IOWA AGRICULTURAL EXPERIMENT STATION

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9 Amino Acid and Acid Amides as Source of Ammonia in Soils.*  
11 Methods for the Bacteriological Examinations of Soils.*  
13 Bacteriological Studies of Field Soils, III.*  
17 The Determination of Ammonia in Soils.  
18 Sulfonation of Soils.  
25 Bacterial Activities and Crop Production.  
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35 Effects of Some Manganese Salts on Ammonification and Nitrification.  
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66 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.

SOIL REPORTS

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SOIL SURVEY OF IOWA
Report No. 18--WAPELLO COUNTY

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

The Lindley loam is found covering the slopes of many of the streams of the county.
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WAPELLO COUNTY SOILS*

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

Wapello county is located in southeastern Iowa in the second tier of counties north of the Missouri state line and in the fourth tier west of the Mississippi river. It is entirely within the Mississippi loess soil area and practically all of its soils are loessial in origin.

The total area of the county amounts to 428 square miles, or 273,920 acres. Of this area, 235,881 acres or 86.1 percent is in farm land. The total number of farms is 1,818 and the average size is 128.6 acres. The following figures from the Iowa Yearbook of Agriculture for 1918 show the utilization of the farm land of the county:

<table>
<thead>
<tr>
<th>Description</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in general farm crops</td>
<td>118,147</td>
</tr>
<tr>
<td>Acreage in pasture</td>
<td>96,474</td>
</tr>
<tr>
<td>Acreage in farm buildings, feed lots and public highways</td>
<td>7,806</td>
</tr>
<tr>
<td>Acreage in waste land</td>
<td>3,188</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>8,258</td>
</tr>
</tbody>
</table>

General farming is the type of agriculture followed most extensively in Wapello county. The feeding of cattle is an important industry, however, and constitutes one of the main sources of farm income. Hog raising is also very important and the raising of sheep is practiced to some extent. Dairying is of minor importance. Hay and grain are the chief crops grown and considerable amounts, particularly of corn, are sold out of the county. There are some commercial apple orchards and fruit growing is a rather important industry. Some cherries are grown to supply the home markets. Grapes, strawberries, raspberries and blackberries are also produced to a small extent.

The area in waste land in the county is considerable and some method should be chosen for reclaiming it. No one method is suitable for all conditions, inasmuch as the causes of infertility are various. Special treatments needed to make the various soil types more productive are considered in a later section of this report. Advice regarding the treatments necessary in special cases may be obtained from the Soils Section of the Iowa Agricultural Experiment Station upon request.

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Average Yields</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>33 bushels</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Corn is by far the most important crop, both in acreage and value, almost one quarter of the farm land of the county being devoted to this crop. Average yields of 33 bushels per acre are secured. Much of the corn produced is sold, but considerable amounts are used for feeding purposes and a large part of the crop is cut for ensilage. The practice of hoggning-down corn is followed to some extent and sometimes rape or cowpeas are sown in the corn at the last cultivation.

*See soil survey of Wapello county by E. C. Hall, of the United States Department of Agriculture, and E. I. Angell, of the Iowa Agricultural Experiment Station.
TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN WAPELLO 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>54,724</td>
<td>23.2</td>
<td>33.5</td>
<td>1,833,851</td>
<td>$1.23</td>
<td>$2,255,636</td>
</tr>
<tr>
<td>Oats</td>
<td>24,274</td>
<td>10.3</td>
<td>41.5</td>
<td>1,008,049</td>
<td>0.64</td>
<td>645,151</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>8,184</td>
<td>3.4</td>
<td>20.4</td>
<td>166,751</td>
<td>1.99</td>
<td>331,834</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>2,456</td>
<td>1.0</td>
<td>19.5</td>
<td>47,823</td>
<td>2.02</td>
<td>96,502</td>
</tr>
<tr>
<td>Barley</td>
<td>493</td>
<td>0.2</td>
<td>27.7</td>
<td>13,549</td>
<td>0.88</td>
<td>12,050</td>
</tr>
<tr>
<td>Rye</td>
<td>868</td>
<td>0.4</td>
<td>16.1</td>
<td>14,007</td>
<td>1.48</td>
<td>20,730</td>
</tr>
<tr>
<td>Hay (tame)</td>
<td>26,482</td>
<td>11.2</td>
<td>1.0</td>
<td>25,926</td>
<td>19.57</td>
<td>507,371</td>
</tr>
<tr>
<td>Hay (wild)</td>
<td>10</td>
<td>.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>120</td>
<td>.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>548</td>
<td>.23</td>
<td>83.7</td>
<td>45,719</td>
<td>1.32</td>
<td>60,349</td>
</tr>
<tr>
<td>Pasture</td>
<td>96,474</td>
<td>40.9</td>
<td></td>
<td>14,801</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>.......</td>
<td>.......</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Oats is second to corn in importance in the county and average yields of 41 bushels per acre are secured. In many cases the yields of this crop are very much larger, depending mainly upon seasonal conditions. Much of the oats produced is sold off the farms, but a large part is used for feeding.

Hay is grown on a considerable acreage, the crop consisting chiefly of timothy and clover mixed. Some clover is grown alone and, in a few cases, timothy is grown alone. Most of the hay produced is used for feeding purposes, but some is sold out of the county. Frequently the clover is used for pasturing purposes the first year, and the second year, the first cutting is used for hay and the second for seed. There is only a small production of wild hay.

Wheat is the fourth crop in acreage and value in the county and both the spring and winter varieties are grown. Winter wheat is produced much more extensively, however, than is spring wheat. Average yields of 20 bushels per acre of the former are secured. Practically all of the wheat produced is sold, altho in some instances only sufficient is grown to supply the home demand.

Potatoes are grown on a rather large area and average yields of 83 bushels per acre are secured. The value of this crop is considerable. Other vegetable crops are produced on practically all farms for home use.

Barley and rye are grown to some extent. Alfalfa is grown on small areas and produces quite satisfactory yields. It is probable that this crop will be grown more extensively as it becomes better known.

The character and extent of the livestock industry in the county are shown in the following figures taken from the Iowa Yearbook of Agriculture for 1918:

- Horses (all ages): 9,233
- Mules (all ages): 852
- Swine (on farms July 1, 1918): 52,609
- Cattle (cows and heifers kept for milk): 8,246
- Cattle (other cattle not kept for milk): 12,965
- Cattle (total, all ages): 21,211
- Sheep (all ages on farms): 16,534
- Sheep (total pounds of wool clipped): 86,414

The feeding of cattle is the most important livestock industry in the county. Angus and Hereford breeds predominate, but there are also many Shorthorn and Red Poll cattle. The raising of hogs is likewise important and many are...
sold on the local markets, as well as at the larger livestock centers. The main breeds are the Duroc Jersey and Poland China, but other breeds are also found in the county, such as the Berkshire, Chester White, Tamworth and Hampshire. Horses and mules are raised in small numbers by practically all farmers. Sheep raising is practiced to some extent and there are a few herds of goats in the county. Dairying is of minor importance, there being only a few commercial dairies. Dairy cattle are kept in small numbers, however, on practically all farms, the Holstein breed predominating. The milk and cream produced is utilized for home consumption or sold at the creameries.

The value of land in Wapello county is extremely variable, depending upon improvements, topography and location with reference to towns and railroad facilities. In general land values range from $35 to $300 per acre and most of the farm land is held at from $100 to $200 per acre.

Crop production on the soils of Wapello county is in general fairly satisfactory, but in many cases increases in yields might be secured by proper methods of soil treatment, and increased money returns from many farms might thus be brought about without great difficulty or large expense. One of the chief needs of the soils is for organic matter and the application of farm manure or green manures would prove distinctly profitable. Farm manure has been shown to give large increases in crop growth and this material may be applied to the soils of the county with the assurance of profit. Where farm manure is not available in sufficient amounts to keep all the soils of the farm supplied, leguminous crops should be used as green manure. Such treatment is particularly necessary on the light-colored and light-textured soils of this county.

LIME AND PHOSPHORUS REQUIREMENTS

Wapello county soils are practically all acid in reaction and applications of lime are necessary if the best crop growth, particularly of legumes, is to be secured. The use of this material has been shown to be distinctly profitable on such crops as clover and alfalfa and, in fact, in some instances these crops cannot be grown at all on acid soils.

The phosphorus content of the soils of the county is not high and the use of phosphorus fertilizers will be needed in the near future, if they do not prove of value at the present time. There are strong indications, however, from field experiments being carried out that these materials may be used with profit in many cases now. It is urged that phosphorus fertilizers be tested on individual farms and their value thus determined for local conditions. Complete commercial fertilizers are not recommended for general use in the county, inasmuch as nitrogen may be added thru the growth of inoculated legumes and the potassium supply in the soils is large. It would seem, therefore, that phosphorus fertilizers might prove more profitable than the complete brands. The field tests now under way in the county include the use of complete brands in comparison with rock phosphate and acid phosphate, and in the course of the next few years definite information along this line may be secured. For the present, it can merely be said that tests are showing the value of the phosphate materials, but the complete brands are not proving of as much value. Farmers may readily test these materials on their own soils and, if a complete fertilizer gives a profitable crop increase on a small area, there is no objection to its use and
there will be no injury to the soil. It is especially advised, however, that complete fertilizers be tested in comparison with rock and acid phosphate to determine whether the latter materials will not prove more economically valuable.

In a few instances, drainage is needed in the county, but in general the soils are well drained. The proper cultivation of the soil, the rotation of crops and the utilization of all the crop residues produced on the farm, are other well known soil treatments which should be followed also if crop production is to be increased and the soils made satisfactorily productive.

THE GEOLOGY OF WAPELLO COUNTY*

The rock material underlying the soils of Wapello county, in practically all cases has been so deeply buried under the surface deposits of drift and loess that it exerts little effect upon the soils. There is only one soil type in the county which is derived from the native rock material. This is known as the Union silty clay loam and it occurs in small areas, chiefly along the Des Moines river and some of its larger tributaries. It has little agricultural importance, practically none of it being under cultivation, owing to its extremely rough topography and the extensive erosion to which it is subject.

At least one great ice sheet passed over Wapello county during the glacial age, which, upon its retreat, left behind a thick deposit of debris known as glacial drift or till. There may have been a previous invasion by an ice sheet, but there is little evidence of any earlier deposit than the one mentioned, which is known as the Kansan. The depth of this deposit of glacial material varies considerably in the county, the maximum thickness being probably about 200 feet. In Center and Polk townships, it averages about 25 feet in depth, while in Hyland and Competine townships, it is 120 to 130 feet in thickness. In Cass township it is said to reach a depth of 170 feet. The average thickness is probably about 100 feet.

This Kansan drift layer is made up of varying proportions of clay, sand, gravel and boulders. The boulders found are not large and their occurrence is not general. The lower layer of the drift is a blue or gray clay, mixed with some sand and gravel. The upper portions, however, have been considerably modified by weathering prior to the deposition of the loess, and the oxidation has changed the color of the drift material to a reddish-brown. There has been considerable leaching, also, and the soluble constituents originally present in the glacial material have been largely washed away.

Practically everywhere in the county the drift deposit has been covered by a layer of so-called loess. Only one of the soil types found in the county is derived principally from the drift deposit, and it has considerable loess mixed with it at the surface. This type is known as the Lindley loam and covers about 15 percent of the total area. The loess, from which all of the other soil types are derived, except the one residual type, the Union silty clay loam already mentioned, is a fine, silt-like material deposited by the wind at some previous geological period when climatic conditions were very different than at present. The color of this loessial deposit varies considerably, in some areas being dark

brown to black, while in others, where the accumulation of organic matter has been smaller, the color is gray and in some instances almost white. The depth of this loess deposit is variable, ranging from a few inches to about 15 feet, the average depth being probably five or six feet. There are areas of alluvial soils in the county which are grouped as terrace or second bottomland soils and first bottomland types. These soils are found on both the old and the more recent flood plains of the Des Moines river and its larger tributaries, and along Cedar and Competine creeks. These alluvial deposits are formed by the action of the streams and are composed of materials of both glacial and loessial origin. The bottomland types are subject to overflow, while the terraces are not reached by the rivers at flood stage.

**PHYSIOGRAPHY AND DRAINAGE**

The upland of Wapello county was originally a nearly level drift plain. This, however, was much modified by erosion prior to the deposition of the loess and at the present time the topography shows the results of much erosion along the streams. The Des Moines river extends diagonally across the county from northwest to southeast, with a broad, deep valley. It is bordered by rather hilly, much eroded areas on both sides and the area along the river is, therefore, particularly rough and uneven in topography. Along the tributaries of the Des Moines, particularly the larger streams, the topography is almost as rough. The general topographic condition in the southwestern part of the county, which is traversed by the large tributaries of the Des Moines river, is therefore rolling, only narrow ridges of the original upland plain remaining. These upland areas are generally high and narrow and lie parallel to the stream valleys.

In the northeastern portion of the county, the areas adjacent to Cedar creek and Competine creek are somewhat rough, but there has been much less erosion here, the slopes are less abrupt and the topography in general is less rough. The upland areas between the streams are broad, gently rolling plains and the topographic condition is much more desirable for general farming purposes. Large areas in Competine, Hyland, Richland, Dahlonega and Pleasant townships are covered with the soil known as the Grundy silt loam, the topography of which is level to undulating or gently rolling.

The drainage of the county is brought about by the Des Moines river with its tributaries, Cedar creek and Competine creek. Over two-thirds of the county is drained by the Des Moines river with its tributaries, the chief of which are Soap creek, Little Soap creek, Village creek, Bear Creek, South Avery creek, Middle Avery creek and North Avery creek. These creeks are all found southwest of the river, the tributaries to the north of the river all being comparatively small and draining only small areas. The largest of these tributaries north of the river is Sugar creek. The northeastern portion of the county is drained by Cedar creek and Competine creek, both of which possess several important tributaries. These creeks have rather shallow valleys and comparatively narrow flood plains. Along Cedar creek, which is the largest of these streams, the flood plain averages about one-half mile in width.

The Des Moines river has an exceedingly variable flood plain, the entire alluvial area, including the terraces, varying from three-fourths of a mile to two
miles in width. The largest areas of this valley land are just south of Eddyville and southeast of Ottumwa. There is also a considerable area of terrace land northwest of Eldon. In general, the tributary streams of the Des Moines river flow thru very narrow valleys and the areas of alluvial soil are found in narrow strips along these streams. The valleys cut by the Des Moines river and its tributaries are all deep, ranging probably from 150 to 200 feet. The valleys of Cedar creek and Competine creek, however, are only 40 to 60 feet in depth.

The drainage system of the county is quite complete, practically all areas being connected with a drainage outlet. Small areas of the Grundy silty clay loam occurring on the more level upland in the northeastern part of the county, are benefited by tiling, and there are other instances where drainage would improve certain areas of some of the other types. In general, however, the natural drainage system of the county is adequate and tiling is not necessary. The accompanying map shows the number of drainage channels in the county and indicates the extensive drainage system.

THE SOILS OF WAPELLO COUNTY

The soils of Wapello county are grouped into four classes according to their origin and location, loess soils, terrace soils, and swamp and bottomland soils. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were quite different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume
TABLE II. THE AREAS OF DIFFERENT GROUPS OF SOILS IN WAPELLO COUNTY

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loess soils</td>
<td>224,320</td>
<td>81.9</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>16,256</td>
<td>5.9</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>30,784</td>
<td>11.3</td>
</tr>
<tr>
<td>Residual soils</td>
<td>2,560</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>273,920</strong></td>
<td><strong>...</strong></td>
</tr>
</tbody>
</table>

of the streams 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 are subject to more or less frequent overflow. Residual soils are those which are formed from the native rock material. The extent and occurrence of these four groups of soils in Wapello county are shown in table II.

By far the largest area of the county, over 81 percent, is covered by the loess soils. The bottomland soils are second in extent, covering 11.3 percent of the total area of the county. The terrace soils are very minor in extent, covering only 5.9 percent of the total area. There is only one residual soil, covering a small area, 2,560 acres or 0.9 percent of the total area.

In topography, the loess soils are in general gently undulating to rolling, although in some areas the soils are rough. The Lindley loam, for example, is quite rough. The Grundy silty clay loam, however, is almost flat to depressed. In some areas the Clinton silt loam is very rough, and where badly eroded it is known as the broken phase. Drainage is well established on most of the loess areas, with the exception of the Grundy silty clay loam and some areas of the Marion and Putnam types. The terrace soils are generally rather level in topography and fairly well drained. The Bremer clay loam, however, is usually in need of drainage. The bottomland types are all level and subject to overflow. In this group drainage is particularly necessary for the Wabash silty clay loam.

There are twenty distinct soil types in Wapello county and these, with the broken phase of the Clinton silt loam, the colluvial phase of the Wabash silt loam and the riverwash, make a total of 23 separate soil areas. There are eight loess soils, seven terrace types, seven swamp and bottomland soils and one residual soil. These various soils types are distinguished on the basis of definite characteristics, which are described in the appendix to this report, and the names denote certain group characteristics. The areas of the different soil types in the county are shown in table III.

There are eight loess soils, the Clinton silt loam, the Grundy silt loam and the Lindley loam being the most extensive. The former, together with the broken phase, covers 31 percent of the total area of the county, while the Grundy silt loam covers 30.1 percent. The Lindley loam, which occurs on the steep slopes along the major streams, covers 15.6 percent. It is largely of drift origin, but there is evidence of loess on the surface. The Marion silt loam is the fourth largest loess soil, covering 3.6 percent of the total area of the county. The Putnam silt loam is considerably smaller and covers only 1.0 percent. The Grundy silty clay loam is very much smaller in area, covering only 0.4 percent, and the Knox fine sand, which is the smallest loess type, covers only 448 acres.

There are seven terrace soils, the most extensive being the Bremer silt loam, which covers 1.8 percent of the county. The Calhoun silt loam is somewhat
TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WAPello 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></td>
<td>LOESS SOILS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>80,192</td>
<td>31.0</td>
</tr>
<tr>
<td>80a</td>
<td>Clinton silt loam (broken phase)</td>
<td>4,608</td>
<td>31.0</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>82,624</td>
<td>30.1</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>42,824</td>
<td>15.8</td>
</tr>
<tr>
<td>67</td>
<td>Marion silt loam</td>
<td>9,884</td>
<td>3.6</td>
</tr>
<tr>
<td>66</td>
<td>Putnam silt loam</td>
<td>2,624</td>
<td>1.0</td>
</tr>
<tr>
<td>115</td>
<td>Grundy silty clay loam</td>
<td>1,216</td>
<td>0.4</td>
</tr>
<tr>
<td>33</td>
<td>Knox fine sand</td>
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<td>TERRACE SOILS</td>
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<td></td>
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<tr>
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<td>Waukesha loam</td>
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<td>0.6</td>
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<td>Bremer silty clay loam</td>
<td>960</td>
<td>0.3</td>
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<tr>
<td>118</td>
<td>Plainfield loamy fine sand</td>
<td>320</td>
<td>0.1</td>
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<td></td>
<td>SWAMP AND BOTTOMLAND SOILS</td>
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<td></td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
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<td>26</td>
<td>Wabash silt loam</td>
<td>7,872</td>
<td>3.0</td>
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<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>3,328</td>
<td>4.1</td>
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<tr>
<td>117</td>
<td>Genesee fine sandy loam</td>
<td>2,176</td>
<td>0.8</td>
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<td>89</td>
<td>Sarpy silt loam</td>
<td>2,112</td>
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<td>Wabash silty clay loam</td>
<td>768</td>
<td>0.3</td>
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<td>Riverwash</td>
<td>320</td>
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<td></td>
<td>RESIDUAL SOIL</td>
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<td>116</td>
<td>Union silty clay loam</td>
<td>2,560</td>
<td>0.9</td>
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smaller, covering 1.4 percent. The Jackson silt loam and Waukesha silt loam are about the same in area, covering 0.9 percent and 0.8 percent respectively. The Waukesha loam and Bremer silty clay loam are minor in extent and cover 0.6 and 0.3 percent of the county respectively. The Plainfield loamy fine sand is very minor in area, covering only 320 acres.

There are seven bottomland soils, the Genesee silt loam being the largest individual type and covering 5.2 percent of the total area of the county. The Wabash silt loam, together with the colluvial phase, stands next to the Genesee silt loam, covering 4.1 percent. The Genesee fine sandy loam, the Sarpy silt loam and the Wabash silty clay loam are all small in area, covering 0.8, 0.8 and 0.3 percent of the county, respectively. There is an area of riverwash, amounting to 320 acres. There is one residual soil known as the Union silty clay loam, which is small in area, covering 0.9 percent of the total area.

THE FERTILITY IN WAPello COUNTY SOILS

Samples were drawn from all the soils in the county, with the exception of the broken phase of the Clinton silt loam, the Union silty clay loam and the riverwash. The more important types were sampled in triplicate and one sample was taken of each of the minor types. All the samples were taken with the greatest care that they should represent accurately the typical soils and that any 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. Analyses were made for total phosphorus, total nitrogen, organic carbon, inorganic carbon and limestone requirement. The official methods were employed in determining the phosphorus, nitrogen and carbon, and the Veitch method was employed for determining the limestone requirement. The results given in the tables are the averages of duplicate determinations on all samples of each type that were analyzed. If more than one sample of a type was taken, the results given are the average of four or six determinations.

**THE SURFACE SOILS**

The results 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 rather variable, but only in two cases is there any considerable amount present, and in several instances the soils seem very poorly supplied with this constituent. There is no relation apparent between the amount of phosphorus present in the various soil groups, and even the average of the bottomland types is very little different from that of the upland soils, altho in other cases the bottomland soils have shown a somewhat better supply of this constituent. There is little relation between the soil type and the phosphorus supply in the soils of this county, altho the loams and sandy loams seem to be somewhat lower in this constituent. Comparisons are difficult, however, inasmuch as so many of the types are silt loams. The Wabash silty clay loam contains the largest amount of phosphorus of any of

<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>80</td>
<td>Clinton silt loam</td>
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<td>2,366</td>
<td>25,500</td>
<td>0</td>
<td>1,734</td>
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<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,273</td>
<td>4,170</td>
<td>51,233</td>
<td>0</td>
<td>5,788</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>1,047</td>
<td>2,245</td>
<td>23,940</td>
<td>0</td>
<td>1,601</td>
</tr>
<tr>
<td>67</td>
<td>Marion silt loam</td>
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<td>1,984</td>
<td>22,820</td>
<td>0</td>
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</tr>
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<td>66</td>
<td>Putnam silt loam</td>
<td>1,367</td>
<td>4,448</td>
<td>47,260</td>
<td>0</td>
<td>5,605</td>
</tr>
<tr>
<td>115</td>
<td>Grundy silty clay loam</td>
<td>1,064</td>
<td>4,648</td>
<td>57,900</td>
<td>0</td>
<td>4,004</td>
</tr>
<tr>
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<td>Knox fine sand</td>
<td>1,046</td>
<td>644</td>
<td>8,160</td>
<td>0</td>
<td>3,203</td>
</tr>
</tbody>
</table>

<table>
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<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>88</td>
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<td>1,917</td>
<td>5,598</td>
<td>71,980</td>
<td>0</td>
<td>5,205</td>
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<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,263</td>
<td>2,625</td>
<td>31,120</td>
<td>0</td>
<td>5,865</td>
</tr>
<tr>
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<td>Jackson silt loam</td>
<td>1,165</td>
<td>1,986</td>
<td>15,800</td>
<td>0</td>
<td>5,265</td>
</tr>
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<td>75</td>
<td>Waukesha silt loam</td>
<td>1,232</td>
<td>5,222</td>
<td>64,880</td>
<td>0</td>
<td>1,601</td>
</tr>
<tr>
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<td>1,780</td>
<td>21,880</td>
<td>0</td>
<td>1,601</td>
</tr>
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<td>4,402</td>
<td>53,320</td>
<td>0</td>
<td>1,601</td>
</tr>
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<td>Plainfield loamy fine sand</td>
<td>532</td>
<td>1,072</td>
<td>22,520</td>
<td>0</td>
<td>1,601</td>
</tr>
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**TABLE IV. PLANT FOOD IN WAPELLO COUNTY, IOWA, SOILS**

Pounds per acre of two million pounds of surface soil (0 - 6 2/3")

**LOESS SOILS**

**TERRACE SOILS**

**SWAMP AND BOTTOMLAND SOILS**

the individual soil types, and the Wabash silt loam and the Bremer silt loam are almost as well supplied. The loessial uplands, which are made up chiefly of the Clinton silt loam and the Grundy silt loam, are considerably lower, containing 1,428 and 1,273 pounds per acre respectively. The Lindley loam, the third largest upland type, is still lower in phosphorus, containing only 1,047 pounds per acre.

It is evident from these results that the phosphorus present in the soils of Wapello county is insufficient to supply the needs of crops over any considerable period. In the very near future, this element will certainly need to be supplied, if crop production is to be made and kept satisfactory. Indeed, it is quite probable that in many cases at the present time, phosphorus fertilizers would prove of value on some of these soils. There are indications from greenhouse experiments and field tests now under way, that phosphorus might be used profitably on some of the important types. Definite recommendations along this line cannot be made until more data have been accumulated, but it is extremely desirable that phosphorus fertilizers be tested on individual farms and their value determined for local conditions.

The nitrogen content of the soils of the county is much more variable than the phosphorus, the amount present ranging from 644 pounds in the case of the Knox fine sand, to 5,598 pounds in the case of the Bremer silt loam. There is no relation apparent here between the nitrogen in the various soil groups, and it is hardly possible to make any comparisons between individual soil types, owing to the fact mentioned above that so many of the types are silt loams. It is evident, however, that the fine sand, loamy fine sand and fine sandy loams are lower in this constituent than are the silt loams and silty clay loams. With a few exceptions, the nitrogen supply in the soils is not strikingly deficient, but in some instances the amount is entirely too low for satisfactory crop production and much too small to provide a sufficient amount for the growth of satisfactory crops over any considerable period of years. Even where the amount present is not low, however, the supply would soon become inadequate, and nitrogen cannot be disregarded in any system of permanent fertility.

Some nitrogenous fertilizer must be used if the soils are to be kept productive, and the cheapest and best materials to use for this purpose are farm manure, green manure and crop residues. By the use of farm manures and crop residues, considerable nitrogen removed by the crops may be returned to the soil. These materials will not increase the supply; they merely reduce the losses. Leguminous crops used as green manures are the best means of increasing the nitrogen in the soil. When well inoculated, they secure at least a part of the nitrogen which they contain from the atmosphere, and hence when turned under in the soil they increase the store of that constituent from which subsequent crops may draw their supply. These materials have a value in addition to supplying nitrogen, in that they increase the amount of organic matter present in soils. There is a rather close relation between the organic matter content of the soil and the nitrogen supply. The organic carbon is a measure of the organic matter present, and the color of the soil also indicates the supply of organic matter. Hence, the color of the soil may usually be taken to indicate the amount of nitrogen present. If the soil is light in color, it is low in organic matter and is
generally low also in nitrogen. On the other hand, a black soil is high in organic matter and generally well supplied with nitrogen. The heavier soil types, such as the silty clay loams, are apt to be darker and to contain more nitrogen and organic matter than light colored soils.

The organic matter present in the soils of Wapello county is considerable in some instances, but in other cases the supply is small. Those types which showed a high nitrogen content show a correspondingly high organic carbon content and likewise the types which are very low in nitrogen are correspondingly low in organic matter. Even where the supply of organic matter is not low, however, continued satisfactory crop production will require the use of fertilizing materials supplying organic matter. Indeed, there is evidence of the value from the use of farm manure on practically all of the soils in the county. This material gives crop increases which are always profitable and this is true even in the case of the soil types which are apparently better supplied with organic matter.

All of the soils of the county should receive applications of this material or of leguminous green manures, if they are to be kept supplied with organic matter.

Only one of the soil types in the county, the Sarpy silt loam, showed any inorganic carbon present in the surface soil. With this exception, the soils of the county all show a lime requirement by the Yeitch method. In some cases, the need of lime is great, while in other types the requirement is rather small. It is evident, however, that these soils should all be tested for acidity and that the amount of lime shown to be necessary should be applied. Each soil must be tested before lime is applied, inasmuch as soils vary widely in lime requirement. The figures given in the table are indicative only of the needs of the various soils and they should not be taken to show how much lime should be

Fig. 2. The Grundy silt loam occurs extensively on the level uplands northeast of the Des Moines river
applied to soils of the same types. If the best crop growth, particularly of legumes, is to be secured, the acidity of the surface soil must be neutralized and applications of lime to acid soils of the county have been proved by much experience to be distinctly profitable.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and the subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. The fertility of the soil is not influenced materially by the plant food present in the lower soil layers unless there is an unusually large amount of some constituent present. The soils of this county show no large supply of any of the essential plant foods in the subsurface and subsoil layers and hence these lower layers have little influence upon the needs of the various types as indicated by the analyses of the surface samples. Phosphorus will be needed on these soils in the near future and phosphorus fertilizers may be of value now. The organic matter and nitrogen content, while not extremely low, in most cases is insufficient for any extended period of crop production and applications of humus-forming materials, particularly farm manure and leguminous green manures, are quite necessary to keep up fertility. With the exception of the Sarpy silt loam, which was found to be basic in the surface soil, there is no large supply of lime in the lower soil layers. Two other types gave basic reactions in the subsoil, but the amount of lime which they

<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><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>2,053</td>
<td>2,456</td>
<td>21,080</td>
<td>0</td>
<td>7,740</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
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<td>6,241</td>
<td>84,560</td>
<td>0</td>
<td>11,477</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
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<td>1,962</td>
<td>21,020</td>
<td>0</td>
<td>6,060</td>
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<tr>
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<td>19,218</td>
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<td>11,210</td>
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<tr>
<td>115</td>
<td>Grundy silty clay loam</td>
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<td>6,812</td>
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<td>5,604</td>
</tr>
<tr>
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<td>Knox fine sand</td>
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<td>4,804</td>
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<tr>
<td><strong>TERRACE SOILS</strong></td>
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</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,600</td>
<td>7,789</td>
<td>64,440</td>
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<td>8,808</td>
</tr>
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<td>0</td>
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<td>0</td>
<td>4,804</td>
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<td>0</td>
<td>1,600</td>
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<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
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</tr>
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<td>Genesee silt loam</td>
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<td></td>
</tr>
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<td>8,012</td>
<td>65,720</td>
<td>0</td>
<td>5,604</td>
</tr>
</tbody>
</table>
TABLE VI. PLANT FOOD IN WAPello 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 phos-phorus</th>
<th>Total nitro-gen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
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<tbody>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
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<td>20,800</td>
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<td>Grundy silt loam</td>
<td>2,359</td>
<td>5,906</td>
<td>72,818</td>
<td>0</td>
<td>14,813</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>2,761</td>
<td>2,037</td>
<td>18,360</td>
<td>0</td>
<td>9,609</td>
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<td>Marion silt loam</td>
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<td>1,128</td>
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<td>2,400</td>
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<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phos-phorus</th>
<th>Total nitro-gen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
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<tr>
<td>88</td>
<td>Bremer silt loam</td>
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<td>8,406</td>
</tr>
<tr>
<td>118</td>
<td>Plainfield loamy fine sand</td>
<td>1,140</td>
<td>636</td>
<td>5,760</td>
<td>0</td>
<td>2,400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phos-phorus</th>
<th>Total nitro-gen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>3,785</td>
<td>7,374</td>
<td>80,131</td>
<td>389</td>
<td>Basic</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>4,593</td>
<td>8,262</td>
<td>98,340</td>
<td>0</td>
<td>6,096</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>2,181</td>
<td>5,178</td>
<td>52,560</td>
<td>0</td>
<td>2,400</td>
</tr>
<tr>
<td>117</td>
<td>Genesee fine sandy loam</td>
<td>2,508</td>
<td>4,674</td>
<td>48,519</td>
<td>330</td>
<td>Basic</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>2,565</td>
<td>2,684</td>
<td>22,497</td>
<td>9,003</td>
<td>Basic</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>4,992</td>
<td>9,528</td>
<td>165,030</td>
<td>0</td>
<td>9,606</td>
</tr>
</tbody>
</table>

contain is inconsiderable and they will evidently soon need applications of this material. Deficiency in lime in the surface soil cannot be supplied from the lower soil layers and if the surface soil indicates acidity, lime should be applied regardless of the reaction of the subsoil. Where the soil is acid, a second application of lime will be needed sooner than if the subsoil is well supplied, but in any case the soils of the county should be tested at regular intervals to determine their need for applications of limestone.

GREENHOUSE EXPERIMENTS

For the purpose of obtaining information regarding the needs of the soils of Wapello county and the value of various fertilizing materials, four greenhouse experiments were carried out on the Clinton silt loam and the Grundy silt loam, the two most extensive soil types in the county. Two of these experiments were conducted in 1917 and two in 1918, and the results for the two years are given separately. The soil treatments tested were the same in all cases, consisting in the application of manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These materials were applied in the same amounts which are used in the field experiments and the results obtained may therefore be considered indicative of what may be obtained in the field. Manure was added at the rate of 8 tons per acre. Lime was applied in amounts sufficient to neutralize the acidity of the soil as indicated by the Veitch test and supply two tons additional. Rock phosphate was applied at the rate of 2,000
Fig. 3. Clover pot culture on Clinton silt loam. Manure is of decided benefit. Rock and acid phosphates also proved of value, applied with the manure

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. Wheat and clover were grown in all these experiments, the clover being seeded about one month after the wheat was up. Duplicate pots were used for each treatment and the figures given in the tables are the averages of the yields on two pots. The results of the experiment on the Clinton silt loam in 1917 are given in table VII.

The application of manure to this soil brought about a slight increase in the wheat crop and a very distinct increase in the clover. The use of lime in addition to the manure increased both crops considerably, the effect being particularly noticeable in the case of the clover. When rock phosphate was used with the manure and lime, the wheat crop was distinctly larger and the clover yield was very much greater. Acid phosphate and the complete commercial fertilizer proved of the same value as the rock phosphate on the wheat and had less effect on the clover. They both showed an influence on the latter crop, however. These results indicate quite definitely the value of manure, lime and phosphorus on this soil type. They do not permit of definite conclusions regarding the relative merits of the various phosphorus fertilizers, but they do serve to emphasize the need of testing various phosphorus carriers on this soil.

Table VIII gives the results obtained on another sample of the same soil type, the experiment being conducted the succeeding year. The treatments were identical and the same crops were grown.

<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>21.0</td>
<td>31.7</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>22.0</td>
<td>47.6</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>26.5</td>
<td>54.3</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>30.7</td>
<td>67.9</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>30.5</td>
<td>58.8</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>30.7</td>
<td>58.9</td>
</tr>
</tbody>
</table>

TABLE VII. GREENHOUSE EXPERIMENT
Clinton silt loam—Wapello county—1917
TABLE VIII. GREENHOUSE EXPERIMENT
Clinton silt loam—Wapello county—1918

<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>17.39</td>
<td>38.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>18.69</td>
<td>44.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>19.27</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>20.46</td>
<td>47.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>23.38</td>
<td>49.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>21.89</td>
<td>52.0</td>
</tr>
</tbody>
</table>

Manure showed a distinct influence in this experiment, just as it did the preceding year, the largest effect being evident on the clover crop. The application of lime with the manure brought about a small increase in the wheat crop, but owing to an abnormal condition in the case of the clover crop, the effects on the clover could not be secured and the yields in this case are not given in the table. Rock phosphate showed a small effect on the wheat and a small effect, likewise, on the clover. Acid phosphate gave a rather distinct increase in the wheat yields and the effect on the clover was quite definite. The complete commercial fertilizer increased the wheat yields somewhat less than the acid phosphate, but the opposite was true with the clover. In that case, the commercial fertilizer showed the largest effect of any of the materials employed. The results of this experiment confirm those of the preceding year on the same soil type.
TABLE IX. GREENHOUSE EXPERIMENT
Grundy silt loam—Wapello county—1917

<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>35.2</td>
<td>45.3</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>35.7</td>
<td>47.6</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>...</td>
<td>47.6</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>37.5</td>
<td>49.8</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>38.5</td>
<td>56.7</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>38.0</td>
<td>63.5</td>
</tr>
</tbody>
</table>

and show the value of applications of manure, lime and a phosphorus fertilizer to the Clinton silt loam.

The results of the experiment on the Grundy silt loam in 1917 are given in table IX.

Manure showed a very slight effect on the two crops in this experiment, increases being noted, however, in both cases. The yield of wheat was not secured on the manure-lime pots and no effect was evidenced from the use of lime on the clover. This is rather surprising, but the results should not be taken to mean that lime will not prove of value on this soil when it is acid. It will be noted in a subsequent test that lime proved of some effect on this same soil and, in general, it may be said that farm experience indicates the value of the use of lime on this soil when it is acid. The application of rock phosphate increased

Fig. 5. Tests on Grundy silt loam show the value of manure, lime and a phosphate fertilizer for wheat
both the wheat and clover crops to a small extent, the effect being more evident on the clover than on the wheat. Acid phosphate increased the wheat crop to a somewhat greater extent than did the rock phosphate, and in the case of the clover, the acid phosphate proved very efficient. The complete commercial fertilizer was about as effective as the acid phosphate on the wheat, but proved more effective on the clover, producing a very large increase. These results serve to show the value of manure on this soil and to indicate that phosphorus fertilizers may prove of considerable value.

The test on the Grundy silt loam, in 1918, was carried out in the same way as in the preceding year. The results of this test are given in table X.

Manure showed a slight effect on the clover in this experiment, but had no effect on the wheat crop. Lime in addition to manure proved of value on both crops, a distinct increase being obtained in the case of the clover. Rock phosphate increased the wheat yields considerably and the clover yield was also increased to a large extent by the use of this material. Acid phosphate proved of practically no effect on the wheat, but the clover crop was increased to a larger extent with this material than by the use of the rock phosphate. The complete commercial fertilizer increased the wheat yield to a smaller extent, however, than did the rock phosphate. The effect on the clover was small, the acid and rock phosphates both showing up much better on this crop. These results confirm

**TABLE X. GREENHOUSE EXPERIMENT**

Grundy silt loam—Wapello county—1918

<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>18.1</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>17.8</td>
<td>34.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>18.4</td>
<td>37.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>24.4</td>
<td>48.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>18.2</td>
<td>55.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>21.1</td>
<td>38.0</td>
</tr>
</tbody>
</table>
very largely the results obtained on the same soil the preceding year and show
the value of manure, lime and a phosphate fertilizer.

These greenhouse experiments as a whole indicate quite definitely that the
two main soil types of the county will respond to applications of manure, lime
and probably, also, to phosphorus fertilizers. Both farm experience and the field
tests given later in this report confirm the conclusions stated regarding the value
of manure and lime and there is also some confirmation of the value of a phos­
phorus carrier. Whether rock phosphate or acid phosphate should be used,
however, must be determined by more complete tests carried on in the field over
a period of years, and the most desirable method of choosing the proper material
is for the individual farmer to test both fertilizers on his own soil.

FIELD EXPERIMENTS

Five field experiments are under way in Wapello county, four of them being
located on the Grundy silt loam and the fifth on the Clinton silt loam. These
experiments were laid out in 1917 and so only a few results have been secured
thus far. There are some indications, however, of value from certain methods
of soil treatment and the results are given here in order to call attention to the
effects which they indicate. These experiments must be conducted for several
years before definite conclusions can be drawn from them and it should be em­
phasized that they are indicative only of what may be expected under similar
field conditions.

In each of these experiments, a series of plots was laid out, 155'6"x28', or 1/10
of an acre in size. Each test includes the soil treatments which should be prac­
ticed both in the livestock system of farming and in the grain system. In the
former, manure is applied, while in the latter, crop residues are employed to
supply the organic matter. The applications tested in all of the experiments
and under both systems of farming, are limestone, rock phosphate and a complete
commercial fertilizer. Manure is applied on the livestock system plots at the
rate of 8 tons per acre once in a four-year rotation. On the grain system plots,
the second crop of clover is plowed under, the corn stalks are cut with a disk
and plowed under and all the straw from the small grains is returned to the
soil. Lime is added in sufficient amounts to neutralize the acidity of the soil and
supply two tons additional. Rock phosphate is applied at the rate of 2000
pounds per acre once in the rotation. Acid phosphate is added at the rate of
200 pounds per acre annually and a standard 2-8-2 complete commercial ferti­
lizer is used at the rate of 300 pounds per acre annually. There are 13 plots in
each of the experiments, three of which are untreated or check plots. Plots 1-7
inclusive represent the livestock system, while plots 7-13 represent the grain
system of farming. The results on the crop residues plots are not included here,
owing to the fact that they are somewhat irregular and in all cases there has
been no opportunity for the residues to show any effect.

THE FARSON FIELD

Three of the experiments are being carried out on the Grundy silt loam near
Farson. These are known as Series I, II and III. The results obtained on
Series I are given in table XI. The effect of manure is shown very definitely
TABLE XI. FIELD EXPERIMENT—FARSON FIELD
Grundy silt loam—Wapello county
Series I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Winter wheat, Bu. per acre—1918</th>
<th>Clover, tons per acre—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>16.9</td>
<td>1.95</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>20.3</td>
<td>2.80</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>22.6</td>
<td>2.65</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>23.7</td>
<td>2.80</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>20.9</td>
<td>2.85</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>19.2</td>
<td>3.05</td>
</tr>
</tbody>
</table>

In this experiment, both on the winter wheat in 1918 and on the clover in 1919, in fact, the application of other fertilizing materials in addition to the manure gave very much less striking effects than did the manure alone. Lime showed a small effect on the wheat, and rock phosphate in addition to manure and lime increased the yield of this crop to a slight extent. The other phosphorus carriers, however, showed no influence on this crop. In the case of the clover, the complete commercial fertilizer was the only material which gave any effect. This test indicates very clearly the beneficial effect of manure on the Grundy silt loam and there are indications also of value from the use of a phosphorus fertilizer. Further results are, of course, necessary before definite conclusions can be reached.

The results of the second test on the Farson field on the same soil type are given in Table XII. These results are much less definite than those obtained in Series I. There is some effect of the manure, however, on the oats in 1918 as shown by a comparison of the average of the checks with the manure treated plot. Neither the rock phosphate nor the acid phosphate showed any influence on the oats, but the complete commercial fertilizer gave a small increase. In the case of the wheat, the application of manure and lime increased the yield considerably and rock phosphate in addition brought about a further increase. With this crop, the acid phosphate and complete commercial fertilizer showed little effect. These results, while not very definite, do serve to confirm those preceding, however, and show the value of manure and the possibility of economic returns from the application of phosphorus fertilizers.

The results of Series III on the Grundy silt loam for corn in 1918 are given in Table XII. The application of manure increased the yield of corn consider-
TABLE XIII. FIELD EXPERIMENT—FARSON FIELD
Grundy silt loam—Wapello county
Series III

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatments</th>
<th>Corn bu. per acre—1918</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>63.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>66.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>66.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>69.7</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>68.7</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>65.7</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>54.0</td>
</tr>
</tbody>
</table>

ably, rock phosphate along with manure and lime showed some effect, while acid phosphate increased the yield, but to a less extent than did the rock phosphate. The complete commercial fertilizer showed no effect on the corn. Again the effect of manure is shown on this soil type and there are evidences of value from the phosphorus fertilizers.

THE AGENCY FIELD

The results obtained on the field at Agency on the Grundy silt loam are given in table XIV.

The beneficial effect of manure on this soil type is evidenced both in the case of the corn and in the case of the oats, the influence on the latter crop being very pronounced. Lime proved of some value, altho any effect from this material would not ordinarily be expected on these crops. Rock phosphate increased the yields of both the corn and the oats, and acid phosphate gave still larger increases in the case of both crops. The complete commercial fertilizer proved less effective than the phosphorus carriers. The results of this test confirm those obtained on the various series on the Farson field and show very distinctly the beneficial effect of manure, and increases from the use of phosphorus fertilizers.

THE CHILlicoTHE FIELD

The results obtained from the field experiment at Chillicothe on the Clinton silt loam, are given in table XV. The crop yield was not secured in the year 1918 and the results for 1919 are all that are available. Manure increased to a large extent the yield of the spring wheat grown in 1919. The use of other fertilizing materials with the manure proved of little value. Lime showed a small effect, and the complete commercial fertilizer increased the yield somewhat, but the rock phosphate and acid phosphate showed no influence on the crop.

TABLE XIV. FIELD EXPERIMENT—AGENCY FIELD
Grundy silt loam—Wapello county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Corn, bu. per acre—1918</th>
<th>Oats, bu. per acre—1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>63.5</td>
<td>44.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>64.5</td>
<td>62.2</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>66.7</td>
<td>58.3</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>68.7</td>
<td>63.6</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>70.9</td>
<td>66.6</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>66.0</td>
<td>65.6</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>59.2</td>
<td>54.5</td>
</tr>
</tbody>
</table>
TABLE XV. FIELD EXPERIMENT—CHILlicoTHE FIELD
Clinton silt loam—Wapello county

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Spring wheat bu. per acre —1919</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>18.1</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>24.9</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>26.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock phosphate</td>
<td>24.9</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid phosphate</td>
<td>23.8</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Complete commercial fertilizer</td>
<td>27.2</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>22.7</td>
</tr>
</tbody>
</table>

It is evident that manure is a particularly valuable fertilizing material for use on this soil type and phosphorus fertilizers may prove of value in addition to manure.

The results of these field experiments as a whole serve to confirm the results of the greenhouse tests, and while definite conclusions are not yet possible, the indications are that the Grundy silt loam and the Clinton silt loam, the two largest upland soils of the county, will be benefited materially by the proper application of manure, by the use of lime when needed, particularly for the growth of legumes, and probably also by the application of phosphorus fertilizers. These field tests will be carried on for several years and it is hoped that after more results have been secured, it will be possible to determine definitely the value from the use of phosphorus on these soils and also whether rock phosphate or acid phosphate should be employed. For the present, it can merely be urged that these two materials be tested in the field by individual farmers.

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

The field experiments which have just been discussed have not been under way long enough to permit of definite conclusions regarding the absolute value of the various fertilizing constituents. The results which have been secured thus far, however, indicate that certain treatments may prove of distinct value on the soils of Wapello county. The results also confirm the indications obtained in the laboratory and greenhouse tests and become, therefore, much more definite than would otherwise be the case. The treatments recommended for the various soil types, are based upon the results obtained thus far in the field tests only in so far as they confirm the laboratory and greenhouse results and only in so far as they are supported by the experience of farmers. No suggestions are made which have not been proved by practical experience to be of value.

LIMING

With the exception of one of the bottomland types, all the soils of Wapello county were found to be acid in reaction, and in many cases the extent of acidity was considerable. Many experiments, coupled with extensive farm experience, have shown that crop growth is much less satisfactory on acid soils. This is particularly true in the case of legumes such as clover and alfalfa. Evidently, if crop production is to be made satisfactory in Wapello county and the fer-
tility of the soil is to be kept at the best, all the soils of the county should be tested for acidity and if acid, lime should be applied in sufficient amounts. Any farmer may test his own soil for acidity, but it will be much more satisfactory for him to send a small sample to the Soils Section at Ames and have it tested more accurately, free of charge. When this is done, lime may be applied in an amount known to be sufficient and still not excessive.

The results given earlier in this report indicate the extent of acidity, or lime requirement, of the various individual soil types, but the results should not be taken to show the amount of lime which should be applied in all cases to the same types. Soils vary widely in lime requirement and even the average results of several determinations will not give satisfactory results upon which to base lime applications. It is necessary that the soil from each individual field on the farm be tested for its reaction, for only in this way can the proper amount of lime be applied. Further information regarding the use of lime on soils, the loss by leaching and other points connected with liming, are given in bulletin 151 of the Iowa Agricultural Experiment Station. Lists of limestone dealers and the cost of the material are given in circular 58.

**MANURING**

Many of the soils in Wapello county are poorly supplied with organic matter and crop production on these types would be very much greater if liberal applications of humus-forming materials were made. Even those types which are better supplied with organic matter are found to respond to fertilization with farm manure and, in general, it may be said that this material is the most valuable fertilizer which can be recommended for use in the county. On the light colored soils and the lighter textured types, manure proves of particularly large value. The greenhouse and field experiments discussed earlier in this report give very definite evidence of value from the application of manure to the Grundy silt loam and the Clinton silt loam, the two most extensive upland types in the county. These tests with manure are confirmed by much practical experience, and the value of manure on many of the other soil types in the county is commonly recognized by farmers.

The beneficial effect of manure when it is applied to soils is due to its physical, chemical and bacteriological influence. It improves the physical condition, making light, open soils more retentive of moisture, less open and porous and less subject to the loss of valuable plant food by leaching. Heavy, impervious soils are opened up, better aerated, rendered less retentive of excessive moisture and put in better condition generally for the production of available plant food. Manure returns a large part of the plant food which has been removed from the soil by the crops which have been grown and fed to livestock. Hence it improves the chemical condition of the soil by the actual addition of these plant food constituents, and the “life” of the soil will thus be considerably lengthened. Enormous numbers of bacteria are present in manure and when they are introduced into the soil, they bring about a large increase in the production of available plant food. The large amount of organic matter present in manure stimulates the development of bacteria, a greater action among these organisms already present in the soil takes place and thus brings about a still further increase in
the production of available plant food, traceable to the bacteriological effect of the manure. In some instances the beneficial effect of manure may be due only to its influence on the physical conditions of the soil, or to its chemical effect, or to its bacterial effect, but in most cases it is undoubtedly the result of all three.

When manure is not properly stored and applied to the soil, much of its value may be lost. In fact, if it is kept in open piles exposed to the weather where it undergoes a washing away of the liquid portion, it may lose 75 to 90 percent of its value. Proper precautions should be taken to prevent such extreme losses, inasmuch as the crop-producing value of the manure is correspondingly reduced. There are various methods of storing manure to prevent serious losses, but no one method can be recommended for all conditions. Some method should be chosen, however, which will keep the manure as nearly as possible unchanged before it is applied to the soil. In general, it may be said that the manure should be kept moist and compact and protected from the weather if losses are to be kept at a minimum. It should be kept in mind that when properly stored and applied, manure may return 75 to 80 percent of the plant food removed from the soil by the crops grown. In order to insure this return of plant food, it is absolutely necessary that all the manure produced on the farm be carefully preserved and returned to the soil. The production of manure on the average farm is insufficient to provide for a larger application than 8 to 10 tons per acre once in a rotation, and in many cases it is impossible to supply even this much to all the soils of the farm. Excessive applications are therefore not likely to be made, but it may be said that for general farm crops, applications of more than 16 to 20 tons per acre are not advisable. In market gardening or truck farming, much larger amounts of manure may of course be used with profit, and in special cases where the soil is particularly low in organic matter, the size of the application may be increased with profit.

On the grain farm there is only a small production of manure and some other material must be employed as a substitute for it. On the livestock farm, also, it is frequently necessary that the manure be supplemented by the use of some other material supplying organic matter. Green manures may thus be used with profit under both types of farming, and they constitute the best substitute for, or supplement to, farm manure. Legumes are ordinarily employed as green manure crops, because of the fact that they not only supply organic matter, but because, when well inoculated, they utilize the free nitrogen of the atmosphere and are able, therefore, to increase the nitrogen content of the soil. There are many legumes which are available for use under a wide variety of conditions and one may be chosen for almost any rotation. In some instances non-legumes may be preferred to legumes, but in general, the latter prove much more satisfactory as green manure crops. Green manuring may prove a very profitable farm practice on some of the soils in Wapello county, especially where farm manure production is small and where the soils are especially low in organic matter and nitrogen. Green manuring should not be practiced blindly nor carelessly, however, for it may sometimes be unprofitable or even injurious. Advice regarding this practice in special cases will be given by the Soils Section upon request.
On many farms, the value of crop residues such as straw and stover is not recognized and they are frequently burned or otherwise destroyed. Such materials should always be completely returned to the soil, inasmuch as they constitute an important means of keeping up the organic matter supply in the soil. They also return some plant food and thus lengthen its life. On the livestock farm, crop residues may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied to the soil directly, or they may be stored and allowed to become better decomposed before application. Under the grain system of farming, it is particularly important that the crop residues be thoroly utilized, owing to the fact that there is only a small production of farm manure, but the practice of returning the residues should be followed also on the livestock farm.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Wapello county show that the phosphorus supply is low and it would seem that phosphorus fertilizers might be used with profit. Such materials will undoubtedly be needed in the near future, even if they do not prove of value at present. The greenhouse and field experiments on the Grundy silt loam and the Clinton silt loam indicate some value from the use of acid phosphate and rock phosphate and, while definite conclusions cannot yet be drawn from these tests, it would seem that on these soils applications of phosphorus carriers might be made profitably at the present time. The relative value of the two phosphorus carriers, rock phosphate and acid phosphate, is being determined in the field tests, and it is hoped that at a later date a definite choice may be made between the two materials. Acid phosphate contains the phosphorus in a readily available form, but it is more expensive than rock phosphate. The latter material, however, must be used in larger amounts and is only slightly available in the soil. There seems to be some difference in the economic returns secured from these two materials under varying soil and crop conditions, and until definite conclusions are permissible from the field experiments, it can merely be urged that individual farmers test the two materials under particular conditions and determine which is the more profitable for use on their soils.

Any farmer may carry out a simple test of these two materials. Full directions for such tests are given in circular 51 of the Iowa Agricultural Experiment Station and further advice will be given by the Soils Section upon request. There are strong indications that phosphorus fertilizers will prove of value in many cases on Wapello county soils, and farmers may provide confirmation of this fact and also learn which phosphorus fertilizers should be used, if they will carry out the tests as suggested.

The nitrogen content of soils gradually decreases when crops are grown, and even where crop residues and farm manure are employed, the nitrogen supply cannot be maintained. The soils of Wapello county are fairly well supplied with this constituent, but some nitrogenous material must be added from time to time if the supply is to be kept up. On some of the types where the nitrogen content is particularly low, nitrogenous fertilizers should be used at the present time. Leguminous green manures have proved the cheapest and most satisfactory nitrogen-supplying fertilizer. Commercial nitrogenous fertilizers are not,
therefore, recommended at the present time for general use on the soils of this county. They may be used in small amounts as top dressings to stimulate the early growth of some crops, and they may also be employed profitably in market gardening, but they are too expensive to be used on general farm crops. There is no objection to the application of commercial nitrogenous fertilizers if they prove profitable and there is no injury to the soil. Leguminous green manures in general, however, have been found to provide nitrogen at a much smaller cost than can be done with any commercial nitrogenous material. They also supply organic matter, so that their value is not limited to nitrogen. When commercial nitrogen is used, some material supplying organic matter to the soil must be employed.

Iowa soils generally have been found to contain a considerable amount of potassium, and it is unlikely that potassium fertilizers would prove of profit for general farm crops. If the best physical conditions are maintained in the soil, especially with regard to air, moisture and organic matter supply, sufficient potassium should be brought into an available form to keep the crops supplied. Potassium fertilizers may possibly be used with profit as top dressings to stimulate the early growth of certain crops. They may also prove of value on the truck farm or in the market garden, but their use cannot be generally recommended. Complete commercial fertilizers contain nitrogen and potassium, as well as phosphorus, and these materials are being tested in the field experiments in comparison with rock phosphate and acid phosphate. The results so far obtained indicate that the latter materials may prove quite as profitable and they are much less expensive.

It seems unlikely that the complete fertilizers will yield as economic returns as phosphorus carriers, inasmuch as the nitrogen and potassium which they contain will not have sufficient effect to offset the greater cost of the material. Nitrogen may be supplied more cheaply by the use of leguminous green manures, and if the soil is kept in the best physical condition, potassium should be provided in an available form in sufficient amounts to keep the crops supplied. Farmers who are interested should test complete commercial fertilizers on their own soils and determine their value before making large applications. They should compare such materials, however, with rock phosphate and acid phosphate and determine whether or not economic returns are secured. If any special brand of commercial fertilizer proves profitable, that material may be applied to the soil without any fear of injury to the soil. The question is one of the profit or value from the use of the fertilizer and it is especially important to determine the value in comparison with phosphorus carriers.

**DRAINAGE**

Wapello county possesses an extensive and generally adequate drainage system. In some sections, however, the drainage is poor and the installation of tile would be of value. The Grundy silty clay loam, the Putman silt loam, and some areas of the Marion silt loam, the Calhoun silt loam, the Bremer silt loam and the Bremer silty clay loam, are occasionally in need of drainage. The Wabash silty clay loam is also poorly drained. The first treatment needed to make soils more productive is to insure the adequate removal of excess moisture,
and the installation of tile proves very profitable in many cases. While the expense involved may be considerable, the results more than warrant the outlay. In general, it may be said that any of the soils in Wapello county that are poorly drained should first be thoroughly tiled out if they are to be made productive.

**THE ROTATION OF CROPS**

Many experiments and much experience have shown that the continuous growing of any one crop is much less satisfactory than the rotation of crops. Even if a crop proves particularly valuable or constitutes what is known as a money crop, still it is more profitable in the long run to rotate crops. No special tests have been carried out in Wapello county to determine the most desirable rotations, but various rotations which have proved satisfactory are practiced throughout the state, and from among these one may be chosen which will be suitable in this county. Modifications of these rotations may be made as desired; in fact, almost any rotation may be employed if it includes a legume and the most profitable crops. It should be emphasized that for permanent fertility it is absolutely necessary that some rotation be practiced.

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.)

**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 depends on 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.

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 to the detriment of the land.

Light, open soils which absorb water readily are not likely 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 likely to be injured by ero-
sion when the topography is hilly or rough, and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is scarcely affected. The character of the cropping of the soil may, therefore, determine the occurrence of this injurious action.

The careless management of land is very 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 the 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 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 his 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 Wapello county erosion occurs to a considerable extent. The Clinton silt loam has been so badly washed in many instances that a broken phase of the type has been separated. The Lindley loam is also subject to extensive erosion and in many cases has been very badly washed. There has been some erosion in a few other instances, but the types mentioned are particularly subject to this destructive action.

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

**EROSION DUE TO DEAD FURROWS**

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

"Plowing In." It is generally 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 effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.
“Staking In.” The method of “staking in” is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three to four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes used in the “staking in” operation. There are some objections to the use of earth dams, but in many cases they may be 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 quantity of brush woven about the stakes. A modification of the system of “staking in” which has been used with success in one case, consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward is left near the top. This heavy branch is caught between a fork 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 in time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion, under some conditions. It
will prove neither efficient nor permanent, however, unless the soil above the
dam is sufficiently open and porous to allow of a rather rapid removal of water
by drainage thru the soil. Otherwise, too large amounts of water may accumu­
late 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 con­
sists merely in laying a line of tile down the gully and beneath the dam, an el­
bow 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 rather definitely upon the method of construction. If
it is laid up too loosely, its efficiency is reduced and it may be washed out.
Such dams can be used only infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method
sometimes followed and a great variety of materials may be employed. The
results are in the main rather unsatisfactory and it is a very unsightly method.
Little effect in preventing erosion results from the careless use of rubbish, even
if a sufficient amount is used to fill the cut. The rubbish dam may be used,
however, when combined with the Dickey system, just as the earth dam or stone
dam, provided it is made sufficiently compact to retain sediment and to with­
stand 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 the stakes, the principle of
construction being otherwise the same as in the ‘‘staking in’’ system. It can
only be recommended for shallow, flat ditches and in general other methods
are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural drainageways 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 rela­
tively small, as the strips are usually only a rod or two in width. Blue grass
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 other cases.

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

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

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

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

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

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

*Deep Plowing.* Deep plowing increases the absorptive power of the soil and decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much sub-

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Fig. 7. Rolling topography of Clinton silt loam, the most extensive soil type in the county
soil 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 WAPELLO COUNTY*

LOESS SOILS

There are eight loess soils in Wapello county, belonging in the Clinton, Grundy, Marion, Putnam and Knox series. The soils of this group make up 81.9 percent of the total area of the county, representing practically the entire upland.

CLINTON SILT LOAM (80)

The Clinton silt loam is the most extensive individual soil type in the county, covering 80,192 acres or, together with the broken phase, 31 percent of the total area. It occurs in all parts of the county, occupying practically every stream slope and the slopes and ridges between almost all small drainage ways. The largest areas occur along the Des Moines river, on both sides, so that the largest development of the type follows the course of this river diagonally across the county from the northwest to the southeast. In other parts of the county, the type occurs in many small areas, which are the most numerous southwest of the Des Moines river.

The surface soil consists of a light brown to buff colored smooth silt loam, extending to a depth of 12 to 14 inches. When dry, the surface soil may be a light gray in color. The subsoil is a compact heavy silt loam to silty clay loam, light brown in color and frequently mottled with gray and brown. The soil is closely associated with the Grundy, Putnam and Marion types, and areas of these soils too small to show on the map have been included with the Clinton silt loam.

In topography, this type varies from undulating to strongly rolling and in some cases it is quite rough. The drainage of the soil is usually adequate and only in a few of the more nearly level areas is there need for artificial drainage. The type is subject to considerable washing, and where this action has been extensive, a separation has been made of the broken phase Clinton silt loam. In many areas of the main type, however, care should be taken to prevent the destructive action of erosion.

The Clinton silt loam was originally a forested soil, the native tree growth including white oak, post oak, elm, ash, hickory, hazel and other species of trees and shrubs. About one-fourth of the type is now under cultivation, the more important crops being corn, oats, wheat, clover, timothy and alfalfa. Some truck crops and fruits, pears and grapes, are also grown near Ottumwa. Corn yields from 25 to 60 bushels per acre, wheat 10 to 30 bushels, rye 10 to 25 bushels, and oats 20 to 40 bushels. Clover and timothy hay yield 1 to 2½ tons per acre and alfalfa 1½ to 3 tons per acre. Sweet potatoes have been grown successfully, and yields of 100 to 200 bushels per acre have been secured.

This soil type is generally deficient in organic matter and has been found to respond particularly well to applications of farm manure. The greenhouse experiments previously reported, the field data referred to and the experience of

*The descriptions of individual soil types given in the Bureau of Soils report have been closely followed in this section of the report.
many farmers indicate definitely that farm manure is a very valuable fertilizing material for use on this soil. This material should be applied in as large quantities as practicable and large increases in crop yields may thus be secured. The soil is acid and in need of lime. Applications of this material prove distinctly profitable, especially for the growth of clover and alfalfa. The phosphorus content of the type is rather low and phosphate fertilizers will undoubtedly be needed in the near future, if they do not prove of value now. The greenhouse experiments indicate that phosphorus carriers might prove distinctly profitable at the present time. The soil is subject to considerable erosion, and it is highly desirable that some one of the methods discussed earlier in this report be followed if this destructive action is to be prevented. With the use of farm manure as suggested and the utilization of leguminous crops as green manures in case farm manure is not available in sufficient amounts, the application of lime and probably the use of phosphorus fertilizers, crop production on the more level areas of this soil should be made much more satisfactory than at present and the continued fertility of the type assured.

CLINTON SILT LOAM (BROKEN PHASE) (80a)

This is a minor type in the county, covering 4,608 acres or less than 2 percent of the total area. It occurs in association with the main type and in many places the boundary line between the two is rather arbitrary. It occurs on the steeper, rougher slopes along the stream courses where much of the surface soil has been removed. It is developed to the largest extent along Sugar creek northeast of Ottumwa, along Turkey and Jim creeks southeast of Monkey Mountain and northeast of the Des Moines river near Ashland.

The surface soil of this type is very much the same as that of the typical silt loam, but it is very much shallower. In fact, in many places the subsoil is exposed, forming what are known as "clay spots" or "gall spots." In texture, this phase ranges from a sandy loam to a silty clay loam, the larger portion of it, however, being a silt loam. The subsoil is very little different than in the case of the typical soil. The drainage of the phase is good to excessive.

Very little of this soil is under cultivation, most of the rougher areas being unsuited for farming and used largely for pasture. Much of it is forested with hickory, oak, and other trees and shrubs. Blue grass grows well, and the growing of this crop and the utilization of the soil for grazing purposes is in general the best method of handling the type. On the small areas where the general farm crops are grown, the yields are usually somewhat lower than on the typical soil. When cultivated, this soil is particularly in need of organic matter, lime and phosphorus fertilizers in order to make it properly productive.

GRUNDY SILT LOAM (64)

The Grundy silt loam is the second most extensive soil type, covering 82,624 acres or over 30 percent of the total area of the county. It occurs most extensively on the more level uplands northeast of the Des Moines river. Large individual areas of the type occur in this locality, separating the rougher land along the Des Moines river, Cedar creek, Wolf creek and Competine creek. In the southwestern corner of the county, there are many small areas of the type and the same is true in the northwestern portion.
The surface soil is a dark brown to black silt loam, 8 to 14 inches in depth. The subsoil is a dark brown silty clay loam, mottled with yellowish-brown in the lower sections. Below 24 to 30 inches, the subsoil is a bluish-gray heavy plastic clay mottled with brown and yellow. In some small areas, particularly in the southwestern part of the county, there is a thin grayish-white layer in the lower part of the surface soil, the occurrence of which is not sufficiently distinct to warrant the soil type being changed to Putnam. On the more level uplands in the northeastern part of the county, the type has a deep black surface soil. Where the soil joins with the Clinton, the surface soil becomes shallower than typical and somewhat lighter in color.

This soil is level to gently rolling in topography and is generally fairly well drained. Occasionally on the more level areas tiling would prove profitable.

Practically all of the type is farmed, corn being the principal crop grown. Oats, wheat, rye, clover and alfalfa are also grown successfully. Corn yields range from 30 to 100 bushels per acre, averaging about 43 bushels. Oats yields range from 25 to 75 bushels per acre and wheat 18 to 40 bushels. Timothy and clover yield from 1 to 2½ tons per acre.

The Grundy silt loam is one of the richest soils in the county, and crop yields are in general very satisfactory. It is possible, however, in many cases to secure considerable increases in crops thru proper fertilization. The application of manure has been found to be of great value in many cases. The greenhouse and field experiments given earlier in this report show evidence of considerable value from the application of this material. The soil is acid and lime should be applied for the best growth of legumes, particularly clover and alfalfa. The phosphorus supply is not large and there are indications from the experiments just mentioned that phosphorus fertilizers may be used with profit on this soil type. The greenhouse experiments gave some striking increases from the use of phosphorus carriers and beneficial effects were also noted in some of the field tests. A phosphorus carrier will undoubtedly be needed on this soil in the near future and it is highly desirable that tests be made on individual farms at the present time in order to determine the actual value from the use of either acid phosphate or rock phosphate. In many cases where areas of this type are not adequately drained, tiling should be practiced and is the first treatment needed to make the soil properly productive.

**LINDLEY LOAM (65)**

The Lindley loam is the third largest soil type in the country, covering 42,624 acres or 15.6 percent of the total area. It is found in association with the Clinton silt loam, occupying slopes between the Clinton silt loam and the streams. It occurs most extensively in the area southwest of the Des Moines river, along the slopes to practically all of the stream channels and small drainage ways in that part of the county. Small areas of the type are also found along the Des Moines river to the northeast and in some instances along Cedar creek and Competine creek.

The surface soil of the Lindley loam is a gray or brown loam, 8 to 10 inches in depth. The subsoil is usually a light brown or yellowish-brown sandy clay loam or sandy clay mottled in places with red, orange and drab. Considerable gravel and fine and coarse sand occur in the subsoil. The surface soil is ex-
tremely variable in texture, ranging from a sandy loam to a silty clay loam. The areas of these variations from the typical loam are too small to be shown separately on the map. Where the soil adjoins the Clinton silt loam, it is decidedly silty in character. On the lower areas, the texture is considerably heavier. The soil varies in color, also, from a gray or dark gray on the higher portions, to a yellowish-brown or reddish-brown along the drainage ways. In some places the subsoil contains a high percentage of sand and gravel.

In topography, the Lindley loam is strongly rolling to rough and is subject to extensive erosion. In some cases, the surface soil has been almost entirely removed by washing. The soil is in general well drained.

A large part of the Lindley loam is forested with hickory, pin oak, white oak, post oak, blackjack oak, hazel, sumac, elm, and other trees and shrubs. Much of the type is used for pasture and, owing to its unfavorable topography, is undoubtedly best suited for grazing purposes. Some areas are cultivated, however, and where erosion is not active, good crop yields of corn, oats, wheat, clover and other hay crops are secured. Corn yields from 20 to 40 bushels per acre and the other crops produce somewhat larger yields than on the Clinton silt loam.

When cultivated, this soil can be made more productive by the proper application of farm manure or the use of a green manure crop, by the application of lime when acid, and probably also by the use of a phosphorus fertilizer. It is particularly necessary that the soil be protected from erosion if crop production is to be satisfactory.

MARION SILT LOAM (67)

The Marion silt loam is a minor type, covering 9,984 acres or 3.6 percent of the total area of the county. The largest areas of this type are found on the tops of ridges and high uplands along the larger drainageways. It is most extensively developed north of Ottumwa and in an area southwest of Agency, an area near Bidwell and an area just north and west of Laddsdale.

The surface soil consists of 2 to 6 inches of a gray, yellowish-gray, or almost white silt loam, underlaid to a depth of 6 to 14 inches by a white or gray flour-like silt to silty clay loam. The subsoil is a yellowish-brown, stiff, tenacious clay, usually mottled in the lower sections. The virgin soil in forested areas of this type is considerably darker than in the cultivated areas, where the soil is almost white.

In topography the Marion silt loam varies from level to almost flat in some areas, or strongly rolling in others. The drainage of the more rolling portions is entirely adequate, but on the more level portions tiling is necessary.

This soil is of minor importance agriculturally, not over 40 percent of it being under cultivation. The larger portion of the type is used for pasture. These areas support a growth of white oak, blackjack oak, hickory and other trees and shrubs. The soil is known locally as “white oak land.” On the cultivated portions, the principal crops grown are small fruits, apples, peaches, pears, grapes, corn, wheat, oats and blue grass. In general, however, crop yields are somewhat larger than on the Putnam and Clinton silt loams. Corn yields from 15 to 40 bushels per acre and wheat from 10 to 20 bushels.
This soil is particularly deficient in organic matter and would be benefited by liberal applications of farm manure and the turning under of leguminous crops for green manures. It is acid and in need of lime. It is low in phosphorus and would probably respond to phosphorus fertilization. It is in need of tiling in some areas and in many places it is subject to considerable erosion and should be protected from this destructive action. The chief need of the type for crop production, however, is the improvement of its physical condition and organic matter should be applied, either as farm manure or green manures.

PUTNAM SILT LOAM (66)

This is a minor type covering 2,624 acres or 1 percent of the total area of the county. The largest area of this type occurs directly south of Bear creek station and there are several other small areas in various parts of the county, particularly in the rougher sections southwest of the Des Moines river.

The surface soil of the Putnam silt loam is a light gray to dark gray in color and extends to a depth of 8 to 10 inches. Below this point there is a distinct layer of ashy gray to white silt, about 6 inches in thickness. This passes abruptly into a heavy silty clay loam to clay, of a mottled gray, brown and yellow color. In some areas the soil is deeper and the color is a dark brown to black, while in the flat, poorly drained areas it is a light gray. The subsoil in the poorly drained areas is almost black in color, with some mottlings of drab and yellow.

In topography this type varies from flat to gently rolling and the drainage is rather poor, owing to the tough, impervious nature of the subsoil.

Practically all of the soil is under cultivation and is used for the production of general farm crops such as are grown on the main upland types. Crop yields are somewhat better than on the Clinton and Marion soils, but smaller than those secured on the Grundy soils.

This soil is generally in need of more adequate drainage in order to increase its producing power. It would be benefited by the application of farm manure or the use of leguminous green manure crops. It is acid in reaction and should be limed for the best growth of clover and other legumes. It is low in phosphorus and phosphorus fertilizers will be needed for the production of satisfactory crops continuously. There are indications that such materials might prove of value at the present time.

GRUNDY SILTY CLAY LOAM (115)

The Grundy silty clay loam is a minor type, covering 1,216 acres or 0.4 percent of the total area of the county. It occurs in several small areas in association with the Grundy silt loam, the largest of which is found northeast of Highland Center. Other less extensive areas occur southeast of Dahlonega and east of Agency.

The surface soil of this type is a very dark brown to black friable silty clay loam, extending to a depth of 8 or 10 inches. Below this point, a heavy, compact clay, dark brown or brownish-drab in color, is encountered. In the lower parts of the subsoil, mottlings of brown and yellow are frequently found.

In topography this type is flat to depressed and on this account and also on account of the impervious nature of the subsoil, the drainage is poor.
The Grundy silty clay loam is all under cultivation and corn, small grains, grasses and clover are the chief crops grown. Corn yields from 50 to 80 bushels per acre and other crops produce about the same as on the silt loam.

This type is primarily in need of thorough drainage in order to produce satisfactory crop yields. When thoroughly tiled, yields of corn are even larger than on the adjoining silt loam. It is important in handling the Grundy silty clay loam that it be plowed and cultivated under proper moisture conditions, neither too wet nor too dry, inasmuch as the soil is apt to bake and clod. Fall plowing is considered very desirable, as it permits of improvement in physical condition during the winter. The soil is acid and should receive applications of lime for the best growth of crops, particularly of legumes. It is not high in phosphorus and phosphorus fertilizers will undoubtedly prove of value in the near future, if they are not of use at the present time. Small applications of farm manure may be used to advantage, as they increase decomposition processes and bring a greater production of available plant food. Crop yields may in general be made quite as satisfactory on these areas of heavy soil as they are on the surrounding silt loam and in many instances the yields are even greater on this type.

KNOX FINE SAND (33)

This is a very minor type, covering only 448 acres or 0.2 percent of the total area of the county. It occurs in one area in the northwestern corner of the county, just east of Eddyville.

The surface soil is a loose, incoherent to medium fine sand, of a grayish-brown or brown color. In general, there is little change in the texture or color to a depth of 3 feet, although occasionally in the subsoil the color may be a very light brown to orange or yellow.

Most of this type is under cultivation, the chief crops being corn, hay, fruit and truck crops. Watermelons and cantaloupes are also grown successfully and truck crops are generally the most productive. A small portion of the type is forested with wild plum, scrub oak and various shrubs.

This soil is particularly lacking in organic matter and should receive liberal applications of farm manure, or leguminous crops should be used as green manures. The soil is acid and in need of lime. It is low in phosphorus and, for the production of general farm crops, phosphorus fertilizers should undoubtedly be used.

TERRACE SOILS

There are seven terrace soils in the county, belonging to the Bremer, Calhoun, Jackson, Waukesha and Plainfield series. Together, they cover 16,256 acres or 5.9 percent of the total area.

BREMER SILT LOAM (88)

The Bremer silt loam is the most extensive terrace soil, occupying 4,992 acres or 1.8 percent of the total area of the county. It occurs on the terraces or second bottoms of the various rivers and creeks. The larger areas of the type occur in the Des Moines river valley northwest of Eldon, southwest of Ottumwa and southeast of Eddyville. There are many other small areas of this soil along the minor streams.
The surface soil of the Bremer silt loam is dark brown to black in color. It extends to a depth of 10 to 12 inches. The subsoil is a heavy, tenacious clay, dark brown to black in color in the upper part, and drab, mottled with yellow, in the lower layers. In some areas sand and gravel are found in the subsoil. There are some variations from the typical soil. The areas northeast of Bladensburg resemble the Calhoun silt loam because of the occurrence of a faint gray subsurface layer. In another area, the subsoil is not quite as impervious as the typical. In general, however, the soil type is rather uniform in the different localities.

In topography this soil is level to very gently sloping and the drainage is poor. Practically 75 percent of the type is cultivated, the remainder being in pasture. Corn, oats, wheat, timothy and clover are the chief crops grown. Corn yields from 25 to 80 bushels per acre and other crops give correspondingly satisfactory yields.

This soil is particularly in need of adequate drainage and when thoroughly tiled, produces very satisfactory crops. It is acid and in need of lime. It would be benefited by small applications of farm manure, particularly when newly drained, and the application of phosphorus fertilizers would probably be of value.

CALHOUN SILT LOAM (42)

The Calhoun silt loam is the second largest terrace type in the county, covering 3,776 acres or 1.4 percent of the total area. It occurs chiefly on the terraces of the Des Moines river, the largest areas being found southwest of Ottumwa and surrounding Kirkville station and Reed school. Smaller areas occur at other places along the river and also along Middle Avery creek and some of the other smaller streams.

The surface soil of the Calhoun silt loam is dark gray to dark brown in color and 8 to 10 inches in depth. It is underlaid by a layer of ashy gray to white flour-like silt, 10 to 12 inches in thickness. Immediately beneath this layer there is very heavy, tough, compact, almost impervious, clay, which is dark brown to black in color and mottled with brown, yellow and drab. The surface soil varies in color from almost white to a dark brown or black. The subsurface layer of silt is not always present and in some areas it is only indistinctly developed. The subsoil varies to some extent, in some cases being less tough and plastic and occasionally being yellow or brown in color.

In topography this soil is level to gently undulating and the drainage is poor. The greater part of the type is under cultivation, the remainder being used for pasture. Corn, oats, wheat, timothy and clover are the chief crops grown. Corn yields 30 to 60 bushels per acre, wheat 10 to 30 bushels, oats 20 to 40 bushels and hay about 1 ton per acre.

This soil is particularly in need of tiling in order to insure adequate drainage. It would be benefited materially by the application of farm manure and the use of leguminous crops as green manures. It is acid and in need of lime, and phosphorus fertilizers would probably prove of value in the growing of general farm crops.

JACKSON SILT LOAM (81)

This is a minor soil type, covering 2,368 acres or 0.9 percent of the total area of the county. It is found on the terraces along the Des Moines river, the largest areas occurring near Eldon, southeast of Eddyville and southwest of Ottumwa.
Other smaller areas are found along the Des Moines river and a few areas occur along the Cedar creek.

The surface soil of this type is a light brown to dark brown silt loam, 12 to 14 inches in depth. Below this point the soil is a slightly lighter brown silt loam, streaked with gray. The subsoil is somewhat heavier and in some areas the lower subsoil is a brown silty clay loam or heavy silty clay loam, mottled with yellow and drab. In some areas there has been considerable sand washed under the surface, and layers and pockets of this material are frequently found throughout the subsoil. In topography this soil is level to gently undulating. The drainage is good.

The greater part of the type is under cultivation, general farm crops being grown. Corn is the principal crop, yielding about 40 bushels per acre on the average. Oats, wheat, timothy and clover also give satisfactory yields and alfalfa has been grown successfully in some cases. The type is used locally for market garden crops and small fruits, and proves satisfactory for such crops.

The soil is low in organic matter and would be benefited by the application of farm manure in liberal amounts or the use of leguminous crops as green manures. It is acid and in need of lime, and phosphorus fertilizers would probably prove of value.

Waukesha Silt Loam (75)

The Waukesha silt loam is a minor terrace type, covering 2,240 acres or 0.8 percent of the total area of the county. It occurs on the high terraces of the Des Moines river. The largest areas are found southeast of Eddyville and west and northwest of Eldon and south of McElroy lake. Other smaller areas are found at various places along the river valley.

The surface soil of the Waukesha silt loam is dark brown to black in color and extends to a depth of 10 to 15 inches. At this point it is underlaid by a heavy brown silt loam to light silty clay loam. In the lower part of the subsoil it becomes a light brown in color, slightly mottled with gray. In topography the soil is level to undulating and drainage is adequate.

Practically all of the type is under cultivation, corn being the most important crop grown. Wheat, oats, timothy and clover are also produced to some extent. Corn yields about 40 bushels per acre on the average and the yields of the other general farm crops are similarly satisfactory.

The soil is naturally productive, but crop yields may be increased thru liberal applications of farm manure, the addition of lime as needed and probably also by the use of phosphorus fertilizers.

Waukesha Loam (60)

This is a minor type, covering 1,600 acres or 0.6 percent of the total area of the county. It occurs on the terraces of the Des Moines river, the largest area being found south of Ottumwa.

The surface soil is a dark brown loam, 12 to 14 inches in depth, underlaid by a brown loam which continues with very little change thru the three foot section. In some areas the surface soil is a sandy loam or a fine sandy loam, and in depressions it may be as heavy as a silt loam. On the average, however, it is a loam in texture. The subsoil is somewhat variable and may be a silt loam or silty clay loam. The topography of this type is level to gently undulating and the drainage is satisfactory.
A large part of this type is occupied by the city of Ottumwa and is not of use agriculturally. Trucking is the most important agricultural industry and watermelons and cantaloupes are produced to some extent for local use. Corn, oats, wheat and hay, apples, small fruits and pears are also grown to some extent. When cultivated, this soil would be benefited materially by liberal applications of farm manure. It should be limed when acid, and phosphorus fertilizers would undoubtedly prove of value.

**BREMER SILTY CLAY LOAM (43)**

This is a very minor terrace type, covering only 960 acres or 0.3 percent of the total area of the county. The largest area of this type occurs at Eddyville and another rather extensive area is found northwest of Eldon. Other small areas occur along the Des Moines river valley.

The surface soil of this type is a black silty clay loam, 6 to 8 inches in depth, grading into a dark brown to black, heavy, compact, dense clay. Below 20 inches, the color changes to drab, mottled with yellow or brown. In topography the soil is level and is poorly drained.

Practically all of the type is under cultivation, corn being the principal crop grown. Yields of 35 to 65 bushels per acre are secured. Oats, wheat and timothy also grow well.

This soil is particularly in need of drainage to make it productive. It would be benefited, also, by small applications of farm manure, particularly when newly drained. It is acid and in need of lime, and phosphorus fertilizers would probably prove of value for increased production of general farm crops.

**PLAINFIELD LOAMY FINE SAND (118)**

This is a very minor soil type, covering only 320 acres or 0.1 percent of the total area of the county. It occurs on the terraces of the Des Moines river, the largest area being found southwest of Eldon.

The surface soil of this type is a dark brown loamy fine sand, underlaid at 12 to 15 inches by a light brown sand, which gradually becomes lighter in color and coarser in texture with increasing depths. In some areas, the type includes a variation which possesses a silt loam surface soil. In topography, this soil is level to gently sloping and drainage is good.

Only a small percentage of the type is under cultivation and watermelons, cantaloupes, truck crops and pears are the most important crops.

**SWAMP AND BOTTOMLAND SOILS**

There are seven swamp and bottomland types in the county, belonging in the Genesee, Wabash and Sarpy series. There is also an area of riverwash included in this group. The total area covered by these bottomland types amounts to 30,784 acres or 11.3 percent of the total area of the county.

**GENESEE SILT LOAM (71)**

This is the largest individual bottomland type, covering 14,208 acres or 5.2 percent of the total area of the county. It occurs in extensive areas in the bottoms of the Des Moines river and also in the bottomlands of many of the minor streams, particularly Little Soap creek, Village creek, Bear creek, South Avery, Middle Avery and North Avery creeks. The largest individual areas
are found along the Des Moines river south of Cliffland, south of Ottumwa, west of Ottumwa and southeast of Chillicothe.

The surface soil of this type is a light brown to grayish-brown in color when dry, and brown or dark brown when wet. It ranges in texture from a light silt loam to almost a silty clay loam. The surface soil extends to a depth of 6 to 15 inches and the subsoil is usually a silty clay loam, dark brown in the upper part and mottled with gray and yellow in the lower layers. Pockets and layers of sand are frequently encountered within the three foot section. Several areas are included within this type that vary considerably from the typical. Sand spots are frequently encountered which are too small to be mapped separately, and along Middle Avery creek the soil has been considerably modified. The topography of this soil is level to gently undulating. Where sand spots occur, the surface presents a hummocky appearance. The drainage is generally adequate.

About 75 percent of the type is cultivated, the remainder being forested and in pasture. General farm crops are grown and satisfactory yields are obtained. Corn yields 30 to 75 bushels per acre, wheat 12 to 25 bushels and hay 1 to 2 tons per acre. Watermelons and cantaloupes are grown on small areas.

This soil is subject to overflow and should be protected from flooding if satisfactory crop growth is to be assured. It is very well supplied with organic matter and will be benefited by applications of farm manure and the use of leguminous green manures. It is acid and in need of lime, and phosphorus fertilizers would undoubtedly prove of value where general farm crops are to be grown.

WAPELLO COUNTY SOILS

WABASH SILT LOAM (26)

The Wabash silt loam is the second largest bottomland soil, covering 7,872 acres or, together with the colluvial phase, which is very much smaller in area, covering 4.1 percent of the total area of the county. The type is found on the bottoms along the various streams, the largest areas occurring along Cedar creek. Along this stream, the areas of this type vary in width from 100 yards to three fourths of a mile. The type is also found in narrow areas along Little Cedar, Wolf, Competine, Buckeye, Comstock, and Rock creeks and Honey Branch, and to a small extent along the Des Moines river. Very small areas also occur along some of the streams in the southwestern part of the county.

The surface soil of this type is a dark brown to black, smooth, uniform silt loam, extending to a depth of 10 to 14 inches. The upper subsoil is dark brown in color and a silty clay loam in texture. At lower depths, the color becomes a dark drab, mottled with brown and yellow, and the texture somewhat heavier. In some areas there are variations from the typical soil. Occasionally it possesses a rather gray subsoil. In the Des Moines river bottom, the type is closely associated with the Genesee silt loam and the Wabash silty clay loam and the boundaries between these types are frequently rather arbitrary. Southeast of Eddyville there is a small area of Wabash fine sandy loam, which is not separated, owing to its small extent. North and east of Ogg school there is an area which is covered with coarse sand and gravel. This has been indicated on the map by gravel symbols.
In topography this soil is level to slightly undulating, and the type as a whole is subject to overflow. In general, the drainage is only fair and in many areas the soil is very much in need of drainage.

A large part of the type is under cultivation and most of the remaining area is used as pasture. The pasture land supports a growth of oak, hickory, elm, ash, maple, sycamore and willow. The cultivated portion is devoted to the production of corn, oats, wheat, timothy, clover and alfalfa. Corn yields from 25 to 80 bushels per acre and oats from 25 to 50 bushels per acre.

This soil is quite productive and in favorable season good crop yields are secured on the cultivated areas. It is subject to overflow and if crop growth is to be satisfactory, protection from flooding should be provided in all cases. The soil is frequently in need of more adequate drainage and tiling would be of value. It is fairly well supplied with organic matter, but small applications of farm manure would be of considerable value. It is acid and should be limed, and phosphorus fertilizers would probably prove of value.

**WABASH SILT LOAM (COLLOUVIAL PHASE) (26a)**

This is a minor bottomland type, covering 3,328 acres or slightly more than 1 percent of the county. It occurs along many of the smaller drainage ways and separates them from the upland areas. It is largely derived from the Grundy silt loam, which has been washed down from the upland, although in many cases the soil has been derived from other upland types.

The surface soil of this phase is a dark brown to black silt loam to silty clay loam, extending to a depth of about 10 inches. Below this point there is a dark brown to black silty clay loam subsoil, which in the lower part is mottled with brown, yellow and drab. In some areas the soil is a fine sandy loam and the subsoil frequently contains pockets of sand and gravel.

The drainage of this type is in general rather poor and practically none of the soil is in cultivation, but it is naturally productive and when properly drained, manured and limed, would undoubtedly produce satisfactory crop yields.

**GENESEE FINE SANDY LOAM (117)**

This is a minor soil type, covering 2,176 acres or 0.8 percent of the total area of the county. It occurs on the first bottoms of many of the smaller streams of the county. Some of the more extensive areas are found along the Des Moines river south of Cliffland and west of Eldon, along South Avery creek, south of Munterville and along Fudge creek southwest of Kirkville. There are several other narrow areas along the smaller streams and drainage ways, particularly in the southwestern portion of the county.

The surface soil of this type is a light brown to grayish-brown fine sandy loam, grading at 10 to 12 inches into a brown light silt loam. The texture and color of the subsoil continue with little change to a depth of 3 feet. In some areas the soil is a very fine sandy loam and in others it is a sandy loam or coarse sandy loam, but the texture is in general a fine sandy loam. The subsoil frequently contains layers of sand and gravel and may vary somewhat in color, sometimes being a light brown mottled with gray.

This type is level to slightly undulating in topography and the drainage is good, especially in seasons of excessive rainfall. It is subject to overflow and
if satisfactory crop production is to be insured, protection against flooding should be provided. Practically all of the type is under cultivation, corn, grasses, truck crops, watermelons, cantaloupes, sweet potatoes and alfalfa being the chief crops grown. Corn yields 20 to 65 bushels per acre and wheat 10 to 25 bushels per acre. Melons and truck crops grow well on this type. Yields of other crops are about the same as those secured on the Genesee silt loam.

In general, this type is fairly productive, but there are areas where the soil is very loose and sandy and in such places, crop production is low. The soil should receive liberal applications of farm manure or leguminous green manures if it is to be made satisfactorily productive. It is acid and in need of lime, and phosphorus fertilizers would probably prove of value.

**SARPY SILT LOAM (89)**

This is a minor type, covering 2,112 acres or 0.8 percent of the total area of the county. It occurs in narrow strips along the Des Moines river, the largest areas being found south of Ottumwa, southwest of Kirkville station and south of Eddyville.

The surface soil of this type is a smooth, uniform, brown silt loam, 10 to 15 inches in depth. The upper subsoil is a brown silt loam grading into a very fine sand or a fine sand in the lower portions. The color becomes somewhat lighter at the lower depths and the soil is mottled with gray and yellow. Included with this type are small areas of a heavier soil, varying from a silt loam to a clay, which are too small to map separately. There is also an area of fine sandy loam which is included with this type, owing to its small extent. The surface soil of this variation is a light brownish-gray or grayish-brown fine sandy loam, extending to a depth of 10 to 15 inches. The subsoil is very similar to the surface soil in color, but it is somewhat coarser in texture. The lower part of the three foot section is frequently a fine or very fine sand. Areas of this variation occur along the Des Moines river, one of the most important being found north of the river at Cliffland bridge.

The topography is generally level to slightly undulating and there are occasional ridges of loose sand and depressions of heavier material. This fine sandy loam is unimportant agriculturally, but is used for the growth of general farm crops to some extent, and truck crops are frequently grown satisfactorily.

In topography the Sarpy silt loam is level to slightly undulating and the drainage is good. The type is subject to overflow. About one-half of the area of the soil is cultivated, the remainder being largely forested. Corn is the chief crop grown on the cultivated portion, but wheat, oats, timothy, clover, alfalfa, melons and truck crops are also produced to some extent.

The soil is particularly in need of organic matter for the better growth of crops and, when cultivated, it should receive liberal applications of manure, or leguminous green manures should be employed. It would probably also respond to the application of phosphorus fertilizers.

**WABASH SILTY CLAY LOAM (48)**

This is a very minor type, covering 768 acres or 0.3 percent of the total area of the county. It occurs in the bottoms along the Des Moines river, the largest
areas being found southeast of Eddyville, northwest of Cliffland and southeast of Eldon.

The surface soil of this type is a dark brown to black silty clay loam, 6 to 8 inches in depth. The subsoil to a depth of 20 inches is a dark brown to black clay and at lower depths becomes brown in color and mottled with drab and rusty brown. One small area of this type near the junction of Buckeye and Cedar creeks is really a Wabash clay, and southeast of Eddyville there is an area of the same texture. These are included in the silty clay loam, owing to their small extent. In the area west of Reed School, there are small areas in this type which are covered with medium to coarse sand, underlaid by a dark brown to black subsoil of a heavy, compact structure.

This soil is gently undulating in topography. It is poorly drained and subject to overflow.

Probably about 60 percent of the type is under cultivation, the remainder being in forested pasture. Corn is the chief crop grown on the cultivated areas and wheat, oats and grasses are also grown to some extent.

This soil is particularly in need of drainage if it is to be used for cultivated crops and should also be protected from overflow. Small applications of farm manure would be of value, lime should be applied to remedy acid conditions and phosphorus fertilizers would probably be of use.

**RIVERWASH (53)**

Riverwash consists of heaps of loose fine sand, sand banks or low-lying sand bars occurring along the streams. It is found along the Des Moines river and is subject to frequent overflow. It is of very minor importance, covering only 320 acres or 0.1 percent of the total area of the county. It consists of a grayish-brown to gray and is extremely variable in texture. The type is non-agricultural.

**RESIDUAL SOIL**

There is one residual soil in the county, belonging to the Union series. It is of minor importance, covering less than 1 percent of the total area of the county.

**UNION SILTY CLAY LOAM (116)**

This type covers 2,560 acres or 0.9 percent of the total area of the county. It occurs in association with the Clinton silt loam and the Lindley loam, and is frequently difficult to separate from these types. The largest areas occur northeast, northwest and southeast of Cliffland. Smaller areas are found at Laddsdale along South Avery creek, south of Munterville and south of Happy Hollow school. There are other small areas occurring along the steep slopes of ravines and ridges.

The surface soil of this type is a brown silty clay loam, 6 to 8 inches in depth. The subsoil is a silty clay loam to clay, varying in color from brown to gray or drab, in places splotched with red and reddish-purple. It contains limestone fragments, shale and sandstone, and in many areas the bed rock is reached within the three foot section.

The type is rolling to rough in topography and is unimportant agriculturally, owing to its topography and rough, eroded condition. Practically none of it is under cultivation. It is largely forested with oak, hickory, hazel and other trees and shrubs.
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.

Fig. 8. Map of Iowa showing the counties surveyed, January, 1921
The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

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

**PLANT FOOD IN SOILS**

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

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

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

**THE "SOIL DERIVED" ELEMENTS**

Phosphorus, potassium, calcium and sulfur, known as “soil-derived” elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true 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 elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be unavailable. Plants cannot take up food unless it is in solution; hence available plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

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

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil 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, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

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

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

It is evident from the table that the continuous 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
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>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>12.75</td>
<td>14</td>
<td>$12.00</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>4.5</td>
<td>39</td>
<td>$5.76</td>
</tr>
<tr>
<td>Corn, crop</td>
<td></td>
<td>111</td>
<td>53</td>
<td>$17.76</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>7.2</td>
<td>7.5</td>
<td>$6.81</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>2.4</td>
<td>27</td>
<td>$2.40</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td></td>
<td>57.6</td>
<td>34.8</td>
<td>$9.21</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>5.5</td>
<td>8</td>
<td>$5.28</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>2.5</td>
<td>26</td>
<td>$2.48</td>
</tr>
<tr>
<td>Oats, crop</td>
<td></td>
<td>45.5</td>
<td>24</td>
<td>$7.76</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>5</td>
<td>5.5</td>
<td>$3.68</td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>13</td>
<td>$1.52</td>
</tr>
<tr>
<td>Barley, crop</td>
<td></td>
<td>32.5</td>
<td>18.5</td>
<td>$5.20</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>6</td>
<td>7.5</td>
<td>$4.70</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>3</td>
<td>21</td>
<td>$1.92</td>
</tr>
<tr>
<td>Rye, crop</td>
<td></td>
<td>41.4</td>
<td>28.8</td>
<td>$6.62</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>12.7</td>
<td>50</td>
<td>$10.08</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>27</td>
<td>144</td>
<td>$45.00</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>9</td>
<td>67.5</td>
<td>$11.52</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.
PERMANENT FERTILITY IN IOWA SOILS

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

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 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 by crops. Crop residues, stover and straw return a portion 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.
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. 9.

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. Th fertility of these soils and their needs are greatly influenced, therefore, by their depth.

Fig. 9. Map showing the principal soil areas in Iowa
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—0.19 mm.
- Very fine sand—0.10—0.05 mm.
- Silt—0.05—0.00 mm.

Inorganic matter

SOILS GROUPED BY TYPES

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.

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*25 mm. equals 1 in. †Bur. of Soils Field Book. ‡Loc. cit.
Peaty Loams—15 to 35 per cent of organic matter mixed with much sand and silt and a little clay.

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

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

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

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

Silt Loams—20 percent clay and more than 50 percent silt mixed with 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 20 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 other grades, less than 20 percent silt and clay.

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

Gravels—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.