered from various pub­
lished 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 prac­
tically 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 micro­
scopic 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 suffi­
cient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether suffi­
cient green manure or barnyard manure has been applied to the soil. Commercial nitro­
genous 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 of 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 of 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 proved 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 ele­
ments 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 is 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, altho 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 growth 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.
SOIL SURVEY OF IOWA

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 Plant Food</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></td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td></td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats, crop</td>
<td></td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley, crop</td>
<td></td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye, crop</td>
<td></td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>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>

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 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 plant food loss.

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 percent of the corn and 35 to 40 percent 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 very quickly becomes deficient in certain necessary plant foods. Evidently, however, all soils are depleted in essential food materials, whatever system of farming is followed.

The 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.
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, there is abundant evidence at hand to prove that the best possible yield 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 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 of 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 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 drouth by thorough cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

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

The loss of moisture by evaporation from soils during periods of drouth 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.

*Bulletin 150, Iowa Agricultural Experiment Station.*
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 rotation. 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 amount of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

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

**MANURING**

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

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

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

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best method of treatment and storage, 15 percent 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 materials 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 different conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

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

**LIMING**

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions 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 map, fig. 11.

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 today, 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 in the time which has elapsed since its formation.

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

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

THE SOIL SURVEY BY COUNTIES

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

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:

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

<table>
<thead>
<tr>
<th>Inorganic matter</th>
</tr>
</thead>
</table>
| The 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.

*25 mm. equals 1 in. †Bur. of Soils Field Book. ‡Lee, el.
Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

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

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

Silt Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

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

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravel—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS 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 the field party must first 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.