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Soil Survey of Iowa, Report No. 65—Clayton County Soils

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SOIL SURVEY OF IOWA
CLAYTON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 65
November, 1930
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

Soil Survey Reports*

1 Bremer County.  
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47 Grundy County.  
48 Floyd County.  
49 Worth County.  
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63 Chickasaw County.  
64 Kossuth County.  
65 Clayton County.

*For list of additional publications on soils see inside back cover.
SOIL SURVEY OF IOWA

Report No. 65—CLAYTON COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of T. H. Benton, H. R. Meldrum, L. W. Forman and R. E. Bennett

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


Clayton County is located in northeastern Iowa in the second tier of counties south of the Minnesota state line and is separated by the Mississippi River from Wisconsin on the east. It is partly in the Iowan Drift and partly in the Mississippi loess soil areas, and the soils are, therefore, of loessial and glacial origin.

The total area of Clayton County is 784 square miles or 501,760 acres. Of this area 468,294 acres, or 93.3 percent are in farm land. The total number of farms is 3,148, and the average size of the farms is 149 acres. Owners operate 63.7 percent of the total farm land and renters the remaining 36.3 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1928 show the utilization of the farm land in the county:

- Acreage in general farm crops ........................................................... 230,366
- Acreage in farm buildings, public highways and feed lots ............ 17,942
- Acreage in pasture ................................................................. 197,486
- Acreage in waste land not utilized for any purpose .................. 5,784
- Acreage in farm wood lots used for timber only ..................... 16,175
- Acreage in cropped land lying idle ........................................ 531
- Acreage in crops not otherwise listed .................................. 858

THE TYPE OF AGRICULTURE IN CLAYTON COUNTY

The type of agriculture most commonly followed in Clayton County at present consists of a system of general farming, including the raising and feeding of cattle and hogs, dairying, and the production of general farm crops such as corn, oats and hay. The income on the farms in general comes mainly from the sale of livestock and of some surplus grain crops. The majority of the farms are operated on practically a livestock basis, with all, or nearly all, of the crops utilized for feeding. The production of corn is the most important and the center of all farming activities. Some income is derived on many farms from the sale of the surplus corn produced. Some oats are sold in certain parts of the county, and certain of the minor crops which are produced and sold locally add to the general farm income.

The chief source of income on the farms of the county, however, is from the sale of the cattle, hogs and dairy products.

The county contains a considerable acreage of waste land, much of which might be reclaimed and made profitably productive with proper methods of soil treatment. General recommendations for the treatment of such land cannot be given, as the causes of unproductiveness are so variable. Different methods of handling soils must be practiced in different cases. In a later section of this report, sug-

gestions will be offered for the management of land on the different soil types where at present the crop yields are unsatisfactory. In special cases where the conditions are more or less abnormal, advice regarding soil treatment will be furnished by the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE CROPS GROWN IN CLAYTON COUNTY

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

Corn is by far the most important crop grown. In 1928, it was raised on 17.8 percent of the total farm land in the county, and yields averaged 43.6 bushels per acre. The most common varieties grown are Reid Yellow Dent, Silver King, Wimple Yellow Dent, Minnesota 13 and a local variety known as Early Yellow Dent. On most farms the entire crop is fed to the work animals, beef cattle, hogs and dairy cows. In some cases the surplus is sold on the market. Some of the corn is cut for silage and hogging-down is practiced to some extent. The major portion of the crop, however, is harvested for grain.

The second crop in acreage and value is oats, occupying, in 1928, 15.5 percent of the total farm land. The yields in that year averaged 45.9 bushels per acre. Most of the oats grown are of the earlier varieties, mainly Iowa 103, Iowa 105, Silvermine, Iowa Champion and Early Yellow. Throughout most of the county the oats produced are threshed for grain and fed on the farms. In the southern part of the county some of the surplus oats grown are sold.

TABLE 1. ACREAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN CLAYTON COUNTY, IOWA*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage</th>
<th>Percent of total farm land of county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>83,618</td>
<td>17.80</td>
<td>43.60</td>
<td>3,645,745</td>
<td>$0.67</td>
<td>$2,442,649</td>
</tr>
<tr>
<td>Oats</td>
<td>72,559</td>
<td>15.50</td>
<td>45.90</td>
<td>3,330,520</td>
<td>$0.36</td>
<td>1,198,987</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>134</td>
<td>0.03</td>
<td>19.00</td>
<td>2,540</td>
<td>1.00</td>
<td>2,540</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>844</td>
<td>0.18</td>
<td>23.50</td>
<td>19,835</td>
<td>1.01</td>
<td>20,033</td>
</tr>
<tr>
<td>Barley</td>
<td>11,540</td>
<td>2.50</td>
<td>37.30</td>
<td>430,741</td>
<td>0.54</td>
<td>232,600</td>
</tr>
<tr>
<td>Rye</td>
<td>190</td>
<td>0.04</td>
<td>15.20</td>
<td>2,896</td>
<td>0.86</td>
<td>2,491</td>
</tr>
<tr>
<td>Clover hay†</td>
<td>560</td>
<td>0.12</td>
<td>1.05</td>
<td>588</td>
<td>13.00</td>
<td>7,644</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>30,166</td>
<td>6.40</td>
<td>0.80</td>
<td>24,434</td>
<td>10.50</td>
<td>256,557</td>
</tr>
<tr>
<td>Clover and timothy hay (mixed)</td>
<td>25,216</td>
<td>5.40</td>
<td>0.77</td>
<td>19,416</td>
<td>13.00</td>
<td>252,408</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>66</td>
<td>0.014</td>
<td>2.11</td>
<td>1,397</td>
<td>16.50</td>
<td>23,051</td>
</tr>
<tr>
<td>All other tame hay</td>
<td>1,214</td>
<td>0.26</td>
<td>1.24</td>
<td>2,240</td>
<td>13.00</td>
<td>29,120</td>
</tr>
<tr>
<td>Wild hay</td>
<td>793</td>
<td>0.18</td>
<td>0.72</td>
<td>571</td>
<td>10.00</td>
<td>5,710</td>
</tr>
<tr>
<td>Soybeans sown with other crops</td>
<td>2,346</td>
<td>0.54</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Soybeans sown alone</td>
<td>213</td>
<td>0.04</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Soybeans sown for seed</td>
<td>81</td>
<td>0.017</td>
<td>12.10</td>
<td>982</td>
<td>1.78</td>
<td>1,748</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,530</td>
<td>0.33</td>
<td>131.00</td>
<td>200,430</td>
<td>0.51</td>
<td>102,219</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>46</td>
<td>0.008</td>
<td>16.10</td>
<td>740</td>
<td>0.88</td>
<td>651</td>
</tr>
<tr>
<td>Timothy seed</td>
<td>365</td>
<td>0.09</td>
<td>4.70</td>
<td>1,713</td>
<td>2.15</td>
<td>3,683</td>
</tr>
<tr>
<td>Clover seed†</td>
<td>568</td>
<td>0.13</td>
<td>0.74</td>
<td>421</td>
<td>18.00</td>
<td>7,578</td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1928.
†Sweet clover not included.
‡All varieties for all purposes.
The third crop in acreage and value is hay. In 1928 timothy hay was produced on 6.4 percent of the total farm land. Clover and timothy mixed was grown on 5.4 percent of the total area. A small area was in clover hay and a limited area in other tame hays. Wild hay was produced on 0.18 percent of the total farm land. Timothy yielded 0.8 ton per acre, clover and timothy mixed 0.77 ton per acre, clover 1.05 tons per acre, other tame hays 1.24 tons per acre, and wild hays 0.72 ton per acre, on the average. Some timothy is grown alone for seed, and some clover is grown for seed. A very limited acreage is in sweet clover.

Alfalfa is grown only on a limited acreage. Yields amounted to 2.11 tons per acre. This crop may be grown most successfully in the county provided the soils are limed, the crop is inoculated and other precautions are taken in connection with the seeding. It has not been grown more extensively because it does not seem to fit in well with the system of farming. Clover is more commonly grown, but too often the hay crop of the rotation consists of timothy alone. It would be very desirable to include alfalfa in more of the rotations in the county because of its value as a hay crop and because of its soil building value.

Barley is grown to some extent, yielding 37.3 bushels per acre. A limited area is in wheat. Spring wheat is most commonly grown, and it has yielded 23.5 bushels per acre. Rye is grown on small areas and buckwheat is likewise produced in a very limited way. Potatoes are grown on practically all farms, but chiefly to supply the home needs and local markets. Early Ohio, Rural New Yorker, Irish Cobbler and Early Rose are the varieties grown. Soybeans are produced to some extent, being seeded with the corn for silage and hoggings-down, or grown alone for seed. Vetch, Sudan grass, millet, rape, Canadian field peas and field peas are all grown on limited areas. Considerable sorghum is grown for syrup. In the southeastern part of the county sweet corn is grown on more than a thousand acres, the crop being largely marketed at the cannery in Cassville, Wisconsin.

Fruit growing has not been developed on a commercial scale. Small orchards are maintained on most farms to supply the home needs. Apples, grapes and small fruits are produced quite successfully in the eastern part of the county and the fruit-growing industry might well be extended in that section and placed on a commercial basis. The varieties of apples most commonly grown are Northwestern Greening, Oldenburg, Whitney, Mammoth Black Twig, Winesap, Tolman Sweet and Delicious.

THE LIVESTOCK INDUSTRY IN CLAYTON COUNTY

The livestock industry includes the raising and feeding of hogs and cattle and some dairying. The following figures taken from the Iowa Monthly Crop Report for July 1, 1928, giving the Jan. 1, 1928; estimates of the Bureau of Agricultural Economics of the U. S. Department of Agriculture in cooperation with the Iowa State Department of Agriculture, show the extent of the livestock industry.

<table>
<thead>
<tr>
<th>Livestock</th>
<th>Number on Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses</td>
<td>13,700</td>
</tr>
<tr>
<td>Mules</td>
<td>450</td>
</tr>
<tr>
<td>Cattle, all</td>
<td>63,600</td>
</tr>
<tr>
<td>Hogs</td>
<td>134,100</td>
</tr>
<tr>
<td>Sheep</td>
<td>8,100</td>
</tr>
</tbody>
</table>
The chief source of income on most farms is from the sale of livestock. The raising and feeding of cattle, the raising and feeding of hogs and dairying are the chief livestock industries.

The total number of hogs on the farms Jan. 1, 1928, was 134,100, an average of 42 per farm. Common breeds are Poland China, Duroc Jersey, Chester White and Hampshire. The hogs are pastured on clover and fattened on corn, usually by hogging-down. They are marketed at packing houses in Chicago, St. Paul, Cedar Rapids and Dubuque.

On Jan. 1, 1928, there were 63,600 cattle on the farms of the county. The average number to the farm was about 22 head, of which about one-third were dairy cows. Many dual purpose cows of the Shorthorn breed are milked. Purebred cattle are mainly of the Shorthorn and Holstein-Friesian breeds. The dairy industry is developed extensively and the county ranks high among Iowa counties in the number of dairy cows and the value of dairy products. Butterfat is the principal product sold from the farms. In 1924, 3,980,396 pounds were marketed. In the same year, 305,556 gallons of whole milk were marketed, mainly at Strawberry Point.

Some horses are raised and a few mules, chiefly to supply the need for farm work. A few sheep are raised principally on the rougher land. The sheep growing industry, however, is not very well developed.

The county ranks among the first in the state in poultry raising. The average number of chickens per farm is about 150. The flocks are largely of mixed breeds. Most of the eggs and poultry are handled thru dealers at nearby towns. The value of poultry products to the farms of the county is high, and much is added to the farm income thru the sale of poultry and poultry products.

THE FERTILITY CONDITIONS IN CLAYTON COUNTY SOILS

The average yields of general farm crops in Clayton County are fairly satisfactory, but in many cases much larger crops might be secured if proper methods of soil management were adopted. Some of the land is not adequately drained, and the installation of tile is necessary if the best crop yields are to be secured. The Clyde silty clay loam and the Clyde silt loam on the drift uplands are normally poorly drained. The Sogn clay loam on the residual uplands is also poorly drained. On small areas in some of the other upland types, drainage is not adequate. On the terraces some areas are not satisfactorily drained, particularly the Davenport silty clay loam, and on the bottomlands the Wabash types are in need of drainage. Adequate drainage is always essential on poorly drained areas before any other soil treatments are employed for the increasing of crop yields.

Practically all of the soils in the county are acid in reaction and, therefore, in need of lime. Only the Dodgeville loam on the drift uplands, the Sogn clay loam on the residual upland and the Cass and Sarpy soils on the bottomlands show any lime content in the surface soil. It is very desirable, therefore, that all the soils in the county, with the exception of the types mentioned, be tested for lime needs and the proper amount of lime be applied if the most satisfactory crop growth is to be secured. Large increases in the yields of such crops as alfalfa and sweet clover are obtained by the use of lime. Benefits from additions of lime have been shown by many experiments and by much farm experience with various legume
crops. Large increases are also frequently secured in the yields of other general farm crops. For building up and maintaining the fertility of the soils of this county, the application of lime as needed is a basic and fundamental treatment.

A number of the soils in Clayton County are not well supplied with organic matter and nitrogen and additions of fertilizing materials supplying these constituents are necessary. On all the soils such fertilizing materials should be applied at regular intervals, however, if the content of organic matter and nitrogen is to be kept up. Even on those types which are apparently richer in organic matter, blacker in color and less in need of fertilization, it is important that additions of organic materials be made regularly. Liberal additions of farm manure to all the soils of the county are strongly recommended. Large increases in the yields of general farm crops follow its use. It is the most valuable fertilizer which can be employed and plays a large part in the building up and maintaining of fertility in the soil. All crop residues should be thoroughly utilized on the farm to aid in maintaining the supply of organic matter and nitrogen.

Where farm manure is not produced in sufficient amounts to permit a regular supply to all the land on the farm, the turning under of leguminous crops as green manures is highly desirable. Legumes, when well inoculated, draw upon the nitrogen of the atmosphere for much of their content of that element, and hence when turned under in the soil, increase the nitrogen content of the soil. They also add large amounts of valuable organic matter and thus have a double value. On some of the lighter-colored, coarser-textured soils in the county, such as the Lindley sandy loam, the Lindley loam, the Carrington sandy loam, the Carrington loam, the Thurston sandy loam on the drift upland, the light colored phase of the Tama silt loam, the Fayette silt loam and the Clinton silt loam on the loess upland, the light colored phase of the Tama silt loam, the Fayette silt loam and the Clinton silt loam on the loess upland, on the O'Neill and Plainfield soils on the terraces, and on the Genesee, Sarpy and Cass soils on the bottoms, the additions of organic matter are particularly necessary. On these types the use of farm manure is of particularly large value. The utilization of crop residues and the turning under of leguminous crops as green manures would have considerable effects. Even on the heavier types of soils and those which are darker in color, the regular use of these natural fertilizing materials is very desirable to stimulate the production of available plant food and to permit the maintenance of the proper amount of organic matter and nitrogen in the land.

The analyses of the various soils in Clayton County have shown that the phosphorus content is rather low. It is certain that the addition of a phosphate fertilizer will be needed in the near future. There is some evidence, however, that the application of a phosphate fertilizer would be of large value in many cases on these soils at present. Either rock phosphate or superphosphate may be employed and economic returns secured from the application. Farmers are urged to test both phosphates and thus determine whether a phosphate fertilizer will prove profitable and which phosphorus carrier will be the more economical. On the lighter-colored, coarse-textured soils and especially those which are low in organic matter, the superphosphate may prove of superior value and give quicker returns. On the soils which are higher in organic matter, rock phosphate may prove quite as desirable.
Complete commercial fertilizers may also be tested in comparison with the phosphates. Their general use cannot be recommended at present, but if tests carried out under field conditions prove them to be of value, there is no possible objection to their application. It is merely a question of the economic returns secured from the treatment. For special crops or truck crops, the application of a complete commercial fertilizer may prove of very large value. Commercial nitrogenous fertilizers are not considered desirable for general use at present. Small amounts as top dressings for special crops may prove profitable, but in general the use of leguminous crops as green manures and the turning under of farm manure will permit building up and maintaining the nitrogen content of the soil without the use of expensive nitrogenous commercial fertilizers. Commercial potassium fertilizers, likewise, cannot be recommended for general use in the county. They may be employed in certain cases with desirable effects. Tests should be carried out on small areas, however, before these fertilizers are applied in any large way. On some of the soils and for special crops, it is quite possible that the addition of muriate of potash or some other potash fertilizer might prove desirable.

Considerable erosion occurs in Clayton County and a number of the soil types have been seriously injured by this destructive action. Gullies have been formed and naturally fertile areas of land have been made unproductive. Sheet washing has occurred, frequently removing much or all of the fertile surface soil. The Lindley soils on the drift uplands are seriously eroded. The Tama, Fayette and Clinton soils on the loessial upland are all eroded, the Fayette and Clinton types being especially seriously influenced. The steep phases of these types show the most extensive erosion. Wherever these injurious effects of erosion are evidenced, some method should be employed to prevent or control the action. From among the methods suggested later in this report, one may be chosen which will prove satisfactory under almost any soil condition.

THE GEOLOGY OF CLAYTON COUNTY

The rock formations underlying the soils of Clayton County have generally been buried so deeply by deposits of glacial material and of loess that they have little influence on the character of the soil. Only in the case of the Sogn loam and Sogn clay loam, the Dubuque silt loam and the Dodgeville loam, the Millsdale loam, the Millsdale fine sandy loam and the Davenport silty clay loam, is the soil derived from the underlying rock material in any part. The Sogn loam, Sogn clay loam and Dubuque silt loam are definitely residual soils and are derived from the underlying rock material. The Millsdale types and the Davenport silty clay loam are formed in part from the underlying rock. The total acreage of the county covered by these soils which are largely or entirely of residual origin, is rather small.

During the glacial age great glaciers swept over the county and upon their retreat left behind thick deposits of debris or glacial till. The movement of the glaciers leveled the surface features of the county and upon their retreat the old valleys were filled and other topographic features were largely obliterated. The earlier glacier known as the Kansan, left behind a deposit which varies considerably in depth. The drift material consisted chiefly of a blue clay containing numer-
ous boulders of varying size. When weathered the surface material has been oxidized to a reddish-brown color and is underlaid by a yellowish boulder clay grading into the unoxidized blue clay of the original drift. None of the soil types in the county has been derived entirely from the Kansan till, as it has been covered in later periods by other deposits. In some instances, however, erosion has occurred and the earlier deposits have been exposed in the three-foot section. Thus the soils of the Lindley series are derived in part from the Kansan till, the surface covering of these soils having been formed from the later deposits. Associated with these old drift deposits, beds of gravel are occasionally found. These are known as the Buchanan gravels. Some of these deposits have an effect on the subsoil conditions. This is particularly the case with the Thurston sandy loam, a minor type on the drift uplands.

The later glaciation known as the Iowan, covered a large part of the county and left a deposit varying in thickness from 10 to 20 feet. The deposit consists of a yellow clay containing numerous boulders, sand and coarse gravel. The soils of the Carrington, Clyde, Dodgeville and Thurston series are derived from this Iowan drift material. The surface covering of the Lindley soils is undoubtedly of Iowan origin, altho the subsoils are derived from the underlying Kansan till.

At a much later period in geological history, when climatic conditions were very different than those occurring at present, there was laid down over the surface of most of the county a finely divided silty material known as loess. This deposition was undoubtedly made by the wind. About three-fourths of the county was covered by this loessial deposit. In its original unweathered condition it consisted of a yellowish fine grained silty material varying widely in thickness, being rather shallow in some areas and extending to considerable depths in other places. The weathering of the surface material and the accumulation of the plant residues have darkened the color of the soil. The erosion which has occurred in some sections has caused considerable variation in the character of the soil material and especially in the thickness of the loessial covering. The soils of the Tama, Fayette and Clinton series are of loessial origin. Erosion has occurred extensively in the Fayette and Clinton soils and the steep phases of these types have been developed. The surface soils of these areas are comparatively shallow. Similarly with the light colored phase of the Tama silt loam, there has been erosion, a less accumulation of organic matter and the soil is much shallower.

Terraces or second bottomlands have been developed to some extent and are derived largely from the loessial and glacial material washed down from the adjacent uplands. They have also been modified to some extent by beds of gravel laid down in the glacial age. The higher terraces are classified in the Waukesha, O'Neil and Judson series. The Davenport and Millsdale soils are terrace deposits on limestone rock. The bottomland soils are made up of loessial and glacial materials washed down from the uplands and are largely subject to overflow. They are classified in the Wabash, Genesee, Cass and Sarpy series. There are small areas of muck in the county and a considerable area of riverwash. These bottomland soils are found in relatively narrow areas along the various streams and creeks.
Clayton County has two main topographic divisions. The first, which includes the entire county except for a small area in the southwestern corner, has a strongly rolling to rough surface, the most prominent feature being the deep, sharply cut valleys of the Mississippi River and the lower stretches of its larger tributaries. These valleys have been carved 500 and 600 feet below the general level of the uplands. Included with this area are the regions which were not overrun by the latest ice sheets which modified the relief so extensively in other parts of the state, and also the region which was covered by the Kansan glacier, the deposits of which have not materially altered the surface features of the land.

The Mississippi River valley is one and one quarter miles wide from cliff to cliff and the channel winds from side to side across the flood plains. The bluffs in places rise abruptly to a height of 300 to 400 feet above the flood plains. From this height the slope has a more gradual ascent to 600 or more feet above the river. For some distance above and below McGregor and also in the vicinity of Guttenberg, limestone cliffs rise abruptly and are a striking feature of the valley. These cliffs stand from 50 to 100 feet high and in some places the slopes are steep and covered with a heavy growth of timber. This rugged relief is seen only in a strip several miles wide which follows the Mississippi River. All the tributary streams

Fig. 2. Map showing the natural drainage system of Clayton County.

PHYSIOGRAPHY AND DRAINAGE

Clayton County has two main topographic divisions. The first, which includes the entire county except for a small area in the southwestern corner, has a strongly rolling to rough surface, the most prominent feature being the deep, sharply cut valleys of the Mississippi River and the lower stretches of its larger tributaries. These valleys have been carved 500 and 600 feet below the general level of the uplands. Included with this area are the regions which were not overrun by the latest ice sheets which modified the relief so extensively in other parts of the state, and also the region which was covered by the Kansan glacier, the deposits of which have not materially altered the surface features of the land.

The Mississippi River valley is one and one quarter miles wide from cliff to cliff and the channel winds from side to side across the flood plains. The bluffs in places rise abruptly to a height of 300 to 400 feet above the flood plains. From this height the slope has a more gradual ascent to 600 or more feet above the river. For some distance above and below McGregor and also in the vicinity of Guttenberg, limestone cliffs rise abruptly and are a striking feature of the valley. These cliffs stand from 50 to 100 feet high and in some places the slopes are steep and covered with a heavy growth of timber. This rugged relief is seen only in a strip several miles wide which follows the Mississippi River. All the tributary streams
flowing across this strip occupy deep narrow valleys. The valleys of the Turkey and Volga rivers have been cut to a depth of 400 or 500 feet. In places the flood plain is one-half mile wide. Cliffs stand out on the steep slopes in many places. Toward the western part of the county where these streams flow thru soft shale, the valleys are wider and the slopes are smoother.

A prominent feature of the topography is the high ridge between the Turkey and Volga rivers which has a width of about 2½ miles between Osborne and Elkader and reaches a height of 450 feet above the adjacent streams. The valley of Bloody Run extends 10 miles thru a narrow steep-sided gorge from 300 to 400 feet deep. The region north and east of Turkey Valley is made up of a succession of broad gently rolling divides separated by stream valleys. South of the Volga and Turkey rivers, for several miles the country is rough and cut by many streams whose valleys extend thru the limestone rocks. The steep slopes are wooded and covered with blocks of limestone which have broken off.

The second topographic division, including the southwestern corner of the county, has been formed largely by the Iowan glacier. It occupies a part of Cass and Lodomillo townships. This region is marked by broad hills or ridges of drift, rising 50 to 60 feet above the general level of the drift plains. The topography of this area is generally more gently rolling to undulating.

Except for a few drainageways in the northern and eastern corner of the county that flow into the Yellow River in Allamakee County, which is also a tributary of the Mississippi River, a few short intermittent branches that empty directly into the Mississippi River and half a dozen small streams in the Iowan drift section, the drainage of the county flows thru one of the five streams discharging into the Mississippi River, all located within the county. Bloody Run, Sny, Magill and Buck creeks drain the northeastern part of the county. Turkey River with its tributaries, including Roberts Creek and Mill Creek, drains the larger portion of the central part of the county and the southeastern section. The Volga River with its tributaries drains the southwestern part of the county. The chief tributaries of this river are Hewett Creek, Pine Creek, Wolf Creek, Coon Creek, Spring Creek and Bear Creek. The Little Turkey River, Blue Bell Creek and a number of minor streams drain the extreme southeastern corner of the county. The Maquoketa River crosses the southwestern corner of the county and brings about the drainage of a limited area there. Hickory Creek in the northwestern corner of the county flows into Allamakee County, draining a small portion of Clayton.

Except in the Iowan drift section where drainage is not very satisfactory, the county as a whole is fairly well drained. The run-off is excessive in all parts of the county except in the southwestern corner and the Garnavillo prairie, but even this area is well drained. The majority of the streams, with their tributaries and intermittent drainageways extend into all parts of the upland and bring about satisfactory drainage conditions. Only the areas of the Clyde soils on the drift uplands are poorly drained together with limited areas in some of the other upland soils. Some of the bottomland types and a few of the terrace soils are in need of drainage to be made more satisfactorily productive. In the case of the bottomland soils, protection from overflow is also needed if the soils are to be satisfactorily cultivated.
TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN CLAYTON COUNTY

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>27,968</td>
<td>5.3</td>
</tr>
<tr>
<td>Loess soils</td>
<td>375,104</td>
<td>74.7</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>11,392</td>
<td>2.4</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>51,584</td>
<td>10.2</td>
</tr>
<tr>
<td>Residual soils</td>
<td>35,712</td>
<td>7.0</td>
</tr>
<tr>
<td>Total</td>
<td>501,760</td>
<td></td>
</tr>
</tbody>
</table>

THE SOILS OF CLAYTON COUNTY

The soils of Clayton County are grouped into five classes according to their origin and location: Drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are formed from materials carried by glaciers and left behind on the surface of the land when the glaciers retreated. They are variable in composition and contain pebbles and boulders. Loess soils are fine dust-like deposits made by the wind at a time when climatic conditions were quite different than at present. Terrace soils are old bottomlands which have been raised above overflow by a deepening of the river channel or by a decrease in the volume of the streams which deposited them. Swamp and bottomland soils occur in low, poorly drained areas along streams and are subject to more or less frequent overflows. Residual soils are those which are formed from the underlying rock material and which remain resting upon it. The extent and occurrence of these groups of soils in Clayton County are shown in table II.

Drift soils cover 5.3 percent of the total area. The loessial soils are much more extensively developed, covering almost three-fourths of the total area, 74.7 percent. Terrace soils are minor in area, covering 2.4 percent of the county. Swamp and bottomland soils cover 10.2 percent of the total area. Residual soils are developed somewhat extensively, covering 7 percent of the county.

There are 31 soil types, and these with the light colored phase of the Tama silt loam, the steep phase of the Fayette silt loam, the steep phase of the Clinton silt loam, the colluvial phase of the Wabash silt loam and the areas of riverwash, muck and rough stony land make a total of 38 separate soil areas. Each type is distinguished on the basis of certain definite characteristics which are discussed later in the appendix to this report. The areas of the different soil types in the county are shown in table III.

The Carrington loam is the most extensively developed drift soil, covering 2 percent of the total area. The Lindley sandy loam is the second largest drift soil, covering 1.1 percent of the area. The Lindley loam is slightly smaller in area, covering 1 percent of the county. The remaining drift soils of the Clyde, Carrington, Dodgeville and Thurston series all cover less than 1 percent of the total area.

The Tama silt loam, together with the light-colored phase which is much smaller in area, is the most extensively developed soil and the largest loess type. It covers 33 1/3 percent of the total area of the county. The Fayette silt loam with the steep phase which is very limited in area, is the second largest soil type in the county and the second largest loess type. It covers 28.8 percent of the total area.
The Clinton silt loam with its steep phase which is much smaller in total area is the third largest type, covering 12.6 percent of the total area.

The terrace soils are all limited in area, none covering more than 0.6 percent of the total area of the county. The Waukesha silt loam is the largest and covers 0.6 percent of the total area. The other types of the O’Neill, Bertrand, Judson, Plainfield, Davenport and Millsdale series all cover 0.4 percent or less of the total area.

The Wabash silt loam, together with the colluvial phase, which is smaller in area, is the largest bottomland type and the fifth largest individual soil type in the

### TABLE III. AREAS OF DIFFERENT SOIL TYPES IN CLAYTON COUNTY

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindley sandy loam</td>
<td>5,376</td>
<td>1.1</td>
</tr>
<tr>
<td>Lindley loam</td>
<td>4,864</td>
<td>1.0</td>
</tr>
<tr>
<td>Clyde silty clay loam</td>
<td>1,856</td>
<td>0.4</td>
</tr>
<tr>
<td>Clyde silt loam</td>
<td>1,856</td>
<td>0.4</td>
</tr>
<tr>
<td>Carrington sandy loam</td>
<td>2,240</td>
<td>0.4</td>
</tr>
<tr>
<td>Dodgeville loam</td>
<td>1,536</td>
<td>0.3</td>
</tr>
<tr>
<td>Carrington loam</td>
<td>10,112</td>
<td>2.0</td>
</tr>
<tr>
<td>Thurston silt loam</td>
<td>128</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tama silt loam</td>
<td>135,552</td>
<td>33.3</td>
</tr>
<tr>
<td>Tama silt loam (light colored phase)</td>
<td>31,808</td>
<td></td>
</tr>
<tr>
<td>Fayette silt loam</td>
<td>140,160</td>
<td>28.8</td>
</tr>
<tr>
<td>Fayette silt loam (steep phase)</td>
<td>4,352</td>
<td></td>
</tr>
<tr>
<td>Clinton silt loam</td>
<td>50,816</td>
<td>12.6</td>
</tr>
<tr>
<td>Clinton silt loam (steep phase)</td>
<td>12,416</td>
<td></td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waukesha silt loam</td>
<td>2,816</td>
<td>0.6</td>
</tr>
<tr>
<td>O’Neill sandy loam</td>
<td>1,920</td>
<td>0.4</td>
</tr>
<tr>
<td>Bertrand silt loam</td>
<td>2,304</td>
<td>0.4</td>
</tr>
<tr>
<td>Judson silt loam</td>
<td>1,600</td>
<td>0.3</td>
</tr>
<tr>
<td>O’Neill loam</td>
<td>832</td>
<td>0.2</td>
</tr>
<tr>
<td>Plainfield sandy loam</td>
<td>1,152</td>
<td>0.2</td>
</tr>
<tr>
<td>Davenport silty clay loam</td>
<td>64</td>
<td>0.1</td>
</tr>
<tr>
<td>Millsdale loam</td>
<td>384</td>
<td>0.1</td>
</tr>
<tr>
<td>Millsdale fine sandy loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wabash silt loam</td>
<td>13,696</td>
<td>4.6</td>
</tr>
<tr>
<td>Wabash silt loam (colluvial phase)</td>
<td>9,664</td>
<td></td>
</tr>
<tr>
<td>Genesee silt loam</td>
<td>11,392</td>
<td>2.3</td>
</tr>
<tr>
<td>Riverwash</td>
<td>6,784</td>
<td>1.3</td>
</tr>
<tr>
<td>Genesee very fine sandy loam</td>
<td>3,264</td>
<td>0.7</td>
</tr>
<tr>
<td>Genesee silty clay loam</td>
<td>1,664</td>
<td>0.3</td>
</tr>
<tr>
<td>Cass silt loam</td>
<td>1,536</td>
<td>0.3</td>
</tr>
<tr>
<td>Wabash loam</td>
<td>1,728</td>
<td>0.3</td>
</tr>
<tr>
<td>Cass sandy loam</td>
<td>1,152</td>
<td>0.2</td>
</tr>
<tr>
<td>Sarpy very fine sandy loam</td>
<td>640</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>RESIDUAL SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough stony land</td>
<td>33,664</td>
<td>6.7</td>
</tr>
<tr>
<td>Sogn loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>Sogn clay loam</td>
<td>768</td>
<td>0.1</td>
</tr>
<tr>
<td>Dubuque silt loam</td>
<td>768</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>501,760</strong></td>
<td></td>
</tr>
</tbody>
</table>
county. It covers 4.6 percent of the total area. The Genesee silt loam is the second largest bottomland soil, covering 2.3 percent of the county. The area of riverwash is third in extent, covering 1.3 percent of the total area. The remaining bottomland soils cover less than 1 percent of the total area.

A considerable area of rough stony land occurs in the county, 6.7 percent of the total area. The areas of residual soils in the Sogn and Dubuque series each cover only 0.1 percent of the total area of the county.

There is some relationship between the development of the various soil types and the topographic features of the upland. The Carrington soils have developed on the more gently undulating to rolling uplands while the Clyde soils are found in the level to depressed areas. The Lindley types and the Thurston sandy loam occur on the more strongly rolling to rough areas of the county. On the loessial uplands the Tama silt loam is found on the more gently rolling to undulating uplands while the Clinton and Fayette types are more strongly rolling to broken in topography. The terrace and bottomland soils are usually somewhat level in topography and on the higher terraces there are some topographic variations. In the case of the Waukesha and the Judson soils, the topography is gently rolling. On the bottomlands the topographic features are generally lacking. The residual soils are usually found on slopes and, therefore, have a rough topography.

**The Fertility in Clayton County Soils**

Samples were taken for analyses from each of the soil types in the county. The areas of riverwash, muck and rough stony land were not sampled owing to the great variability of the material in these areas and their unimportance agriculturally. The more extensive soil types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest care so that the results should be representative of the particular soil type and to avoid variations due to abnormal soil conditions or previous treatments. Samples were secured at three depths, 0 to 6\(\frac{1}{2}\) inches, 6\(\frac{1}{2}\) to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirements. The official methods were employed in the nitrogen, phosphorus and carbon determinations and the Truog qualitative test was followed for the determination of the limestone requirement. The figures given in the tables are the averages of duplicate determinations of all samples of each type and they represent, therefore, the averages of two or six determinations.

**The Surface Soil**

The results of the analyses of the surface soil are given in table IV. They are calculated on the basis of 2 million pounds of surface soil per acre. The content of phosphorus in the different soil types in the county varies widely, ranging from 458 pounds per acre in the Lindley sandy loam up to 2,094 pounds per acre in the Sogn clay loam. There is little evidence of any relationship between the phosphorus content of the soils and the various soil groups. The bottomland soils average slightly higher than the upland and terrace types, but the difference is not great. It might be expected that the bottomland soils would be somewhat higher in plant
food inasmuch as there has been less crop growth on those areas and hence a smaller removal of plant food from the soil. The variations within groups are much more striking than those between groups.

Some relationships are evidenced between the phosphorus content of the various types and the soil series in which they are grouped. Thus on the drift uplands the Clyde soils are the highest in phosphorus and the Carrington and Dodgeville soils are lower than the other soils in the group. The highest average phosphorus content is found in the Carrington soils, 1.4 lb. per acre, and the lowest in the Lindley soils, 0.5 lb. per acre. This relationship is not, however, maintained in the same manner on the loess soils.

### TABLE IV. PLANT FOOD IN CLAYTON COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>161</td>
<td>Lindley sandy loam</td>
<td>458</td>
<td>1,000</td>
<td>10,626</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>1,030</td>
<td>2,720</td>
<td>27,737</td>
<td>4,500</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>1,037</td>
<td>5,400</td>
<td>43,059</td>
<td>3,000</td>
</tr>
<tr>
<td>84</td>
<td>Clyde silt loam</td>
<td>1,778</td>
<td>8,240</td>
<td>64,684</td>
<td>7,000</td>
</tr>
<tr>
<td>3</td>
<td>Carrington sandy loam</td>
<td>781</td>
<td>1,230</td>
<td>14,435</td>
<td>4,000</td>
</tr>
<tr>
<td>223</td>
<td>Dodgeville loam</td>
<td>1,568</td>
<td>6,900</td>
<td>43,410</td>
<td>9,574</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,091</td>
<td>3,680</td>
<td>34,732</td>
<td>8,000</td>
</tr>
<tr>
<td>162</td>
<td>Thurston sandy loam</td>
<td>1,158</td>
<td>1,160</td>
<td>12,680</td>
<td>4,000</td>
</tr>
</tbody>
</table>

**LOESS SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>1,131</td>
<td>3,480</td>
<td>35,496</td>
<td>5,500</td>
</tr>
<tr>
<td>177</td>
<td>Tama silt loam (light colored phase)</td>
<td>1,198</td>
<td>2,560</td>
<td>27,079</td>
<td>3,000</td>
</tr>
<tr>
<td>163</td>
<td>Fayette silt loam</td>
<td>1,010</td>
<td>2,280</td>
<td>18,407</td>
<td>3,000</td>
</tr>
<tr>
<td>235</td>
<td>Fayette silt loam (steep phase)</td>
<td>538</td>
<td>1,280</td>
<td>12,462</td>
<td>3,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>835</td>
<td>1,800</td>
<td>22,006</td>
<td>3,500</td>
</tr>
<tr>
<td>176</td>
<td>Clinton silt loam (steep phase)</td>
<td>794</td>
<td>2,200</td>
<td>25,043</td>
<td>None</td>
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</tbody>
</table>

**TERRACE SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,226</td>
<td>3,740</td>
<td>38,873</td>
<td>6,000</td>
</tr>
<tr>
<td>126</td>
<td>O'Neill sandy loam</td>
<td>875</td>
<td>1,580</td>
<td>16,848</td>
<td>None</td>
</tr>
<tr>
<td>193</td>
<td>Bertrand silt loam</td>
<td>821</td>
<td>2,280</td>
<td>19,907</td>
<td>3,000</td>
</tr>
<tr>
<td>131</td>
<td>Judson silt loam</td>
<td>1,884</td>
<td>4,640</td>
<td>51,458</td>
<td>4,000</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>1,535</td>
<td>3,480</td>
<td>35,429</td>
<td>4,000</td>
</tr>
<tr>
<td>98</td>
<td>Plainfield sandy loam</td>
<td>606</td>
<td>1,400</td>
<td>14,234</td>
<td>1,000</td>
</tr>
<tr>
<td>101</td>
<td>Davenport silty clay loam</td>
<td>1,064</td>
<td>3,960</td>
<td>36,596</td>
<td>5,000</td>
</tr>
<tr>
<td>209</td>
<td>Millsdale loam</td>
<td>1,670</td>
<td>3,880</td>
<td>39,596</td>
<td>6,000</td>
</tr>
<tr>
<td>236</td>
<td>Millsdale fine sandy loam</td>
<td>956</td>
<td>2,360</td>
<td>25,415</td>
<td>6,000</td>
</tr>
</tbody>
</table>

**SWAMP AND BOTTOMLAND SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,144</td>
<td>3,280</td>
<td>32,287</td>
<td>3,000</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (coluvial phase)</td>
<td>1,498</td>
<td>4,860</td>
<td>41,471</td>
<td>3,000</td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>1,522</td>
<td>2,600</td>
<td>20,451</td>
<td>None</td>
</tr>
<tr>
<td>70</td>
<td>Genesee very fine sandy loam</td>
<td>956</td>
<td>2,040</td>
<td>14,660</td>
<td>None</td>
</tr>
<tr>
<td>182</td>
<td>Genesee silty clay loam</td>
<td>956</td>
<td>2,280</td>
<td>21,105</td>
<td>None</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>1,804</td>
<td>4,520</td>
<td>43,271</td>
<td>1,000</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,158</td>
<td>5,400</td>
<td>54,785</td>
<td>7,000</td>
</tr>
<tr>
<td>19</td>
<td>Cass sandy loam</td>
<td>808</td>
<td>1,840</td>
<td>19,151</td>
<td>3,346</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>970</td>
<td>1,360</td>
<td>10,193</td>
<td>None</td>
</tr>
</tbody>
</table>

**RESIDUAL SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>237</td>
<td>Sogn loam</td>
<td>1,252</td>
<td>6,920</td>
<td>69,102</td>
<td>3,000</td>
</tr>
<tr>
<td>164</td>
<td>Sogn clay loam</td>
<td>2,694</td>
<td>4,440</td>
<td>40,031</td>
<td>3,575</td>
</tr>
<tr>
<td>183</td>
<td>Dubuque silt loam</td>
<td>794</td>
<td>2,200</td>
<td>18,789</td>
<td>3,000</td>
</tr>
</tbody>
</table>
are better supplied than the Lindley types. The Thurston sandy loam is very similar to the Carrington soils. On the loessial uplands the Tama silt loam is much higher in phosphorus than the Fayette and Clinton types, and the Fayette is better supplied than the Clinton. On the terraces the Judson and Millsdale soils are the richest in phosphorus, and the Plainfield and O'Neill types are the lowest. The Waukesha, Davenport and Bertrand soils are somewhat lower than the Millsdale and Judson types. On the bottomlands the Cass and Wabash soils are richer than the Genesee and Sarpy types. Among the residual soils the Sogn types are very much richer in phosphorus than the Dubuque soils.

It appears that there is, in general, some relationship between the characteristics which serve to determine the soil series and the phosphorus content. The color of the soil, the topographic position and the characteristics of the subsoil are all important. Those soils which are dark in color, level or flat in topography and have heavier subsoils are generally better supplied with phosphorus than are the light colored types and those which occur on more rolling to steep topographic positions and have sandy or gravelly subsoils. Thus the Clyde soils on the drift uplands are darker in color, more level in topography and have heavier subsoils and they are the richest in phosphorus of the drift types. On the loessial upland the Tama soils are darker than the Fayette and Clinton types, not so strongly rolling in topography and they are higher in phosphorus. On the terraces those types which have heavy subsoils and are dark in color, like the Judson and Millsdale types, are richer than the Plainfield and O'Neill soils which are light in color and have gravelly subsoils. On the bottomlands the Wabash and Cass soils are richer than the Genesee and Sarpy types which are lighter in color.

The texture of the soil is of considerable significance in relation to the phosphorus content. On the drift uplands, the Lindley loam is much better supplied than the Lindley sandy loam. The Carrington loam is richer than the Carrington sandy loam, and the Clyde silt loam has more phosphorus than the Clyde silty clay loam, which is contrary to what is usually found. Ordinarily the silty clay loam would be the richer in the element. No comparisons are possible among the loess soils except that the steep phase of the Fayette silt loam and the steep phase of the Clinton silt loam are lower in phosphorus than the typical soils, as would be expected. There is little difference in the phosphorus content of the light colored phase of the Tama silt loam and that of the typical soil, altho the light colored phase might naturally be expected to be somewhat lower in phosphorus. On the terraces the O'Neill loam is much higher than the O'Neill sandy loam. The Millsdale loam is richer in phosphorus than the Millsdale fine sandy loam. On the bottomlands the Genesee silt loam is richer than the Genesee very fine sandy loam. The Genesee silty clay loam is no higher than the fine sandy loam. It would ordinarily be expected to be richer than the silt loam. The Wabash silt loam and colluvial phase of the type are somewhat richer than the Wabash loam. The Cass silt loam is very much higher in phosphorus than the Cass sandy loam. Of the residual soils the Sogn clay loam is richer in phosphorus than the Sogn loam. The results as a whole bear out previous observations in showing that the fine textured types are better supplied with plant food than are coarse textured soils. Silty clay loams are usually higher than silt loams and silt loams are better supplied with phosphorus.
The analyses as a whole show that there is no large content of phosphorus in any of the soils of Clayton County. Additions of phosphorus fertilizers will certainly be needed on these soils in the near future if the supply is to be kept up and satisfactory crop yields secured. There is evidence from experiments which have been carried out, and from the experience of some farmers, that applications of phosphorus fertilizers might be of value now.

The nitrogen content in the various soils in the county varies considerably, ranging from 1,000 pounds per acre in the Lindley sandy loam, up to 8,240 pounds per acre in the Clyde silt loam. As was noted in the case of phosphorus, there is no evidence of any definite relationship between the nitrogen content of the soil and the various soil groups, although the bottomland soils are a little better supplied on the average than the upland soils. This again might be expected because of the lesser crop growth removed from the bottomland types and, hence, the smaller utilization of the plant food present.

There is some relationship apparent between the nitrogen content of the soils and the various series. Those characteristics which largely serve to determine the series seem to influence the supply of nitrogen. The color of the soil, the topographic position and the characteristics of the subsoil are significant. Thus on the drift uplands the Clyde soils are the richest in nitrogen and they are the darkest in color, level to flat in topography and have heavy subsoils. The Lindley and Thurston soils are the lowest in nitrogen, they are the lightest in color, the roughest in topography and have loose or coarse textured subsoils. On the loessial uplands the Tama silt loam is the richest in nitrogen and is the darkest in color and is not so strongly rolling to rough in topography as the Fayette and Clinton types. On the terraces the Waukesha, Judson, Davenport and Millsdale types are the richest in nitrogen, the darkest in color, and have heavier subsoil conditions. The O'Neill and Plainfield types are the lowest in nitrogen, as would be expected from their lighter color and sandy to gravelly subsoils. On the bottomlands the Wabash and Cass soils are richer in nitrogen than the Genesee and Sarpy types, due largely to their darker color. On the residual uplands the Sogn soils are richer in nitrogen than the Dubuque types.

The textural differences in the soil also affect the nitrogen content. On the drift uplands the Lindley loam is much higher in nitrogen than the Lindley sandy loam. The Clyde silt loam is higher than the Clyde silty clay loam which is contrary to what is usually the case. The silty clay loam is ordinarily richer in nitrogen. The Carrington loam is much better supplied than the Carrington sandy loam. On the loessial uplands the Tama silt loam is naturally richer in nitrogen than the light colored phase of the type, and the typical Fayette silt loam is richer in nitrogen than the steep phase of the type. The results are reversed in the case of the Clinton silt loam and the steep phase of that type, probably owing to some abnormal condition in the particular sample taken of the steep phase. Ordinarily the steep phase would be much lower in nitrogen. On the terraces the O'Neill loam is much richer in nitrogen than the O'Neill sandy loam. The Millsdale loam is higher in the element than the Millsdale fine sandy loam. On the bottomlands the Genesee silt loam is somewhat lower than the silt loam, which is the opposite of what is
commonly found. The Genesee silt loam is higher than the very fine sandy loam, however. The Cass silt loam is much richer in nitrogen than the Cass sandy loam. The Wabash loam is higher than the Wabash silt loam, which is different than is ordinarily the case. In general the data bear out previous conclusions in showing that heavy textured soils are richer in nitrogen than are coarse textured types.

It is evident that the soils of this county are not overly well supplied with nitrogen and, except for one or two soils, the supply of nitrogen is rather low. In all cases where the content of the element is not quite adequate, additions of fertilizing materials supplying nitrogen must be made in order to provide the best conditions for crop yields. Throughout the county, nitrogen must not be overlooked when systems of permanent fertility are planned.

There is usually a definite relationship between the nitrogen content of the soil and the amount of organic carbon or organic matter present. The color of the soil indicates roughly the content of organic matter and thus, indirectly, the content of nitrogen. Black soils are high in organic matter, and they are usually high in nitrogen, while the light colored types are low in both of these constituents. The color of the soils in Clayton County varies widely and there is, hence, a wide range in content of organic carbon as well as in nitrogen. The range in amount of organic carbon is from 10,193 pounds per acre in the Sarpy very fine sandy loam up to 69,102 pounds per acre in the Sogn loam.

The relationships between the various soil types and the organic carbon content are very similar to those noted in the case of nitrogen. There is very little difference on the average in the organic carbon content of the soils within the various groups altho the bottomland types are somewhat richer than the upland soils. It will be noted that the characteristics which determine the soil series affect the organic matter content. The color of the soil, the topographic position and the subsoil characteristics have a definite influence. Thus the Clyde soils on the drift uplands are richer in organic matter than are the other drift upland soils. The Carrington and Dodgeville soils are better supplied than the Lindley and Thurston types. On the loessial uplands the Tama soils are richer than the Fayette and Clinton. On the terraces the Waukesha, Judson, Davenport and Millsdale soils are the richest in organic matter. On the bottomlands the Wabash and Cass types are richer than the Genesee and Sarpy soils. Thus the darker colored Clyde, Carrington and Dodgeville soils on the drift uplands are richer than the Lindley and Thurston types. The darker colored Tama soils on the loessial uplands are richer than the Fayette and Clinton soils, and the darker Waukesha, Judson, Davenport and Millsdale soils are richer than the O'Neill and Plainfield types. The latter soils also have sandy or gravelly subsoils, which reduces the content of organic matter. The darker colored Wabash and Cass soils are richer than the lighter colored Genesee or Sarpy types.

The texture of the soil also has an effect on the content of organic matter. The Lindley loam is higher in organic matter than the Lindley sandy loam. The Clyde silt loam is richer than the Clyde silty clay loam, which is contrary to the usual results. The Carrington loam is higher in organic matter than the Carrington sandy loam, and the typical Tama, Fayette and Clinton soils are richer in organic matter than the phases of those types. The O'Neill loam is much richer in organic
matter than the O'Neill sandy loam on the terraces. The Millsdale loam is higher than the Millsdale fine sandy loam. On the bottomlands the Cass silt loam is much richer than the Cass sandy loam. The Genesee silty clay loam is higher than the Genesee silt loam, which in turn is better supplied than the Genesee very fine sandy loam. The Wabash loam is lighter than the Wabash silt loam, which is contrary to the usual results. As a whole the finer textured types are higher in organic matter than the coarse textured soils.

Some of the soil types in the county are not overly well supplied with organic matter, and it is apparent that additions of fertilizing materials supplying this constituent are necessary. On some of the soils, especially those which are coarse in texture and light in color, there is a distinct deficiency in organic matter. In a few cases the types seem to be very well supplied. It is necessary, however, to add organic matter to the soils of the county regularly to keep up the supply, and the use of organic materials on the light colored coarse textured types is very necessary now in order to bring about conditions satisfactory for the best crop yields. The use of farm manure is very desirable, particularly on the latter soils. The turning under of crop residues and leguminous crops as green manures is also very necessary to build up the organic matter. Small amounts of farm manure will be of value even on the richer soils in order to stimulate the production of available plant food, and on all the soils regular additions of materials supplying organic matter should be made if the content is to be kept up.

The relationship between the organic carbon content and nitrogen in the soil indicates something of the rate at which plant food is being made available. When this relationship is not at the best, crops may suffer for the necessary plant food. In some of the Clayton County soils the proper relationship between these two constituents is not found. On such types the application of farm manure would be of particularly large value in stimulating the production of available plant food. This condition is found to occur on the Lindley sandy loam, the Lindley loam, the Clyde silt loam, the Clyde silty clay loam, the Dodgeville loam, the Carrington loam, the Thurston sandy loam, the Fayette silt loam and on many of the terrace and bottomland soils. On these types the value of farm manure is particularly evident, but on all the soils of the county farm manure will bring about large crop increases.

With the exception of the Dodgeville loam on the drift uplands, the Cass sandy loam, the Sarpy very fine sandy loam on the bottomlands and the Sogn clay loam on the residual uplands, there is no inorganic carbon content in any of the surface soils of the county. In the types mentioned, inorganic carbon does not occur in the surface soil. These types are, therefore, not acid in reaction and do not need lime. All the other soils in the county, however, should be tested for need of lime and the amount of lime shown to be necessary by the tests should be applied if the best crop yields, especially of legumes, are to be secured.

The lime requirements shown in the tables are merely indicative of the needs of the soils. Application should be made only after the particular soil has been tested in order that the proper amount of lime should be applied. Soils vary widely in lime requirement, and even within areas of the same type wide differences may occur. Farmers are urged to have their soils tested and apply the lime shown to be necessary by the test, in order to secure the most satisfactory crop growth.
### TABLE V. PLANT FOOD IN CLAYTON COUNTY, IOWA, SOILS

Pounds per acre of 4 million pounds of subsurface soil (6'-20")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>161</td>
<td>Lindley sandy loam</td>
<td>795</td>
<td>3,573</td>
<td>9,985</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>1,845</td>
<td>2,880</td>
<td>27,268</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>2,208</td>
<td>4,880</td>
<td>41,559</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>84</td>
<td>Clyde silt loam</td>
<td>1,938</td>
<td>6,160</td>
<td>57,629</td>
<td></td>
<td>8,000</td>
</tr>
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<td>Carrington sandy loam</td>
<td>1,508</td>
<td>2,150</td>
<td>29,178</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
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<td>Dodgeville loam</td>
<td>1,642</td>
<td>4,960</td>
<td>50,722</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>7</td>
<td>Carrington loam</td>
<td>1,685</td>
<td>4,640</td>
<td>53,476</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>162</td>
<td>Thurston sandy loam</td>
<td>2,288</td>
<td>2,560</td>
<td>21,270</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>177</td>
<td>Tama silt loam (light colored phase)</td>
<td>2,137</td>
<td>6,480</td>
<td>63,757</td>
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<td>6,000</td>
</tr>
<tr>
<td>163</td>
<td>Fayette silty loam</td>
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<td>3,360</td>
<td>30,106</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>235</td>
<td>Fayette silt loam (steep phase)</td>
<td>1,293</td>
<td>1,760</td>
<td>16,089</td>
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<td>4,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,494</td>
<td>1,920</td>
<td>18,707</td>
<td></td>
<td>6,500</td>
</tr>
<tr>
<td>176</td>
<td>Clinton silt loam (steep phase)</td>
<td>1,320</td>
<td>2,400</td>
<td>26,833</td>
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<td>2,000</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,060</td>
<td>4,120</td>
<td>48,649</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>126</td>
<td>O'Neill sandy loam</td>
<td>2,424</td>
<td>2,520</td>
<td>17,559</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>193</td>
<td>Bertrand silt loam</td>
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<td>41,123</td>
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<td>3,000</td>
</tr>
<tr>
<td>131</td>
<td>Judson silt loam</td>
<td>3,636</td>
<td>4,260</td>
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<td>4,000</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>2,227</td>
<td>2,440</td>
<td>32,549</td>
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<td>4,000</td>
</tr>
<tr>
<td>98</td>
<td>Plainfield sandy loam</td>
<td>1,212</td>
<td>1,200</td>
<td>13,962</td>
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<td>1,000</td>
</tr>
<tr>
<td>101</td>
<td>Davenport silty clay loam</td>
<td>2,288</td>
<td>4,080</td>
<td>33,814</td>
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<td>8,000</td>
</tr>
<tr>
<td>209</td>
<td>Millsdale loam</td>
<td>3,422</td>
<td>7,040</td>
<td>84,537</td>
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<td>6,000</td>
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<tr>
<td>236</td>
<td>Millsdale fine sandy loam</td>
<td>2,074</td>
<td>3,600</td>
<td>51,922</td>
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<td>6,000</td>
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<td>26</td>
<td>Wabash silt loam</td>
<td>2,424</td>
<td>4,640</td>
<td>42,759</td>
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<td>5,000</td>
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<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>2,840</td>
<td>7,480</td>
<td>72,688</td>
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<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>3,070</td>
<td>5,600</td>
<td>40,210</td>
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<td>None</td>
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<tr>
<td>70</td>
<td>Genesee very fine sandy loam</td>
<td>2,128</td>
<td>4,480</td>
<td>41,285</td>
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<td>None</td>
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<tr>
<td>182</td>
<td>Genesee silty clay loam</td>
<td>2,074</td>
<td>3,680</td>
<td>42,251</td>
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<td>None</td>
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<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>3,556</td>
<td>7,280</td>
<td>82,900</td>
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<tr>
<td>49</td>
<td>Wabash loam</td>
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<td>9,760</td>
<td>89,991</td>
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<tr>
<td>19</td>
<td>Cass sandy loam</td>
<td>2,288</td>
<td>3,440</td>
<td>34,136</td>
<td></td>
<td>2,733</td>
</tr>
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<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>1,912</td>
<td>1,680</td>
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<td>48,867</td>
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<td>Dubuque silt loam</td>
<td>1,804</td>
<td>2,320</td>
<td>17,343</td>
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<td>5,000</td>
</tr>
</tbody>
</table>

### THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in Tables V and VI. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

It is not necessary to consider the analyses of the lower soil layers in detail unless the supply of some essential plant food constituent is very high or the soil is dis-
### TABLE VI. PLANT FOOD IN CLAYTON COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus (lb/acre)</th>
<th>Total organic nitrogen (lb/acre)</th>
<th>Total inorganic carbon (lb/acre)</th>
<th>Limestone requirement (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>161</td>
<td>Lindley sandy loam</td>
<td>1,279</td>
<td>3,127</td>
<td>21,052</td>
<td>3,000</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>2,646</td>
<td>4,020</td>
<td>35,874</td>
<td>3,000</td>
</tr>
<tr>
<td>85</td>
<td>Clyde silty clay loam</td>
<td>3,959</td>
<td>2,780</td>
<td>18,720</td>
<td>None</td>
</tr>
<tr>
<td>84</td>
<td>Clyde silt loam</td>
<td>2,302</td>
<td>4,120</td>
<td>30,924</td>
<td>6,000</td>
</tr>
<tr>
<td>3</td>
<td>Carrington sandy loam</td>
<td>2,220</td>
<td>3,320</td>
<td>24,146</td>
<td>None</td>
</tr>
<tr>
<td>223</td>
<td>Dodgeville loam</td>
<td>Nosample</td>
<td>Nosample</td>
<td>Nosample</td>
<td>Nosample</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
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<td>5,100</td>
<td>43,277</td>
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</tr>
<tr>
<td>162</td>
<td>Thurston sandy loam</td>
<td>3,111</td>
<td>4,780</td>
<td>22,497</td>
<td>6,000</td>
</tr>
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</table>

LOESS SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus (lb/acre)</th>
<th>Total organic nitrogen (lb/acre)</th>
<th>Total inorganic carbon (lb/acre)</th>
<th>Limestone requirement (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,651</td>
<td>6,700</td>
<td>48,704</td>
<td>6,000</td>
</tr>
<tr>
<td>177</td>
<td>Tama silt loam (light colored phase)</td>
<td>3,111</td>
<td>6,220</td>
<td>28,469</td>
<td>5,000</td>
</tr>
<tr>
<td>163</td>
<td>Fayette silt loam</td>
<td>2,362</td>
<td>4,280</td>
<td>25,524</td>
<td>3,000</td>
</tr>
<tr>
<td>233</td>
<td>Fayette silt loam (steep phase)</td>
<td>2,505</td>
<td>5,100</td>
<td>22,824</td>
<td>6,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>2,989</td>
<td>2,860</td>
<td>18,693</td>
<td>6,500</td>
</tr>
<tr>
<td>176</td>
<td>Clinton silt loam (steep phase)</td>
<td>2,868</td>
<td>3,320</td>
<td>21,597</td>
<td>3,000</td>
</tr>
</tbody>
</table>

TERRACE SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus (lb/acre)</th>
<th>Total organic nitrogen (lb/acre)</th>
<th>Total inorganic carbon (lb/acre)</th>
<th>Limestone requirement (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,343</td>
<td>5,500</td>
<td>40,864</td>
<td>6,500</td>
</tr>
<tr>
<td>126</td>
<td>O’Neill sandy loam</td>
<td>2,121</td>
<td>3,210</td>
<td>16,521</td>
<td>None</td>
</tr>
<tr>
<td>193</td>
<td>Bertrand silt loam</td>
<td>2,262</td>
<td>4,940</td>
<td>34,523</td>
<td>None</td>
</tr>
<tr>
<td>131</td>
<td>Judson silt loam</td>
<td>4,323</td>
<td>12,780</td>
<td>111,834</td>
<td>4,000</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>2,732</td>
<td>5,433</td>
<td>37,620</td>
<td>4,000</td>
</tr>
<tr>
<td>98</td>
<td>Plainfield sandy loam</td>
<td>2,181</td>
<td>3,100</td>
<td>17,016</td>
<td>1,000</td>
</tr>
<tr>
<td>101</td>
<td>Davenport silty clay loam</td>
<td>2,262</td>
<td>5,250</td>
<td>31,169</td>
<td>8,000</td>
</tr>
<tr>
<td>209</td>
<td>Millsdale loam</td>
<td>5,334</td>
<td>12,780</td>
<td>110,770</td>
<td>6,000</td>
</tr>
<tr>
<td>236</td>
<td>Millsdale fine sandy loam</td>
<td>3,069</td>
<td>3,260</td>
<td>50,394</td>
<td>None</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus (lb/acre)</th>
<th>Total organic nitrogen (lb/acre)</th>
<th>Total inorganic carbon (lb/acre)</th>
<th>Limestone requirement (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,192</td>
<td>3,800</td>
<td>22,579</td>
<td>3,000</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (col-luvial phase)</td>
<td>4,584</td>
<td>15,360</td>
<td>105,959</td>
<td>4,000</td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>5,976</td>
<td>11,500</td>
<td>65,982</td>
<td>None</td>
</tr>
<tr>
<td>70</td>
<td>Genesee very fine sandy loam</td>
<td>3,393</td>
<td>7,820</td>
<td>57,850</td>
<td>None</td>
</tr>
<tr>
<td>182</td>
<td>Genesee silty clay loam</td>
<td>3,393</td>
<td>9,100</td>
<td>66,395</td>
<td>None</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>4,586</td>
<td>7,580</td>
<td>71,174</td>
<td>None</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2,586</td>
<td>9,420</td>
<td>29,615</td>
<td>None</td>
</tr>
<tr>
<td>19</td>
<td>Cass sandy loam</td>
<td>2,220</td>
<td>1,820</td>
<td>9,725</td>
<td>None</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>2,928</td>
<td>3,370</td>
<td>30,704</td>
<td>None</td>
</tr>
</tbody>
</table>

RESIDUAL SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus (lb/acre)</th>
<th>Total organic nitrogen (lb/acre)</th>
<th>Total inorganic carbon (lb/acre)</th>
<th>Limestone requirement (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>237</td>
<td>Sogn loam</td>
<td>2,907</td>
<td>4,780</td>
<td>26,980</td>
<td>143,511</td>
</tr>
<tr>
<td>164</td>
<td>Sogn clay loam</td>
<td>3,069</td>
<td>6,220</td>
<td>28,239</td>
<td>21,910</td>
</tr>
<tr>
<td>183</td>
<td>Dubuque silt loam</td>
<td>Nosample</td>
<td>Nosample</td>
<td>Nosample</td>
<td>Nosample</td>
</tr>
</tbody>
</table>

Distinctly deficient in some constituent. The influence of the composition of the lower soil layers on the fertility of the soil is usually rather unimportant. The results of the analyses as given in the tables serve merely to emphasize the needs of the soils of this county, which have been pointed out in the discussion of the analyses of the surface soil.

Phosphorus fertilizers will certainly be needed on these soils in the near future.
and may be of value in many cases at the present time. The supply of organic matter and nitrogen is low in some of the soils and in all the types must be kept up thru utilization of the manure produced, all the crop residues and the proper turning under of leguminous crops as green manures. By the use of these materials, those soils which are low in organic matter and nitrogen may be built up and kept in a high state of productivity. All the soil types except the Dodgeville loam, the Cass sandy loam, the Sogn loam and the Sogn clay loam are acid in reaction and in need of lime. These types should all be tested, therefore, for lime needs and the lime should be applied as necessary, especially if legumes are to be grown. Tests should also be made at regular intervals, at least once in a rotation, in order to permit of the maintenance of the supply of lime in the soil. On the types mentioned as containing lime and being, therefore, not in need of additions, occasionally additions of lime may be necessary, and unless it is definitely known that the soils are not acid in reaction they should be tested before legumes are grown.

Greenhouse Experiments

Two greenhouse experiments were carried out on the Tama silt loam and the Fayette silt loam, the two most extensively developed soil types in Clayton County.

The treatments employed in all the experiments included the application of manure, lime, superphosphate and muriate of potash. These materials were used in the amounts which are ordinarily employed in the field and the results, therefore, indicate quite definitely the results which may be secured in the field. Manure was applied at the rate of 10 tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil. Superphosphate was added at the rate of 250 pounds per acre, and muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown in the experiment, the clover being seeded about one month after the wheat was up.

THE RESULTS ON THE TAMAL SILT LOAM

The results of the experiment on the Tama silt loam from Clayton County are given in Table VII. The application of superphosphate increased the yield of wheat to a considerable extent and brought about a very large gain in the clover. Limestone applied with the superphosphate gave a large increase in the case of
wheat and showed a gain also in the clover crop. Manure applied alone increased the yields of both the wheat and clover but had a smaller effect than the combination treatment with limestone and superphosphate. It had a greater effect on the wheat than the superphosphate alone but a smaller effect than the superphosphate on the clover.

Superphosphate applied with the manure increased the yield of wheat to a considerable extent and doubled the yield of clover. Limestone applied with the manure and superphosphate showed no effect on either crop. Muriate of potash applied with the manure, lime and superphosphate showed no effect on the wheat and brought about a small gain in the clover.

## TABLE VIII. GREENHOUSE EXPERIMENT, FAYETTE SILT LOAM, CLAYTON COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>12.6</td>
<td>12.2</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>14.0</td>
<td>32.3</td>
</tr>
<tr>
<td>3</td>
<td>Limestone + superphosphate</td>
<td>16.8</td>
<td>44.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>17.3</td>
<td>38.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>17.2</td>
<td>44.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>21.2</td>
<td>50.0</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>20.4</td>
<td>45.3</td>
</tr>
</tbody>
</table>

Field Experiments

No field experiments have been carried out in this county, but tests are under way in adjacent counties on some of the same soil types which occur extensively
in Clayton County. The results secured on some of these fields will be given here to indicate the effect of fertilizer treatments on some of the important soil types in this county. The data obtained on the Tama silt loam on the Hudson Field in Black Hawk County, on the Van Horn Field in Benton County, on the Grundy Center Field in Grundy County, on the West Branch Field in Cedar County and on the Newton Field in Jasper County and the results on the Clinton silt loam on the Princeton Field in Scott County and on the Julien Field in Dubuque County are included. The results secured on these fields may be considered definitely applicable to conditions in Clayton County.

These field experiments are all planned to determine the relative value of the various soil treatments and they are laid out on land which is representative of the various soil types. They are permanently located by the installation of corner stakes, and all precautions are taken in the application of fertilizers and in the harvesting of the crops to be sure that the results secured are accurate.

In these fields, tests are included under both the livestock and grain systems of farming, manure being employed in the former and crop residues being utilized in the latter. Other fertilizing materials tested include limestone, rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. Manure is applied at the rate of 8 tons per acre once in the rotation. Limestone is used in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in the four-year rotation. Until 1925, rock phosphate was applied at the rate of 2,000 pounds per acre once in the rotation. Superphosphate is applied at the rate of 150 pounds per acre three times in the four-year rotation. Until 1923 this material was applied at the rate of 200 pounds per acre annually. Until 1923, the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. Between 1923 and 1929 the new standard 2-12-2 brand was employed, the application being made at the rate of 200 pounds per acre annually, thus supplying the same amount of phosphorus as that contained in the superphosphate. Muriate of potash is applied at the rate of 50 pounds per acre. Beginning in 1929, a 2-12-6 complete fertilizer was used on the Tama silt loam soil experiment fields and a 4-16-4 complete fertilizer on the Clinton silt loam fields, applications in both cases being made in
sufficient amounts to supply the same amount of phosphorus as that added in the superphosphate.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk County are given in Table IX. The value of manure on this soil is evidenced by the fact that increased yields were secured in every season from its application. In many cases the increases were very large. The application of lime with the manure increased crop yields in every case, the legume crops being particularly benefited by the lime.

The rock phosphate with the manure and lime increased the yields of crops in most seasons, particularly the oats in 1919, the corn in 1920 and the oats in 1924. The superphosphate with the manure and lime showed slightly larger effects than did the rock phosphate, on the clover and timothy in 1925 and 1926 and on the corn in 1927 and 1928, but in the other seasons the increases brought about by the phosphates were very similar. The complete commercial fertilizer had a larger effect than the superphosphate in one or two cases, notably on the oats in 1922 and on the corn in 1923 and 1928. In other seasons, however, the effects were less pronounced than those brought about by the superphosphate.

The crop residues showed little effect on the yields, increases being noted only in

**TABLE IX. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD, SERIES II**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1919 Corn</th>
<th>1920 Corn</th>
<th>1920 Oats</th>
<th>1921 Corn</th>
<th>1921 Oats</th>
<th>1921 Corn</th>
<th>1922 Corn</th>
<th>1922 Oats</th>
<th>1923 Corn</th>
<th>1923 Oats</th>
<th>1924 Corn</th>
<th>1924 Oats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>45.8</td>
<td>47.6</td>
<td>53.2</td>
<td>44.8</td>
<td>54.0</td>
<td>40.3</td>
<td>43.0</td>
<td>40.8</td>
<td>45.7</td>
<td>50.8</td>
<td>47.6</td>
<td>53.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>49.3</td>
<td>54.7</td>
<td>62.8</td>
<td>53.1</td>
<td>63.9</td>
<td>50.6</td>
<td>61.4</td>
<td>61.7</td>
<td>64.6</td>
<td>64.8</td>
<td>57.2</td>
<td>50.6</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>54.4</td>
<td>59.2</td>
<td>67.4</td>
<td>59.5</td>
<td>66.7</td>
<td>52.5</td>
<td>22.0</td>
<td>22.3</td>
<td>21.7</td>
<td>26.8</td>
<td>65.6</td>
<td>72.2</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>56.5</td>
<td>64.0</td>
<td>73.3</td>
<td>59.0</td>
<td>63.4</td>
<td>62.4</td>
<td>20.2</td>
<td>15.6</td>
<td>56.7</td>
<td>57.6</td>
<td>56.7</td>
<td>56.7</td>
</tr>
<tr>
<td>5</td>
<td>Manure + limestone + superphosphate</td>
<td>57.4</td>
<td>62.2</td>
<td>73.3</td>
<td>59.8</td>
<td>62.5</td>
<td>63.7</td>
<td>25.2</td>
<td>61.7</td>
<td>76.3</td>
<td>58.4</td>
<td>45.9</td>
<td>45.9</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>58.8</td>
<td>55.7</td>
<td>57.2</td>
<td>62.2</td>
<td>64.0</td>
<td>60.0</td>
<td>22.0</td>
<td>64.5</td>
<td>76.4</td>
<td>64.4</td>
<td>56.1</td>
<td>56.1</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>56.9</td>
<td>62.2</td>
<td>64.0</td>
<td>41.4</td>
<td>54.8</td>
<td>85.0</td>
<td>61.4</td>
<td>21.5</td>
<td>26.8</td>
<td>59.8</td>
<td>64.9</td>
<td>58.9</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>57.9</td>
<td>64.6</td>
<td>71.3</td>
<td>59.2</td>
<td>65.7</td>
<td>75.7</td>
<td>22.7</td>
<td>66.6</td>
<td>66.6</td>
<td>51.3</td>
<td>54.1</td>
<td>54.1</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + limestone</td>
<td>62.8</td>
<td>58.1</td>
<td>74.9</td>
<td>59.6</td>
<td>65.7</td>
<td>66.6</td>
<td>42.3</td>
<td>70.5</td>
<td>59.3</td>
<td>56.6</td>
<td>56.6</td>
<td>56.6</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + limestone + rock phosphate</td>
<td>55.6</td>
<td>55.8</td>
<td>74.9</td>
<td>64.4</td>
<td>62.8</td>
<td>60.9</td>
<td>26.4</td>
<td>79.4</td>
<td>58.5</td>
<td>55.6</td>
<td>55.6</td>
<td>55.6</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + limestone + superphosphate</td>
<td>52.5</td>
<td>58.7</td>
<td>57.4</td>
<td>71.3</td>
<td>62.6</td>
<td>86.1</td>
<td>52.5</td>
<td>20.3</td>
<td>70.2</td>
<td>63.6</td>
<td>56.7</td>
<td>56.7</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + limestone + complete commercial fertilizer</td>
<td>54.8</td>
<td>58.7</td>
<td>70.1</td>
<td>59.7</td>
<td>70.8</td>
<td>71.9</td>
<td>94.1</td>
<td>43.5</td>
<td>84.7</td>
<td>142.2</td>
<td>142.2</td>
<td>142.2</td>
</tr>
</tbody>
</table>

(1) Four tons of lime. Hail damaged corn.
(2) Yields on plot 7 evidently an error.
(3) Corn cut and put in silo.
(4) Not very ripe when cut.
(5) Dry season.
(6) High yields on crop residue series due to lower ground and more moisture.
(7) Large number of missing hills on plot 4.
(8) Yield on a 15 percent moisture basis.
one or two cases. Lime with the crop residues increased the crop yields in every season, showing large effects on the clover and timothy in 1925 and 1926 and on the corn in 1927 and 1928. Beneficial effects were also evidenced in other seasons on the oats and corn. Rock phosphate applied with the residues and lime increased the crop yields in several seasons. In a few cases no gains were noted. Superphosphate with the crop residues and lime showed very similar effects to those brought about by the rock phosphate, the increases being somewhat more pronounced in some seasons but not so definite in others. The complete commercial fertilizers had a greater effect than the superphosphate in several seasons, particularly on the clover and timothy in 1925 and 1926. In several other seasons there was a less effect evidenced than from the phosphates.

THE VAN HORN FIELD

The results secured in the field experiment on the Tama silt loam on the Van Horn Field in Benton County are given in Table X. The application of manure increased the crop yields in most seasons, showing an especially large effect on the corn in 1926 and 1928. Lime applied with the manure showed large beneficial effects on the crops in all but one season. The oats in 1925 and 1927 and the corn in 1926 and 1928 were very largely benefited by the addition of the lime.

Rock phosphate with the manure and lime increased the crop yields in all but one season, showing large beneficial effects on the oats in 1927. Only in the case of the corn in 1928 was there no increase from the addition of the rock phosphate. The superphosphate applied with the manure and lime showed somewhat larger effects than the rock phosphate in the first three seasons, 1923, 1924 and 1925. The yield on this plot in 1927 was evidently abnormal. In 1928 the effect of the superphosphate was very much the same as that of the rock phosphate. In most cases the difference between the influence of the two phosphates was not very great. The addition of the muriate of potash to the manure, lime and superphosphate showed

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 corn bu. per A.</th>
<th>1924 corn bu. per A.</th>
<th>1925 oats bu. per A.</th>
<th>1926 corn bu. per A.</th>
<th>1927 oats bu. per A.</th>
<th>1928 corn bu. per A.</th>
<th>1929 oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>51.2</td>
<td>14.7</td>
<td>68.9</td>
<td>53.1</td>
<td>47.4</td>
<td>62.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>51.5</td>
<td>14.7</td>
<td>62.6</td>
<td>58.4</td>
<td>49.2</td>
<td>78.9</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>47.2</td>
<td>18.3</td>
<td>81.7</td>
<td>62.9</td>
<td>55.4</td>
<td>89.9</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>51.5</td>
<td>18.8</td>
<td>88.7</td>
<td>66.7</td>
<td>61.7</td>
<td>85.1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>51.0</td>
<td>14.4</td>
<td>67.0</td>
<td>57.3</td>
<td>48.1</td>
<td>66.3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>56.0</td>
<td>22.4</td>
<td>92.6</td>
<td>54.7</td>
<td>33.2</td>
<td>85.4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>58.8</td>
<td>18.7</td>
<td>81.7</td>
<td>53.9</td>
<td>56.6</td>
<td>85.4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>56.7</td>
<td>20.6</td>
<td>92.6</td>
<td>62.4</td>
<td>60.6</td>
<td>91.3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>47.9</td>
<td>14.4</td>
<td>68.9</td>
<td>48.8</td>
<td>45.6</td>
<td>70.2</td>
<td></td>
</tr>
</tbody>
</table>

(1) Limestone not applied until 1924.
(2) Late variety of corn was planted, and it was seriously damaged by frost.
(3) Stand very uneven on plots, which accounts for high and low yields.
(4) Unable to account for low yield on plots 6 and 7.
(5) Unable to account for low yield on plot 6.
(6) No results secured.
no beneficial effects on the crops. Small differences were apparent in the various seasons, but they were not significant. The complete commercial fertilizer applied with the manure and lime showed larger effects than the superphosphate on the corn in 1926 and 1928. In the other seasons the influence of the two materials was very similar.

THE GRUNDY CENTER FIELD

The results secured on the Tama silt loam on the Grundy Center Field in Grundy County are given in Table XI. The application of manure increased the crop yields on this soil in all but one season, a large beneficial effect being apparent on the clover in 1929. There was no effect from the addition of manure on the corn in 1927. The use of lime with the manure increased the yield of oats in 1928 and brought about a large gain in the yield of clover in 1929. The other crops were not influenced. Rock phosphate with the manure and lime increased the crop yields in all seasons, showing especially large effects on the clover in 1929.

Superphosphate with manure and lime gave larger increases than the rock phosphate in every season, showing very much larger gains on the clover in 1929. The muriate of potash applied with the manure, lime and superphosphate showed little effect on the crops grown. In most cases the yields were not increased by the addition of the muriate of potash. The complete commercial fertilizer with the manure and lime had a greater effect than the superphosphate on the oats in 1928 but in the other seasons showed less beneficial influence.

THE WEST BRANCH FIELD

The results secured on the Tama silt loam on the West Branch Field in Cedar County are given in Table XII. The application of manure increased the crop yields on this soil in every season, showing very large effects in some cases, for example on the oats in 1925 and 1929, when increases of 11 and 12 bushels per acre were secured. The corn was also largely increased in 1927 and 1928. Lime applied with the manure increased the crop yields in practically all seasons. The beneficial effects in most cases, however, were not very large.

The application of rock phosphate with the manure and lime showed a very

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TABLE XI. FIELD EXPERIMENT, TAMA SILT LOAM, GRUNDY COUNTY, GRUNDY CENTER FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1926 corn bu. per acre (1)</th>
<th>1927 corn bu. per acre (2)</th>
<th>1928 oats bu. per acre</th>
<th>1929 clover tons per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>64.9</td>
<td>57.3</td>
<td>43.1</td>
<td>1.71</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>67.9</td>
<td>54.5</td>
<td>48.8</td>
<td>1.91</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>64.7</td>
<td>52.4</td>
<td>51.0</td>
<td>2.14</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>65.7</td>
<td>54.9</td>
<td>52.2</td>
<td>2.35</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>59.3</td>
<td>38.4</td>
<td>46.5</td>
<td>1.91</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>67.9</td>
<td>54.8</td>
<td>53.3</td>
<td>2.94</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>68.2</td>
<td>49.4</td>
<td>52.2</td>
<td>2.73</td>
</tr>
<tr>
<td>8</td>
<td>Check</td>
<td>67.8</td>
<td>48.0</td>
<td>64.7</td>
<td>2.77</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>67.4</td>
<td>47.8</td>
<td>53.3</td>
<td>1.99</td>
</tr>
</tbody>
</table>

(1) Plots 1 and 9 appear to show increased fertility.
(2) Very uneven stand on all plots, which accounts for varying yields.
TABLE XII. FIELD EXPERIMENT, TAMA SILT LOAM, CEDAR COUNTY,
WEST BRANCH FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 Clover ton per A.</th>
<th>1923 Corn bu. per A.</th>
<th>1924 Corn bu. per A.</th>
<th>1925 Oats bu. per A.</th>
<th>1926 Timothy and Clover ton per A.</th>
<th>1927 Corn bu. per A.</th>
<th>1928 Corn bu. per A.</th>
<th>1929 Oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>2.2</td>
<td>61.3</td>
<td>29.5</td>
<td>62.1</td>
<td>49.7</td>
<td>69.9</td>
<td>60.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>2.4</td>
<td>65.3</td>
<td>32.0</td>
<td>73.2</td>
<td>59.9</td>
<td>75.7</td>
<td>72.6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>2.5</td>
<td>66.9</td>
<td>34.7</td>
<td>77.0</td>
<td>60.2</td>
<td>73.6</td>
<td>76.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>2.5</td>
<td>64.8</td>
<td>32.3</td>
<td>89.0</td>
<td>61.9</td>
<td>71.7</td>
<td>76.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>2.1</td>
<td>64.5</td>
<td>32.1</td>
<td>63.2</td>
<td>47.0</td>
<td>58.6</td>
<td>62.4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>2.9</td>
<td>81.3</td>
<td>37.5</td>
<td>100.7</td>
<td>63.9</td>
<td>76.1</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>3.0</td>
<td>71.4</td>
<td>36.3</td>
<td>98.0</td>
<td>66.8</td>
<td>74.3</td>
<td>87.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>2.7</td>
<td>70.6</td>
<td>37.3</td>
<td>93.4</td>
<td>68.2</td>
<td>82.1</td>
<td>80.6</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>2.1</td>
<td>65.3</td>
<td>28.6</td>
<td>67.2</td>
<td>56.5</td>
<td>66.9</td>
<td>56.8</td>
<td></td>
</tr>
</tbody>
</table>

(1) Field was pastured, no results taken.

The results secured on the Tama silt loam in 1925. In the other seasons, however, only small benefits or none at all were secured from the use of the rock phosphate. The superphosphate applied with the manure and lime showed a larger effect than the rock phosphate in practically all seasons. Much larger benefits were secured from the superphosphate on the corn in 1923, on the oats in 1925 and on the corn in 1928.

The muriate of potash applied with the manure, lime and superphosphate showed beneficial effects in one or two seasons. The corn in 1927 was benefited slightly and the oats in 1929 were increased considerably. In the other seasons no beneficial effects from the muriate of potash were shown. The complete commercial fertilizer with the manure and lime had a somewhat larger effect than the superphosphate in 1927, 1928 and 1929. In the other seasons, however, the influence of the complete commercial fertilizer was less than that of the superphosphate. In most instances the differences between the effects of the two materials were not very great.

THE NEWTON FIELD

The results secured on the Tama silt loam on the Newton Field in Jasper County are given in Table XIII. The application of manure to this soil increased the crop yields in practically all seasons. Very large beneficial effects were evidenced on the clover in 1923 and 1927 and on the corn in 1928 and 1929. The application of lime with the manure increased the crop yields in all seasons following the first. The gains in most instances were not very large but were definite.

The use of rock phosphate with manure and lime proved of benefit in practically all seasons, the largest influence appearing on the clover in 1927. The superphosphate with the manure and lime showed very much the same effects as the rock phosphate in practically all seasons, in some cases having slightly greater effects and in other instances not showing quite as large an influence. The differences in most cases were not large. The application of muriate of potash with the manure, lime
TABLE XIII. FIELD EXPERIMENT, TAMAN Silt Loam, Jasper County, New ton Field, Series I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 Red Clover tons per A.</th>
<th>1924 Corn bu. per A.</th>
<th>1925 Corn bu. per A.</th>
<th>1926 Oats bu. per A.</th>
<th>1927 Red Clover tons per A.</th>
<th>1928 Corn bu. per A.</th>
<th>1929 Corn bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>1.28</td>
<td>58.5</td>
<td>52.5</td>
<td>57.9</td>
<td>1.13</td>
<td>69.4</td>
<td>57.3</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>1.36</td>
<td>59.8</td>
<td>51.7</td>
<td>56.8</td>
<td>1.37</td>
<td>75.9</td>
<td>64.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>1.35</td>
<td>61.7</td>
<td>55.5</td>
<td>56.8</td>
<td>1.44</td>
<td>81.7</td>
<td>66.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>1.45</td>
<td>66.0</td>
<td>57.9</td>
<td>62.6</td>
<td>1.79</td>
<td>79.2</td>
<td>64.8</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>1.42</td>
<td>57.8</td>
<td>53.3</td>
<td>49.4</td>
<td>1.27</td>
<td>69.3</td>
<td>56.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>1.32</td>
<td>66.5</td>
<td>58.9</td>
<td>67.3</td>
<td>1.79</td>
<td>78.2</td>
<td>67.7</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>1.35</td>
<td>65.9</td>
<td>58.7</td>
<td>63.3</td>
<td>1.81</td>
<td>78.2</td>
<td>68.3</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>1.34</td>
<td>66.1</td>
<td>53.6</td>
<td>76.9</td>
<td>1.72</td>
<td>81.2</td>
<td>67.2</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>1.20</td>
<td>56.0</td>
<td>49.6</td>
<td>51.9</td>
<td>1.20</td>
<td>73.4</td>
<td>59.7</td>
</tr>
</tbody>
</table>

(1) Plots 8 and 9 damaged considerably by hail.

and superphosphate showed little or no beneficial effects on the crops grown in the various seasons. The complete commercial fertilizer with the manure and lime had very much the same effect as the superphosphate in most seasons. In one or two cases, slightly larger effects were evidenced, but in general the differences were too small to be significant.

THE PRINCETON FIELD

The results secured on the Clinton silt loam on the Princeton Field in Scott County are given in Table XIV. Manure increased the crop yields on this soil in nearly every season. In some cases considerable increases were secured, as for example on the wheat in 1925, on the corn in 1923, 1927 and 1928, on the oats in 1929 and on the clover in 1922 and 1926. Lime with the manure increased still further yields of crops on this soil, especially the clover in 1922 and 1926 and the corn in 1927. Increases in the yields of wheat, corn and oats were also secured in practically every season.

The addition of rock phosphate with the manure and lime increased the yields of crops in most seasons. The gains, however, were not generally large. The superphosphate with the manure and lime gave considerable increases in the yields in several cases. In one or two seasons, however, the effects of the superphosphate were no greater than those brought about by the rock phosphate. The oats in 1924 and the clover in 1926 showed the largest effects from the use of superphosphate. The complete commercial fertilizer with manure and lime gave somewhat greater effects than the superphosphate in most seasons, but in other seasons the beneficial influence was less, and in no case was the difference greatly in favor of the complete commercial fertilizer.

Crop residues had little effect on the various crops grown, bringing about only slight increases in some seasons. Lime with the residues noticeably increased the crop yields in most seasons, the largest beneficial effects being shown on the clover in 1922 and in 1926 and on the corn in 1919, 1920, 1923 and 1928.

The rock phosphate with the crop residues and lime increased the crop yields in
## TABLE XIV. FIELD EXPERIMENT, CLINTON SILT LOAM, SCOTT COUNTY, PRINCETON FIELD, SERIES I

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>40.7</td>
<td>69.3</td>
<td>61.8</td>
<td>27.7</td>
<td>1.41</td>
<td>54.0</td>
<td>65.8</td>
<td>13.6</td>
<td>6.0</td>
<td>96.7</td>
<td>64.6</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>37.4</td>
<td>67.6</td>
<td>68.3</td>
<td>28.4</td>
<td>1.93</td>
<td>63.2</td>
<td>64.8</td>
<td>8.22</td>
<td>61.5</td>
<td>57.9</td>
<td>79.7</td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>43.0</td>
<td>68.2</td>
<td>70.0</td>
<td>32.2</td>
<td>1.32</td>
<td>70.2</td>
<td>65.8</td>
<td>5.27</td>
<td>71.5</td>
<td>97.3</td>
<td>57.4</td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rockphosphate</td>
<td>47.4</td>
<td>67.5</td>
<td>73.5</td>
<td>31.9</td>
<td>2.25</td>
<td>72.5</td>
<td>63.1</td>
<td>3.22</td>
<td>71.0</td>
<td>96.4</td>
<td>76.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure+limestone+superphosphate</td>
<td>45.2</td>
<td>64.0</td>
<td>70.8</td>
<td>35.1</td>
<td>2.29</td>
<td>73.2</td>
<td>75.1</td>
<td>3.18</td>
<td>71.3</td>
<td>86.9</td>
<td>79.2</td>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>37.3</td>
<td>68.4</td>
<td>73.0</td>
<td>36.4</td>
<td>2.34</td>
<td>68.1</td>
<td>71.9</td>
<td>3.24</td>
<td>80.0</td>
<td>77.5</td>
<td>53.9</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>31.7</td>
<td>57.5</td>
<td>57.5</td>
<td>24.4</td>
<td>1.60</td>
<td>53.0</td>
<td>62.6</td>
<td>2.16</td>
<td>9.0</td>
<td>73.5</td>
<td>79.7</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>31.7</td>
<td>62.6</td>
<td>67.3</td>
<td>29.7</td>
<td>1.61</td>
<td>61.8</td>
<td>65.6</td>
<td>2.31</td>
<td>84.6</td>
<td>66.6</td>
<td>60.1</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+limestone</td>
<td>35.0</td>
<td>64.1</td>
<td>68.7</td>
<td>29.8</td>
<td>2.28</td>
<td>65.0</td>
<td>63.4</td>
<td>2.67</td>
<td>81.0</td>
<td>81.3</td>
<td>85.8</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>31.7</td>
<td>66.6</td>
<td>61.5</td>
<td>31.1</td>
<td>1.12</td>
<td>68.0</td>
<td>75.1</td>
<td>1.71</td>
<td>89.0</td>
<td>74.4</td>
<td>41.9</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>36.2</td>
<td>65.2</td>
<td>69.5</td>
<td>30.8</td>
<td>2.25</td>
<td>70.1</td>
<td>73.5</td>
<td>2.25</td>
<td>83.8</td>
<td>74.6</td>
<td>56.8</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>28.9</td>
<td>59.3</td>
<td>58.5</td>
<td>28.5</td>
<td>0.98</td>
<td>54.4</td>
<td>54.2</td>
<td>0.98</td>
<td>64.4</td>
<td>54.4</td>
<td>55.4</td>
</tr>
</tbody>
</table>

(1) Three tons lime applied August, 1917. Yield on plot 8 an error.
(2) Clover poor and mowed up.
(3) Plot 11 many missing hills, low yields.
(4) Yields on plots 13 and 14 lost due to error.
(5) Stand of wheat very thin due to extremely dry spring.
(6) Oats down badly on plots 3, 4, 5, 10, 11 and 12.

all but one season. In the case of the clover crop the increases were very definite. On the other crops small increases were secured. Superphosphate with the crop residues and lime showed larger effects than the rock phosphate in some seasons. This was particularly true of the oats in 1921 and 1924 and of the corn in 1927 and 1928. In several seasons, however, there was a smaller effect from the superphosphate than from the rock phosphate. The complete commercial fertilizer gave larger increases than did the rock phosphate and superphosphate in several cases. This was noted particularly on the clover in 1926 and on the oats in 1929. In most seasons, however, there was little difference between the effects of that material and of the phosphates.

### THE JULIEN FIELD

The results secured on the Clinton silt loam on the Julien Field in Dubuque County are given in Table XV. The application of manure increased the crop yields on this soil to a considerable extent in all seasons. The largest beneficial effects were evidenced on the timothy and clover in 1926 and on the timothy in 1927. Large gains were also brought about on the oats in 1925 and 1929. Lime with the manure increased the crop yields very appreciably. It showed particularly large effects on the clover in 1923 and on the timothy in 1927. Large gains were also evidenced on the oats in 1925 and 1929.

Rock phosphate applied with the manure and lime increased the crop yields in most seasons. It showed the largest beneficial effect on the oats in 1925 and also...
increased the timothy considerably in 1927. Superphosphate with the manure and lime showed a larger effect than the rock phosphate on the crops in 1923 and 1924. In the succeeding seasons, however, it had less effect than the rock phosphate. Muriate of potash applied with the manure, lime and superphosphate showed a beneficial effect in some seasons. In some instances no increases were secured from the use of this material, and in all seasons the differences brought about by the use of the muriate of potash were too small to be of significance.

The complete commercial fertilizer with the manure and lime showed a larger beneficial effect on the crops grown in one or two seasons than that occasioned by the superphosphate. The oats in 1925 were particularly benefited by the complete commercial fertilizer, and the corn in 1928 also showed a much larger beneficial effect from the complete fertilizer than from the superphosphate. In general, however, the results from the use of the two materials were very similar.

**TABLE XV. FIELD EXPERIMENT, CLINTON SILT LOAM, DUBUQUE COUNTY, JULIEN FIELD, SERIES I**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 Clover ton per A.</th>
<th>1924 Corn bu. per A. (1)</th>
<th>1925 Oats bu. per A. (2)</th>
<th>1926 Timothy and Clover ton per A.</th>
<th>1927 Timothy ton per A.</th>
<th>1928 Corn bu. per A.</th>
<th>1929 Oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>0.67</td>
<td>21.3</td>
<td>72.7</td>
<td>0.85</td>
<td>1.28</td>
<td>61.1</td>
<td>48.7</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>0.96</td>
<td>25.5</td>
<td>76.2</td>
<td>1.33</td>
<td>1.63</td>
<td>61.6</td>
<td>56.7</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>1.68</td>
<td>30.4</td>
<td>84.4</td>
<td>1.41</td>
<td>1.85</td>
<td>72.9</td>
<td>66.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>1.68</td>
<td>29.3</td>
<td>101.8</td>
<td>1.18</td>
<td>2.00</td>
<td>74.3</td>
<td>70.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure + limestone + superphosphate</td>
<td>1.82</td>
<td>31.3</td>
<td>97.2</td>
<td>1.09</td>
<td>1.66</td>
<td>69.7</td>
<td>58.9</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>1.73</td>
<td>33.1</td>
<td>101.5</td>
<td>1.12</td>
<td>1.61</td>
<td>72.6</td>
<td>64.6</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>1.83</td>
<td>32.7</td>
<td>107.3</td>
<td>1.10</td>
<td>1.58</td>
<td>76.2</td>
<td>60.1</td>
</tr>
<tr>
<td>8</td>
<td>Check</td>
<td>1.44</td>
<td>20.2</td>
<td>53.9</td>
<td>0.96</td>
<td>1.48</td>
<td>69.2</td>
<td>49.9</td>
</tr>
</tbody>
</table>

(1) Poor stand of corn due to damage by squirrels.
(2) Poor stand of oats on plot 8.

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

From the results secured in the laboratory, greenhouse and field experiments, which have just been described in this report, some general recommendations may be drawn regarding the best systems of management for the more important soil types in Clayton County. While no field experiments have been conducted in this county, and it has not been possible to carry out tests on all the soil types in the county, still from the results secured on the more important types in the laboratory and greenhouse and on similar types occurring in adjacent counties in field experiments, suggestions regarding soil treatments, which will undoubtedly prove of value in this county, may be offered. These suggestions are based not only upon the results of experimental work but also upon the experiences of many farmers. No suggestions are offered except such as have been found to be of value in practice, and any of the recommendations made may be put into effect on any farm.
Liming

Practically all of the soils in Clayton County are acid in reaction in the surface soil, and in most cases this acidity extends down thru the lower soil layers. Only the Dodgeville loam on the drift upland, the Sogn clay loam on the residual upland and the Cass sandy loam and the Sarpy very fine sandy loam on the bottomlands show any lime content in the surface soil. The Sogn loam on the residual uplands is high in lime in the subsoil but shows no lime content in the surface soil. Except for these types, the soils in the county are all acid in reaction and in need of lime. The surface soils show considerable acidity in practically all cases, and the lower soil layers are also generally acid. There is certainly a need for the rather extensive application of lime to the soils of this county.

The figures in table VI indicate roughly the lime requirements of the various soils. There is a wide variation, however, in the lime needs of soils, and even those of the same types from different fields will frequently show great differences in lime requirement. In order that the proper amount of lime may be added to the soil, it is very necessary that a sample be taken from the area to be treated and the need for lime determined on that sample. Farmers may test their own soils for acidity or lime requirement, but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station, where it will be tested free of charge.

Legumes such as sweet clover, alfalfa and red clover will not ordinarily grow satisfactorily on acid soils. In many cases these crops may fail entirely if lime is not applied to the soil before they are seeded. Corn and small grains are ordinarily not so sensitive to soil acidity as the legumes, but even these crops are often greatly benefited by applications of lime to the soil when it is acid. It is generally true that the most satisfactory yields of farm crops are not obtained on acid soils. It is most desirable, then, that lime be applied to all acid soils in the amounts shown to be necessary by the tests if the yields of crops, and particularly of legumes, are to prove most profitable.

The experiments discussed earlier in this report have shown the large crop increases which may be secured from the application of lime to the more extensively developed soil types in the county. Large effects were evidenced on the Tama silt loam, on the Clinton silt loam and on the Fayette silt loam. Other soil types in the county would also be benefited to a very large extent by the use of lime.

Lime should be applied regularly in the rotation if the soil is to be kept in the best condition for crop growth. It is not sufficient to make one application of lime. Tests for acidity and lime needs are necessary at least once in the rotation and should be made preferably preceding the growing of the legume crops. Thus the lime may be applied where it is most needed and where it will have the greatest effect.

Manuring

A number of the soil types in Clayton County and particularly those which are sandy in texture are rather poorly supplied with organic matter, the lack of which is evidenced by the light color of the soil. In some of the types the supply of organic matter is adequate, and the soils are dark in color and high in fertility. In
these cases, however, it is important that additions of fertilizing materials supplying organic matter should be made regularly if the content is to be kept up. On the light colored sandy soils where the supply of organic matter is inadequate, it is very necessary that fertilizers supplying organic matter be applied at the present time if the best crop growth is to be secured. The Lindley sandy loam, the Lindley loam, the Carrington sandy loam and the Thurston sandy loam on the drift uplands, the Fayette silt loam on the loessial uplands, the O'Neill sandy loam and the Plainfield sandy loam on the terraces and the Cass and Sarpy soils on the bottoms are all very low in organic matter and in need of liberal applications of fertilizing materials supplying this constituent if they are to be made most satisfactorily productive. Many of the other soil types in the county are likewise low in organic matter and will respond to additions. This is true of the Clinton silt loam on the loessial uplands, the Lindley loam and the Carrington loam on the drift uplands and many of the terrace and bottomland types and the Dubuque silt loam on the residual uplands. In fact, it may be said that all the soils of the county will need organic matter now or in the very near future if the supply is to be kept up.

Farm manure is the cheapest and best source of organic matter. Its application will be of particularly large value on the light colored sandy soils, but large increases are also frequently secured on the dark colored, heavy textured types. On the former soils heavier applications may be made, while on the latter types small amounts of manure will often prove very desirable. Greenhouse and field experiments described earlier in this report have shown the large value of applications of farm manure to some of the main types in this county. The Tama silt loam, the Clinton silt loam and the Fayette silt loam, have all shown large effects from the application of manure. On some of the other types in the county, the beneficial effects of manure would be even more striking than on these types.

The turning under of leguminous crops as green manures is a very desirable practice as a means of building up and maintaining the supply of organic matter in the land. On grain farms where little or no manure is produced, green manuring is of especial importance. It is of value, however, on many livestock farms on which insufficient manure is produced to supply the needs of all the land. Green manuring with legumes not only supplies large amounts of organic matter to the soil, but it may also add large quantities of nitrogen as this element is taken from the atmosphere. Thus the practice is doubly valuable. Many of the soils in Clayton County would respond very profitably to green manuring. The practice is recommended especially for the light colored, sandy soils and under any system of farming in which there is not sufficient manure produced to supply all the land on the farm regularly. The practice of green manuring is a very desirable supplement to, or substitute for, the use of farm manure. The practice should not be followed blindly or carelessly, however, as undesirable results may occur if the conditions in the soils are not right for the decomposition of the green material.

The thorough utilization of all crop residues produced on the farm aids materially in keeping up the supply of organic matter in the soil. These materials should never be burned or otherwise destroyed but should always be returned to the land. Under the livestock system of farming, they may be used for feed or bedding and returned
with the manure. Under the grain system of farming they may be decomposed partially or they may be returned directly to the soil. Thru the proper use of all crop residues and farm manure, supplemented with green manures, the organic matter content of the soils of this county may be built up and maintained.

**The Use of Commercial Fertilizers**

The supply of phosphorus is not large in any of the soils in Clayton County, as has been indicated in the analyses discussed earlier in this report. In most cases the supply is so low that it seems quite probable that phosphorus in an available form is inadequate at the present time for the best crop growth. It is quite evident that phosphorus fertilizers will be needed on these soils in the very near future, and it seems probable that a phosphorus fertilizer might be used with considerable profit in many cases on the soils of this county at the present time.

The results of the field and greenhouse experiments have shown large crop increases from the application of rock phosphate or superphosphate on some of the more important soil types in the county. Beneficial effects from these materials have been shown on the Tama silt loam, the Clinton silt loam and the Fayette silt loam. Similar beneficial effects would undoubtedly be evidenced on many of the other types in the county, and, in the case of some of the poorer soils very much larger increases in crop yields would undoubtedly be secured from the addition of one or the other of the phosphate fertilizers. In some of the tests the superphosphate seemed more effective, but in other instances the rock phosphate proved quite satisfactory.

The superphosphate contains the element phosphorus in an immediately available form, while that in the rock phosphate must be changed in the soil before it can be utilized by crops. Ordinarily the superphosphate is applied, therefore, in smaller amounts, usually at the rate of about 150 pounds per acre annually or three years out of four in the four-year rotation. While the superphosphate is more expensive, the smaller application means, therefore, a smaller cost for the addition. The rock phosphate is usually applied at the rate of 1,000 to 2,000 pounds per acre once in the four-year rotation. Ordinarily the largest beneficial effects from the rock phosphate may not appear until the second year after application. The beneficial effects from the addition may continue over several years following the application. Definite information is not yet available regarding the relative value of the two phosphates for all soil conditions in this county. It is recommended and urged, therefore, that farmers test both materials under their particular conditions and determine which will be the most desirable. Simple tests may be carried out on any farm.

A number of the soil types in Clayton County are rather poorly supplied with nitrogen, and the addition of some fertilizing material supplying this element is necessary at the present time. The light colored sandy soils are particularly low in this constituent, and on these types the need of some nitrogenous fertilizing material is evident. On all the soils, however, it is important that some nitrogenous material be applied regularly if the supply of nitrogen is to be kept up. There is a constant removal of nitrogen from the land in the drainage water and by crops, and unless a return is made the element will soon become deficient.
The use of farm manure is a very important means of keeping up the supply of nitrogen in the soil. The proper preservation and application of all the manure produced on the farm will aid materially in preventing a deficiency in this constituent. Crop residues also supply nitrogen, and the proper utilization of these materials will aid in keeping up the supply. In spite of the return to the soil of some nitrogen through the use of farm manure and the plowing under of crop residues, there is a constant decrease in the content of this constituent. The treatment with farm manure and crop residues must be supplemented by the use of leguminous crops as green manures if the supply of nitrogen in the land is to be built up and maintained.

Legumes when well inoculated take a large part of the nitrogen which they contain from the atmosphere. When the crop is turned under in the soil, therefore, a considerable increase in the content of nitrogen in the soil may be secured. The practice of green manuring would be of large value on many of the soils in Clayton County at the present time, especially on those types which are deficient in nitrogen or organic matter.

The general use of commercial nitrogenous fertilizers cannot be recommended for the soils of this county, at the present time. The utilization of crop residues and farm manure and the turning under of leguminous crops as green manures will add sufficient nitrogen to permit the maintenance of the proper content in the land. Small amounts of commercial nitrogenous materials may sometimes be used profitably as top dressings for certain crops. These materials should always be tested, however, on small areas before extensive applications are made. Ordinarily the use of leguminous crops as green manures will prove a cheaper and more satisfactory method of building up and keeping up the supply of nitrogen in the land.

The supply of potassium is generally adequate in the soils of this county and it would not seem that the use of commercial potassium fertilizers would be desirable at the present time or for many years to come. In some cases, however, the production of available potassium in the soil seems to be inadequate to meet the needs of growing crops, and additions of commercial potassium fertilizers sometimes prove profitable. Small amounts may sometimes be of value as top dressings. Tests of these fertilizers should always be carried out on small areas, however, before extensive applications are made. They cannot be recommended for general use in the county at the present time.

In some cases the application of a complete commercial fertilizer may prove of large value on some of the soil types in this county. The results which have been described earlier have indicated, however, that phosphates may generally give quite as large effects and, as they are less expensive, it would be more desirable to use a phosphate fertilizer. On some of the poorer soil types in the county, complete commercial fertilizers would probably prove of larger value than the phosphates. Tests of any complete fertilizers should be carried out in comparison with superphosphate before any extensive application of the material is made. Much larger crop increases must be secured from the fertilizer than are brought about by the superphosphate if it is to prove as profitable for application. There is no objection to the application of any complete fertilizer. It is simply a matter of the crop increase secured and the profit from the application. Farmers who are interested are urged to test
complete fertilizers under their own conditions and thus determine whether they may be applied with profit and especially with greater profit than superphosphate.

Drainage

As has been indicated earlier, the natural drainage system of Clayton County is generally quite adequate and the majority of the soils are well drained. In some areas, however, the natural drainage is not sufficient. On the flat depressed areas of the Clyde silty clay loam and the Clyde silt loam on the drift uplands, there is need for drainage. There are occasional areas in the Carrington loam and the Tama silt loam where drainage would be desirable. On the terrace and bottomland soils there are areas where drainage would be desirable, but in general most of these types are fairly well drained. The bottomland soils, of course, are in need of protection from overflow in many cases if they are to be satisfactorily cropped. Drainage of these types should be provided after they have been protected from overflow.

On all the soil types in the county, and on all areas in which the drainage is not adequate, the installation of tile would prove of value. Satisfactory crop yields cannot be secured when the soil is too wet. Tiling is the first treatment needed on such areas. No fertilizing treatment will prove of value on soils which are not properly drained. Tiling sometimes means the difference between a crop failure and a profitable crop growth. While the expense involved is often considerable, farmers will find that the increased crop yields will soon more than pay for the installation.

The Rotation of Crops

The continuous growing of any one crop very quickly reduces the fertility of the soil. As a result, yields of crops rapidly decline and the growing of such crops may soon become unprofitable. It is much more desirable to practice a rotation, even if crops of low money value are included in the rotation. This is due to the fact that under a rotation system, yields of crops do not decrease as rapidly as under continuous cropping. The system is more profitable in general because it permits the ready maintenance of the fertility of the land.

No special crop rotation experiments have been carried out in Clayton County, but some general recommendations may be offered regarding rotations which will undoubtedly prove of value. From among the rotations listed below, some one may be chosen for use in this county or to serve as a basis upon which a rotation may be worked out for individual farm conditions. Almost any rotation will prove of value provided it contains a legume and a money crop.

1. SIX-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover or clover and grass)
Fourth year—Clover or clover and grass
Fifth year—Wheat (with clover) or grass and clover
Sixth year—Clover or clover and grass

This rotation may be reduced to a five-year rotation by cutting out either the second or sixth year and to a four-year rotation by omitting the fifth and sixth years.
2. FOUR OR FIVE-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or 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.)

3. 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 and the alfalfa shifted to one of the fields which previously was in the four-year rotation.)

4. FOUR-YEAR ROTATIONS

First year—Wheat (with clover)
Second year—Corn
Third year—Oats (with clover)
Fourth year—Clover

First year—Corn
Second year—Wheat or oats (with clover)
Third year—Clover
Fourth year—Wheat (with clover)

First year—Wheat (with clover)
Second year—Clover
Third year—Corn
Fourth year—Oats (with clover)

5. THREE-YEAR ROTATIONS

First year—Corn
Second year—Oats or wheat (with clover seeded in the grain)
Third year—Clover (In grain farming, only the grain and clover seed should be sold, 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 and only the seed taken from the second crop.)

First year—Corn
Second year—Oats or wheat (with sweet clover)
Third year—Sweet clover (The clover may be mixed clovers and used largely as pasture and green manure.)
This may be changed to a two-year rotation by plowing the sweet clover under the following spring for corn.

First year—Wheat (with clover)
Second year—Corn
Third year—Cowpeas or soybeans

The Prevention of Erosion

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

The two types of erosion are sheet washing and gullying. The former may occur over a rather large area, and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but is less harmful and 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.
Erosion occurs to some extent in Clayton County. On the loessial upland the light colored phase of the Tama silt loam has been formed largely thru the washing away of the surface soil from the typical soil type. The steep phases of the Fayette silt loam and of the Clinton silt loam are seriously injured by erosion, and the typical soils of these two series are also injured by erosion. The Lindley types and the Carrington soils on the drift upland are also subject to erosion in many areas. The residual soils are likewise frequently injured by the washing action of water. Wherever erosion occurs some means to prevent or control it must be adopted.

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

**EROSION DUE TO DEAD FURROWS**

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

"Plowing In"—It is customary to "plow in" the small gullies that result from dead furrows, and in level areas this process may be quite effective. In the more rolling areas, however, it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In"—This method requires less work, and there is less danger of washing out. The process consists of driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed 3 or 4 inches apart. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes with the tops pointing upstream, thus 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. There are some objections to the use of earth dams, but in many cases they are effective in preventing erosion in dead furrows.

**SMALL GULLIES**

Gullies result from the enlargement of surface drainageways, and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. A number of methods may be used to fill small gullies, but it is not practicable to fill them with soil; too much work is involved and the effect is not lasting.

*Checking Overfalls*—The formation of small gullies or ditches is practically always the result of overfalls. An easy method of checking the overfalls is to put in an obstruction of straw and brush, staking it down with posts. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them, and the straw and brush are held in place by cross pieces nailed to the posts.

"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 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 Earth Dam—The use of an earth dam or mound of earth across a gully may satisfactorily control erosion under some conditions. In general, however, when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided the dam is called a “Christopher” or “Dickey” dam.

The “Christopher” or “Dickey” Dam—This modification of the earth dam consists merely in laying a long line of tile down the gully and beneath the dam. An elbow or a “T”, called the surface inlet, usually extends 2 or 3 feet above the bottom of the gully. A large tile should be used in order to provide for flood waters, and the dam should be provided with a concrete 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 the dam, such as sorghum, or even oats or rye, later seeding it to grass.

The Adams Dam—This dam is practically the same as the “Christopher” or “Dickey” dam. In fact the principle of construction is identical. In some sections the name “Adams Dam” has been applied and hence it is mentioned separately.

The Stone or Rubble Dam—Where stones are plentiful, they are frequently used in constructing dams for the control of erosion.

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.

The Woven Wire Dam—The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies.

Sod Strips—The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover, or alfalfa may serve as well, and for quick results thickly planted sorghum may be employed.

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. Owing to their high cost and to the difficulty involved in securing the correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil and thus decreases the tendency toward erosion.
LARGE GULLIES

The erosion in large gullies or ravines may in general be controlled by the same methods as for small gullies. 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, especially where such low-lying areas are crossed by small streams, and the land may be badly cut up and rendered almost 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.

*Trees*—Erosion is sometimes controlled by rows of trees, such as willows, which extend up the drainage channels. While the method has some good features it is not generally desirable.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value in preventing the injurious washing and which also aid materially in securing satisfactory crop growth.

*Use of Organic Matter*—Organic matter or humus is the most effective means of increasing the absorbing power of the soil, and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw and cornstalks, may also be turned under in soils to increase their organic matter content.

*Growing Crops*—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also desirable for use in such locations.

*Contour Disking*—Disking 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 disk ing" and it has proven satisfactory in many cases in Iowa.

*Sod Strips*—The use of narrow strips of sod is very desirable for preventing gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

*Deep Plowing*—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains.

INDIVIDUAL SOIL TYPES IN CLAYTON COUNTY*

There are 31 soil types in Clayton County which, with the light colored phase of the Tama silt loam, the steep phase of the Fayette silt loam, the steep phase of the Clinton silt loam, the colluvial phase of the Wabash silt loam and the areas of

*The descriptions of the individual soil types given in the Bureau of Soils Report have been closely followed in this section of the report.
riverwash, muck and rough stony land, make a total of 38 soil areas. They are divided into five large groups according to their origin and location. These groups are the drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

**Drift Soils**

There are eight drift soils in the county, classified in the Lindley, Clyde, Carrington, Dodgeville and Thurston series. Together they cover 5.3 percent of the total area.

**LINDLEY SANDY LOAM (161)**

The Lindley sandy loam is a minor type, covering 1.1 percent of the total area. The largest development of the soil is along the Maquoketa River, in the south-western corner of Cass Township. Two areas occur along the Delaware County line in the same township, numerous areas are found scattered along the Volga River, and a few are found along the Turkey River.

The surface soil of the Lindley sandy loam to a depth of 15 inches is a grayish-brown sandy loam containing considerable fine sand. In some places the upper four-inch layer is somewhat darkened by a small amount of organic matter. The subsurface soil to a depth of about 20 inches is a light yellowish-brown sandy loam and the subsoil to a depth of 40 inches is a yellowish-brown sandy loam faintly colored with gray in places. This layer contains a small amount of silt, fine gravel and rock fragments.

In sections 23, 24 and 25 of Boardman Township, one-half mile east of Elkader, some areas of sand have been included with the soil because of their small total extent. To a depth of 5 inches these variations consist of a light grayish-brown or yellowish-brown sand, underlain to a depth of 30 inches by a yellowish-brown uniform medium sand. No gravel or coarse material occurs in this type. In topography the Lindley sandy loam varies from gently rolling to rolling, and drainage is good. The soil is inclined to be drouthy, and crops may suffer in dry seasons.

Practically all of the soil is under cultivation, corn being the chief crop grown. Crop yields are usually somewhat lower than on some of the better soil types in the county. The chief need of the soil, if it is to be made more satisfactorily productive, is for the liberal addition of organic matter. Large amounts of farm manure would prove of value, and the turning under of leguminous crops as green manures would also increase the productivity of the soil. The type is acid and in need of lime, especially for the best growth of legumes. The use of a phosphate fertilizer would also undoubtedly prove of value, and tests of superphosphate are recommended.
LINDLEY LOAM (65)

The Lindley loam is a minor type, covering 1 percent of the total area. It occurs in several areas on the slopes of the tributaries of the Turkey and Volga rivers, especially along Hewitt and Spring creeks. The largest area is about ½ mile northwest of Strawberry Point. The other areas are small.

The surface soil of the Lindley loam is a grayish-brown friable loam containing a considerable amount of silt. It averages about 4 inches in depth. The subsurface soil is a yellowish-brown loam to a depth of 12 inches, becoming somewhat heavier in texture in the lower parts of the layer. The subsoil is a gritty, silty clay loam continuing to a depth of 34 inches, yellowish-brown to reddish-brown in color. The underlying parent material is a yellowish-brown silty clay loam or silty clay mottled with gray and stained with a few iron stains. The coarser material, including glacial gravel and small boulders, is found locally in the upper layers of the soil but is abundant in the parent material. Small areas of silt loam are included with the type as mapped because of their small extent. The only difference is in the somewhat higher silt content of the surface layer.

In topography the Lindley loam is generally sharply rolling as it occurs on the tops and slopes of ridges. In the area northwest of Strawberry Point, the topography is gently rolling. Drainage is good to excessive. Only a small part of it is under cultivation. The greater portion of the timbered land is covered by a growth of hardwoods, including oaks, hickory, elms and other trees. The crop yields on the cultivated areas are usually low.

The Lindley loam is chiefly in need of organic matter if it is to be made satisfactorily productive. Large additions of farm manure would prove of value, and the turning under of leguminous crops as green manures would build up the fertility of the soil. The type is acid and in need of lime, especially for the growing of legumes. The use of a phosphate fertilizer would undoubtedly prove of value and tests of superphosphate are recommended.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is a minor type, covering 0.4 percent of the total area. It occurs in the drift area in the southwestern corner of the county, in a number of small areas, usually at the heads of streams. There are no large areas of the type.

The surface soil of the Clyde silty clay loam is a black silty clay loam extending to a depth of about 10 inches. The subsurface soil to a depth of 20 inches is a dark grayish-brown silty clay loam heavier in texture than the surface soil. The subsoil is a silty clay containing some coarse sand and gravel, being somewhat lighter in color than the subsurface soil. Boulders are found occasionally scattered over the surface or thru the soil. Occasionally the surface soil is covered by a
grayish-brown material, mottled with gray and yellow, washed in from the higher lands. A few iron stains and concretions are found below 30 inches. The parent material consists of glacial drift.

In topography the Clyde silty clay loam is level to flat. Drainage is poor, and only a small part of the soil has been reclaimed by artificial drainage. Except for a few small strips along the edge of areas which are included within cultivated fields, the soil is all used for pasture. The greater part of the land supports a growth of meadow grass. As a rule it is used only for pasture, but hay is cut on a small part of the area.

The chief need of this soil, if it is to be satisfactorily cultivated, is for the installation of an efficient system of drainage. Drainage is possible in practically all areas and, until it is accomplished, satisfactory crop yields cannot be secured. The addition of a small amount of farm manure to newly drained areas would be of value to stimulate the production of available plant food. Large additions should not be made. The use of lime is necessary as the soil is acid, and the application of a phosphate fertilizer would undoubtedly prove of value.

CLYDE SILT LOAM (84)

The Clyde silt loam is a minor type, covering 0.4 percent of the total area. It occurs, like the Clyde silty clay loam, in the drift area in the southwestern corner of the county. There are a number of small areas of the type occurring in broad swales along the drainage channels.

The surface soil of the Clyde silt loam is a very dark grayish-brown silt loam extending to a depth of 16 inches. The subsurface soil is a dark brown or almost black silty clay loam. Below about 21 inches it is mottled gray, brown and yellow, and the subsoil is a clay loam. Some coarse sand and gravel occur throughout the soil, being more abundant in the subsoil. Small areas of the silt clay loam have been included with the type because of their small extent.

Like the silt clay loam, this type is level to flat in topography and drainage is poorly established. Yields are low ordinarily because of the poor drainage situation. Most of the type is in pasture, and if it is to be cultivated it must first be adequately drained. The addition of lime is necessary as the soil is acid.
Small applications of farm manure would be of value on newly drained areas. The use of a phosphate fertilizer would undoubtedly prove worthwhile, and tests of rock phosphate and superphosphate are recommended.

**CARRINGTON SANDY LOAM (3)**

The Carrington sandy loam is a minor type covering 0.4 percent of the total area. It occurs in a few comparatively small areas in the southwestern part of the county in the drift region.

The surface soil of the Carrington sandy loam is a very dark grayish-brown or dark brown friable sandy loam, extending to a depth of about 10 inches. The subsurface soil to a depth of about 15 inches is a sandy loam, but the color changes thru this layer from the very dark grayish-brown of the surface soil to the yellowish-brown of the subsoil. The subsoil is a yellowish-brown sandy loam somewhat lighter in color than the surface and subsurface soil. Scattered gravel and boulders are found at all depths. The soil varies widely in texture at different places ranging from a sand to a loam. These variations cannot be shown on the map because of their small extent.

In topography the Carrington sandy loam is gently rolling to almost flat. In dry seasons crops may suffer on the sandier areas, but in general the type is not dry. Drainage is good to excessive. The soil is rather unimportant agriculturally because of its small extent. Practically all of it is under cultivation and general farm crops are grown, but yields are much lower than on the better Carrington loam.

The chief need of the type if it is to be made more satisfactorily productive is for the addition of organic matter. Liberal amounts of farm manure should be applied. The turning under of leguminous crops as green manures would help materially. The type is acid and in need of lime. The use of a phosphate fertilizer would certainly prove of value, and tests of superphosphate are recommended.

**DODGEVILLE LOAM (223)**

The Dodgeville loam is a minor type, covering 0.3 percent of the total area. It occurs only in Cass Township in the extreme southwestern corner of the county in the drift area. The main development of the type is one and one-half miles west of Strawberry Point. Small areas are scattered thru the Carrington loam.

The surface soil of the Dodgeville loam is a dark grayish-brown or dark brown loam, ex-
tending to an average depth of 10 inches. It is underlaid by a yellowish-brown loam. Ordinarily lime rock occurs at a depth of from 20 to 32 inches. In places, however, it is impossible to reach the lime rock within the 36-inch depth.

There is some variation in the texture of the soil, particularly at the surface. In small areas it is a sandy loam. In other small areas a considerable amount of silt is mixed with the surface soil. Included with the type there are also small areas of the Gasconade loam. This soil was included because of its small extent. In these areas the soil consists of a dark grayish-brown loam or sandy loam 5 inches in thickness, underlaid to a depth of about 10 or 12 inches by a soil of similar texture but grayish-brown in color. This layer rests on the limestone. The rock sometimes outcrops at the surface. Other variations from the typical soil are characterized by the presence of the yellowish or reddish clay containing rock fragments between the surface soil layer and the bedrock.

Practically all of this type is under cultivation, and general farm crops are grown. Yields are very similar to those secured on the Carrington loam. The type is in need of organic matter, and additions of farm manure would prove of large value. The turning under of leguminous crops as green manures would also help. The type is acid and in need of lime, especially for the growth of legumes. The use of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are recommended.

**CARRINGTON LOAM (1)**

The Carrington loam is the largest of the drift soils, covering 2 percent of the total area. It occurs only in the extreme southwestern part of the county, considerable areas of the type occurring in the southwestern townships.

The surface soil of the Carrington loam is a very dark grayish-brown loam, extending to a depth of about 10 inches. The subsurface soil to a depth of about 18 inches is somewhat lighter in color than is the surface soil and a little heavier in texture. The lower part of the layer is almost brown in color and the texture almost a light clay loam. The subsoil to a depth of 36 inches is a brown or yellowish-brown gravelly clay loam. Below this point the yellowish-brown clay loam, representing the glacial drift parent material, extends to a depth of many feet. Iron concretions and iron stains occur throughout the entire soil. Glacial gravel and small boulders are occasionally found.

In topography the Carrington loam is gently rolling, and drainage is good. Nearly all the soil is under cultivation, and general farm crops are grown. Corn yields from 30 to 45 bushels per acre. Oats, hay crops and other minor crops, such as millet, barley and rye, are occasionally grown on this type. A small part of the area is used for pasture purposes.

The soil will respond to applications of farm manure with large increases in crop yields. The turning under of leguminous crops as green
manures would also frequently prove of value. The type is acid and in need of lime for the best growth of general farm crops and especially of legumes. The application of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate and rock phosphate are recommended.

THURSTON SANDY LOAM (162)

The Thurston sandy loam is a minor type, covering 0.1 percent of the total area. Only a few small areas of the type have been mapped in the county. These are all in the drift region of Cass Township, in sections 5, 6, 24, 25, 28, 31 and 33.

The surface soil of the Thurston sandy loam consists of a dark grayish-brown sandy loam, extending to a depth of about 5 inches. The subsurface soil to a depth of 22 inches is a brown sandy loam containing some gravel. The subsoil below this point is a coarse sandy gravel, continuing for a depth of several feet.

The Thurston sandy loam is of little agricultural value as the type is drouthy, and the yields of crops are low. The chief need of the type to be made satisfactorily productive is for the liberal addition of farm manure and the turning under of leguminous crops as green manures. It is acid and in need of lime. The use of a phosphate fertilizer would be of value, and tests of superphosphate are desirable.

Loess Soils

There are three loess types in the county, classified in the Tama, Fayette and Clinton series, and these with the light colored phase of the Tama silt loam, the steep phase of the Fayette silt loam and the steep phase of the Clinton silt loam make six separate soil areas. Together they cover 74.7 percent of the total area of the county.

TAMA SILT LOAM (120)

The Tama silt loam together with the light colored phase, which is rather extensively developed, is the most important soil type in the county, covering 33.3 percent of the total area. It occupies the northern three-fifths of the county and is the principal upland soil north of a line drawn thru Guttenberg, Elkader and Highland. This soil covers the broad interstream divides and extends down the slopes except along the more deeply cut valleys. Small areas occur in other parts of the county on the smooth areas of the uplands.

The surface soil of the Tama silt loam to a depth of about 10 inches consists of a very dark grayish-brown silt loam, which is almost black when wet. The subsurface soil to a depth of about 22 inches is a heavy silt loam or silty clay loam, dark grayish-brown in color. The subsoil is a brown or yellowish-brown silty clay loam, heavier in texture than the layer above. A few iron stains and con-
cretions occur. This material extends to a depth of from 30 to 36 inches, averaging about 32 inches. The material below this subsoil is similar in color but somewhat lighter in texture, being a more friable silty clay loam or heavy silt loam. Iron stains and concretions are numerous at these lower depths. At a depth of 4 feet or more, faint gray mottlings are sometimes found.

In topography the Tama silt loam is undulating to gently rolling. On some of the steeper stream slopes, it is moderately rolling.

All of the type is under cultivation, and general farm crops are grown. Yields of corn range from 35 to 50 bushels per acre. Occasionally yields of 80 to 100 bushels per acre are reported on the better farms. Oats ordinarily yield from 30 to 60 bushels per acre, and yields of 70 or 80 bushels are obtained in favorable seasons. Clover is grown for hay or pasture, from 1 to 3 tons per acre of the hay being secured. Timothy and clover are often grown together for hay. Some wheat is grown, but the acreage is small. Small acreages of sweet clover, alfalfa and soybeans are found.

This soil will respond profitably to applications of farm manure as has been indicated in the experimental results discussed earlier in this report. The regular application of normal amounts of farm manure to this type will prove of large value in increasing crop yields. The type is acid and in need of lime, especially for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended. Experiments with these fertilizers have indicated that profitable results may be secured on this soil from their application. Complete commercial fertilizers may sometimes be used profitably, but tests in comparison with superphosphate should be carried out before extensive applications are made. Erosion occurs to some extent in this soil, and on the slopes it is particularly important that precautions be taken to prevent the removal of the surface soil by washing. From among the methods which have been discussed earlier in this report, some one may be chosen which will be suitable for use under any farm condition to prevent the formation of gullies or the carrying away of the surface soil by washing.

TAMA SILT LOAM (light colored phase) (177)

The light colored phase of the Tama silt loam is minor in area, in comparison with the typical Tama silt loam, but it covers about 6 percent of the total area. It occurs in irregular strips between the typical Tama silt loam and the Fayette silt loam and also on flat divides within areas of the Fayette silt loam and in low areas in association with the Clinton silt loam. An area of this soil several square miles in extent occurs along the north side of the railroad between Edgewood and Strawberry Point, bordering the areas of drift soil. Numerous small areas of the type occur.

The light colored phase of the Tama silt loam is very similar in texture and
structure and in characteristics of the various soil layers to the typical Tama silt loam. The chief difference is that the surface soil is lighter in color. The surface layer which consists of a grayish-brown silt loam extends to a depth of about 16 inches. The subsurface soil to a depth of 22 inches is a grayish-brown to brown, somewhat heavier silt loam. The subsoil is practically the same as of the typical Tama silt loam.

In topography, the light colored phase of the Tama silt loam is similar to the typical soil, the topography being gently rolling or smooth. The greater part of the type was forested or at least supported a sparse growth of trees or underbrush when the land was first settled. Practically all of the soil is now under cultivation, and general farm crops are grown. The yields, however, are somewhat lower than those secured on the typical Tama silt loam.

The chief need of this phase of the Tama silt loam, if it is to be made more satisfactorily productive, is the liberal addition of farm manure and the turning under of leguminous crops as green manures. The type is acid and in need of lime. It would be benefited by additions of a phosphate fertilizer, and tests of superphosphate are recommended. Protection from erosion is desirable on this soil.

**FAYETTE SILT LOAM (163)**

The Fayette silt loam with the steep phase, which is small in area, is the second largest loess soil and the second largest type in the county, covering 28.8 percent of the total area. The principal areas of this type occur in a broad belt following the Turkey and Volga rivers and their larger tributaries. Numerous areas of the type are found, some of which are rather extensive. Many small areas occur.

The surface soil of the Fayette silt loam to a depth of about 5 inches is a grayish-brown or yellowish-brown smooth friable silt loam, which when dry appears quite gray. The subsurface soil to a depth of about 18 to 20 inches is a yellowish-brown friable silt loam, differing little in texture and structure from the surface soil. The subsoil to a depth of about 40 inches is a light yellowish-brown or light yellow silty clay loam. Below 40 inches there is a light yellow silty clay loam faintly mottled with gray. The parent material of the loessial silt lies in most places below a depth of 66 inches. It has a grayish-brown color faintly mottled with gray
or brown and some iron stains. Iron concretions are abundant in some places.

In topography the Fayette silt loam varies from rolling to strongly rolling. It occurs on slopes and rolling areas, being found not only on the steeper slopes but along narrow ridges and on some of the rounded knolls and ridges. In a few places small or narrow flat areas are covered with this soil. The type is well drained and in places drainage is excessive.

About 30 percent of the Fayette silt loam is cultivated. A large part of the remainder is covered by a timber growth of oak, hickory, ash and other hardwood. On the cultivated areas the principal crops grown are corn, oats and clover. The yield of corn ranges from 20 to 50 bushels per acre with an average yield of about 30 bushels. Oats yield from 20 to 40 bushels per acre, averaging not more than 30 bushels. Clover yields from 1 to 3 tons per acre.

Considerable care is required in handling this soil to prevent erosion. Contour plowing is quite generally practiced. Other methods for the prevention of erosion are very desirable. These have been discussed earlier in this report. The soil is in need of organic matter, and liberal additions of farm manure would prove of large value in increasing crop yields, building the soil up in fertility and reducing the danger of erosion. The turning under of leguminous crops as green manures would be of large value. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

**FAYETTE SILT LOAM (Steep Phase) (235)**

The steep phase of the Fayette silt loam is minor in area. It occurs in a number of small areas in association with the typical Fayette silt loam on the steeper slopes.

The surface soil of the steep phase of the Fayette silt loam is very shallow but, similarly to the typical Fayette silt loam, is grayish-brown in color. The average thickness is probably about 4 inches. The lower layers of the soil are very much the same as those of the typical Fayette silt loam altho the color is a somewhat lighter yellowish-brown.

The topography of the steep phase of the Fayette silt loam varies from sharply rolling to very steep and precipitous. The soil erodes rapidly and many gullies and ravines are found. Only a few small patches of the smoother land on the slopes are cultivated. Some of the land is timbered and used for pasture. The greater part of the forest occurring on the soil consists of oak, hickory, elm, ash, basswood and other hardwoods. Most of the soil should undoubtedly be left in pasture and forested as it is too steep for satisfactory cultivation.

**CLINTON SILT LOAM (80)**

The Clinton silt loam with the steep phase, which is somewhat smaller in area, is the third
largest loess type and the third most extensively developed type in the county, covering 12.6 percent of the total area. The largest areas are found along the slopes of the Mississippi River. The soil occupies an irregular continuous strip in places 6 or 8 miles in width between the dark colored terrace soils and the river bottoms. Other areas occur along the southern border of the county, and a number of small areas of the type are found.

The surface soil of the Clinton silt loam is a grayish-brown silt loam to a depth of about 7 inches. The subsurface soil to a depth of 12 inches is a brown silt loam, somewhat lighter in color than the surface soil and slightly different in texture. The subsoil is a yellowish-brown heavy silt loam extending to a depth of about 20 inches, underlaid to a depth of 28 inches by a light yellowish-brown silty clay loam, which is heavier in texture than the layer above. The substratum consists of a yellowish-brown silty clay loam.

There are a number of variations in the Clinton silt loam as mapped owing to differences in topographic positions. The heavy layer is not so well developed as in some parts of the state, and in some places the very heavy layer is only faintly developed. It also occurs at various depths, sometimes immediately below the surface soil and in other places 3 or more feet below the surface. The soil gradually grades into the Fayette silt loam, and boundary lines between the two types are often placed quite arbitrarily. Small areas of the Fayette silt loam occur in the areas of Clinton silt loam, as they could not be separated on the map. Where erosion has occurred to some extent, the heavy layer of the subsoil material is exposed, usually in small areas on the slopes or tops of ridges.

In topography the Clinton silt loam is gently to sharply rolling. Drainage is adequate and in many places excessive. A large acreage of the soil is under cultivation, but the major portion of the type is used for pasture and timber land. The principal crops grown are corn, oats and clover. The yields of these crops are very similar to those secured on the Fayette silt loam. Orchards and vineyards are more common on this soil than on any others in the county. Various orchard fruits are grown, and small fruits are produced to some extent. The forest growth consists of hardwoods, including oak, hickory, ash, basswood and elm.

This soil will respond in a very large way to applications of farm manure, and liberal additions of this material are necessary. The turning under of leguminous crops as green manures is also very desirable. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.
CLAYTON COUNTY SOILS

CLINTON SILT LOAM (steep phase) (176)
The steep phase of the Clinton silt loam is minor in area. It occurs in narrow strips on the steeper slopes along the Mississippi River and its larger tributaries. It lies below the typical Clinton silt loam on the very steep slopes near the streams. A number of small areas of the type are found.

The surface soil of the Clinton silt loam is similar in color to the typical soil, but it is extremely variable in thickness and averages only about 4 inches, having a much shallower surface soil than the typical Clinton. In some places a large percentage of very fine sand occurs on the surface. The lower soil layers are very similar to those in the typical Clinton silt loam areas.

None of the type is cultivated except for small patches on the lower slopes. Nearly all the land is forested with hardwoods which occur commonly in this part of the county. The areas of the type are too steep to be satisfactorily cultivated and should undoubtedly be left in pasture and forest.

Terrace Soils

There are nine terrace soils in the county, classified in the Waukesha, O’Neill, Bertrand, Judson, Plainfield, Davenport and Millsdale series. Together they cover 2.4 percent of the total area.

WAUKESHA SILT LOAM (75)
The Waukesha silt loam is the largest of the terrace soils, covering 0.6 percent of the total area. It occurs in several areas along the Volga and Turkey rivers and their tributaries. The largest area is 1 mile west of Volga.

The surface soil of the Waukesha silt loam is a very dark grayish-brown silt loam extending to a depth of 8 inches. The subsurface soil is a brown or dark brown friable silt loam to a depth of 20 inches, gradually becoming heavier in texture. The subsoil is a yellowish-brown silty clay loam extending to a depth of several feet. Small areas of the Waukesha loam have been included with this type because of their small extent. The largest of these loam areas is found 1 mile northwest of Volga. Smaller areas are scattered along the Volga and Turkey rivers.

The Waukesha silt loam occurs on terraces 10 to 30 feet above overflow. It is well drained. Nearly all of the soil is under cultivation, and
general farm crops are grown. Corn is the most important, followed by oats, clover, timothy, rye, barley and millet. Yields of these crops are much the same as those secured on the Tama silt loam on the uplands.

This type, while highly productive, will respond to applications of farm manure and the turning under of leguminous crops as green manures. It is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

**O’NEILL SANDY LOAM (126)**

The O’Neill sandy loam is a minor type, covering 0.4 percent of the total area. It occurs in a number of small areas on the terraces above the Turkey and Volga rivers and their tributaries.

The surface soil of the O’Neill sandy loam is a dark brown sandy loam extending to a depth of 12 inches. It contains some small gravel and small amounts of coarse sand. The subsurface soil to a depth of 24 inches is a light brown coarse sandy loam. The subsoil is a gravel substratum continuing to a depth of several feet.

The areas of the O’Neill sandy loam are very drouthy, and yields are low in seasons of deficient rainfall. On account of the gravelly subsoil and the drouthiness of the soil, it has a low agricultural value. It is largely under cultivation and general farm crops are grown. Yields are apt to be light.

The chief need of this soil to be made more productive is liberal additions of organic material. Large applications of farm manure will be of value, and the turning under of leguminous crops as green manures would also improve the fertility conditions of the soil. The type is acid and in need of lime, and the use of a phosphate fertilizer would undoubtedly be of value. Tests of superphosphate are recommended.

**BERTRAND SILT LOAM (193)**

The Bertrand silt loam is a minor type covering 0.4 percent of the total area. It occurs in a number of very small areas along the Volga and Turkey rivers and their tributaries.

The surface soil of the Bertrand silt loam is a grayish-brown silt loam extending to a depth of about 18 inches without any marked change in texture. The subsurface soil is a yellowish-brown friable silty clay loam containing some very fine sandy loam. In a few places, as in the area 3 miles northwest of
Volga, the soil is heavy and plastic. The soil occupies terraces 10 feet above the flood plains. The topography is flat or very gently sloping toward the streams. The soil is well drained. Nearly all of the type is in cultivation, and general farm crops are grown. Corn yields from 25 to 50 bushels per acre, and oats produce from 20 to 40 bushels per acre.

This soil will respond to applications of farm manure, and the turning under of leguminous crops as green manures would also be of value. The type is acid and in need of lime, and the use of a phosphate fertilizer would undoubtedly be of value. Tests of superphosphate are recommended.

**JUDSON SILT LOAM (131)**

The Judson silt loam is a minor type, covering 0.3 percent of the total area. It occurs in narrow strips, principally along Robert Creek in the northwestern part of the county. Other small areas are found along the Turkey River, Volga River and Silver Creek.

The surface soil of the Judson silt loam is a mellow silt loam extending to a depth of 18 inches, very dark grayish-brown in color and almost black when wet. The subsoil is a dark brown smooth friable silt loam becoming slightly lighter colored with depth. There is very little change in texture from the surface soil to the subsoil.

There is considerable variation in the depth of the surface soil of this type. Near the uplands the wash from the uplands causes much deeper deposits, and the surface soil may be several feet in thickness. The soil gradually thins out on the flats towards the streams.

Most of the type is well above overflow, but some of the lower slopes may be flooded for a short time in periods of high water. Drainage is adequate. Practically all of the type is under cultivation chiefly to corn. Yields are about the same as those secured on the better areas of the Tama silt loam. Oats and other small grains make good yields. The soil is well adapted to hay crops.

The type would be benefited by applications of farm manure. It is acid and in need of lime. A phosphate fertilizer would be of value, and tests of superphosphate and rock phosphate are recommended.

**O'NEILL LOAM (108)**

The O'Neill loam is a minor type covering 0.2 percent of the total area. It occurs in a number of small areas on the terraces along the Volga and Turkey rivers and their tributaries.

The surface soil of the O'Neill loam is a dark grayish-brown loam extending to a depth of 12 inches. It contains considerable coarse sand and gravel. The subsurface soil to a depth of 20 inches is a brown fine sandy loam, which in turn is underlaid by a light brown
O'NEILL LOAM

Medium to low acidity

Light brown sandy gravel

Sandy gravel subsoil.

In topography the type is flat. Drainage is excessive owing to the gravelly nature of the subsoil. In dry seasons crops are apt to suffer from a lack of moisture. The soil is all under cultivation. Average yields are low. The chief need of the type is for organic matter, and liberal applications of farm manure would be of value. The turning under of leguminous crops as green manures would improve the water-holding power of the soil and hence its fertility. The type is acid and in need of lime. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended.

PLAINFIELD SANDY LOAM (98)

The Plainfield sandy loam is a minor type, covering 0.2 percent of the total area. It occurs mainly in small areas on the terraces, near the junction of the Turkey and Volga rivers. One area is in the town of Volga, and another larger area is 1 mile west of that town. The other areas are small.

The surface soil of the Plainfield sandy loam is a light grayish-brown sandy loam underlaid at a depth of 12 inches by a slightly lighter colored sandy loam, which contains coarse sand and fine gravel. Considerable variations occur, and in places the surface soil is heavy in texture, approaching a loam. In other areas there is a large proportion of loam derived from colluvial material washed down from the high lands.

This soil occurs on terraces well above the streams. The topography is level to flat, drainage is excessive, and crops are apt to suffer in periods of low rainfall. Nearly all of the soil is under cultivation, and general farm crops are grown. Yields are lower than those secured on the heavier textured, darker colored soils and very much the same as those obtained on the O'Neill types.

The chief need of this soil as in the case of the O'Neill soils is the addition of organic matter. Large applications of farm manure would prove of value, and the turning under of leguminous crops as green manures would improve the condition of the soil materially. The type is acid and in need of lime. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended.
DAVENPORT SILTY CLAY LOAM (101)

The Davenport silty clay loam is a minor type, covering 0.1 percent of the total area. Two small areas of this type occur on the benches of Buck Creek near its mouth. The surface soil to a depth of 6 inches is a grayish-brown or brown plastic clay loam. It is underlaid at a depth of 22 inches by a light brown silty clay or clay, having a distinctly pinkish hue under normal field conditions. Below this layer there is a pinkish-brown or reddish-brown tenacious clay, faintly mottled with brown or gray.

A part of this soil is under cultivation, and corn is the chief crop grown. The type is in need of more adequate drainage in some cases before it can be made satisfactorily productive. Small applications of farm manure would prove of value in stimulating the production of available plant food in this type. Large additions should not be made. The soil is acid and in need of lime. The use of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are recommended.

MILLSDALE LOAM (209)

The Millsdale loam is a minor type, covering 0.1 percent of the total area. It occurs in several small areas along the Volga River between the towns of Osborne and Volga. The surface soil of the type to an average depth of 15 inches is a dark grayish-brown heavy loam. The subsoil is a heavy clay loam, varying in depth and resting upon limestone bedrock, which is usually encountered from 30 to 40 inches below the surface.

Nearly all of this soil is under cultivation, and general farm crops are grown. Yields are very much the same as those secured on the Carrington loam. The type will respond to applications of farm manure. Lime is necessary as the soil is acid at the surface. The use of phosphate fertilizer would be of value, and tests of superphosphate are recommended.

MILLSDALE FINE SANDY LOAM (236)

The Millsdale fine sandy loam is a minor type, covering 0.1 percent of the total area. It occurs on the higher parts of the terraces above the areas of the Millsdale loam. Several small areas are found along the Volga River between the towns of Osborne and Volga.

The surface soil to a depth of 10 inches is
MILLSDALE FINE SANDY LOAM

A  Dark grayish-brown fine sandy loam
B  Grayish brown fine sandy loam
C  Brown clay loam

**MILLSDALE FINE SANDY LOAM**

a dark grayish-brown fine sandy loam. The subsoil to a depth of 22 inches is a fine sandy loam having a slightly browner color, otherwise being similar to the surface soil. The subsoil below 22 inches is a brown or dark brown clay loam containing much fine sand. The limberock is encountered at depths of about 30 inches.

All the soil is under cultivation, and general farm crops are grown. Yields are slightly less than those secured on the Millsdale loam and on the Carrington loam. The soil is chiefly in need of additions of organic matter. The liberal application of farm manure would prove of value, and the turning under of leguminous crops as green manures would help. The type is acid in the surface and in need of lime. The application of a phosphate fertilizer would prove of value, and tests of superphosphate are recommended.

**Swamp and Bottomland Soils**

There are eight swamp and bottomland soils in the county, and these with the colluvial phase of the Wabash silt loam and the areas of riverwash and muck make a total of 11 bottomland areas. The soil types are classified in the Wabash, Genesee, Cass and Sarpy series. Together they cover 10.2 percent of the total area.

**WABASH SILT LOAM (26)**

The Wabash silt loam together with the colluvial phase, which is somewhat smaller in extent, is the fifth largest soil type in the county, covering 4.6 percent of the total area. It is the largest bottomland soil. It is found in numerous areas along the small streams that flow across the areas of the dark colored loessial soil. It is found developed in more or less extensive areas along practically all the streams in the loessial section of the county.

The surface soil of the Wabash silt loam is a very dark grayish-brown or black friable silt loam extending to a depth of 12 inches. This is underlaid by a brown silty clay loam, which in turn is underlaid at a depth of 20 inches by a grayish-brown silty clay loam subsoil. A few faint iron stains occur in some places.

The Wabash silt loam occurs on the flood plains, rising above the stream level to a height of several feet. It is subject to overflow at every rise of the streams. Drainage is good over much of the area. There are a few areas
CLAYTON COUNTY SOILS

WABASH SILT LOAM-COLLUVIAL PHASE

A greater part of the soil is used for pasture, but some areas are under cultivation. Corn is grown on the cultivated land, and when the soil is well drained satisfactory crop yields are secured. Drainage is the first treatment needed by the type after it has been protected from overflow. It is acid in reaction and in need of lime if legumes are to be grown. The use of a phosphate fertilizer would undoubtedly be of value when the land is to be cultivated, and tests of rock phosphate and superphosphate are recommended.

LOAM (colluvial phase) (26a)

The colluvial phase of the Wabash silt loam is somewhat smaller in area than the typical Wabash silt loam. It covers somewhat less than 2 percent of the total area. It occurs in association with the typical soil along the various streams which extend thru the loessial section of the county. It is found developed principally along the upper part of the smaller streams. There are numerous areas of the type, most of which are rather small in extent.

The surface soil of the Wabash silt loam colluvial phase is a very dark grayish-brown silt loam extending to a depth of from 12 to 20 inches. The subsurface soil is a brown or dark grayish-brown heavy silt loam. The subsoil to a depth of 40 inches is very similar. In many areas there is little difference in the surface soil to a depth of 3 feet or more. In these areas the type resembles the Judson silt loam. In the eastern part of the county about 3 miles east of Garnavillo, there are small areas of the soil which contain some rock fragments. The color of the soil is somewhat darker in these areas. They are small and unimportant.

A large part of the type is under cultivation, the remainder being utilized for pasture. Corn is the chief crop grown. The greater part of the land is subject to overflow, but the excess of water is soon removed. The chief need of the type if it is to be cultivated is for protection from overflow. Additions of lime are necessary if legumes are to be grown, and the use of a phosphate fertilizer would undoubtedly prove of value.

GENESEE SILT LOAM (71)

The Genesee silt loam is a minor type covering 2.3 percent of the total area. It is the second largest bottomland soil. It occurs in continuous strips along the smaller stream
channels, crossing the Fayette and Clinton soils.

The surface soil of the Genesee silt loam is a smooth grayish-brown silt loam extending to a depth of 18 inches. The subsoil is a heavy silt loam slightly lighter in color extending to a depth of 40 inches. In some places the color of the subsoil is slightly yellow. In general it is very similar to that of the surface soil. In places the type contains a considerable percentage of very fine sand or thin layers of fine sand, silt or clay. Under a small part of the soil there is a dark heavy layer occurring below a depth of 24 inches.

Only a small part of the type is used for cultivated crops, the remainder being utilized for pasture. Corn is grown almost exclusively. The soil is subject to overflow and must be protected from flooding if satisfactory crop yields are to be secured. Drainage is usually adequate except for a few low basin-like depressions. Additions of farm manure would be of value on this type if it is to be cultivated. The use of lime is necessary to correct the acidity of the soil, and the application of a phosphate fertilizer would undoubtedly be of value. Tests of superphosphate are recommended.

RIVERWASH (53)

There is a small area of Riverwash, covering 1.3 percent of the total area. The areas of this material have been mapped along the Mississippi River in the eastern part of the county. It is hardly a soil, but consists of recently deposited sediment, mostly unassorted, made up of a mixture of coarse and fine material. In one case it is largely a sandbar and in another case a mud bank. These deposits are reworked at every period of high water and the areas are subject to a change of outline or even total removal by any flood. The land has little agricultural value. A few trees, mostly willows, are scattered over the more permanent areas. A sparse growth of grass has established itself on some of the better soil material.

GENESEE VERY FINE SANDY LOAM (70)

The Genesee very fine sandy loam is a minor type, covering 0.7 percent of the total area. The principal area of this soil begins on Turkey River 2 miles west of Osterdock and extends along the river to its mouth. A few small areas are found along Elk Creek and Volga River.

The surface soil of the Genesee very fine sandy loam is a light grayish-brown silty very fine sandy loam 15 inches in depth. It is underlaid by a grayish-brown silty very fine sandy loam somewhat heavier in texture in most places than the surface soil. The lower layers may be somewhat lighter or heavier than the surface soil or there may be a succession of lighter or heavier layers. There are many variations in the type. On account of its low topographic position it is frequently flooded and changed by additions of sediment from the river.

About one-half of the soil is under cultivation, almost exclusively to corn. In favorable
seasons, the yields are good. This type should be protected from overflow if it is to be made satisfactorily productive. It will then respond to liberal applications of farm manure. It is acid and in need of lime for the best growth of legumes. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended.

GENESEE SILTY CLAY LOAM (182)

The Genesee silty clay loam is a minor type, covering 0.3 percent of the total area. The principal areas are found along Buck Creek near its mouth and on the Mississippi River bottoms northeast of Guttenberg, south of Turkey River.

The surface soil of the Genesee silty clay loam is a grayish-brown silty clay loam extending to a depth of 7 inches. The subsurface soil to about 15 inches is a silty clay loam, grayish-brown and mottled with rusty brown iron stains. The subsoil is a silty clay, strongly discolored with rusty iron stains in the upper part and changing at about 22 inches into a light slate gray silty clay.

The greater part of the type is used for pasture. Very little of it is cultivated. Much of the areas in this soil are under water for a large part of the year. The chief need of the type is for protection from overflow and adequate drainage. When this is accomplished the soil might be profitably cultivated. Additions of farm manure would be of value. The soil is acid and in need of lime. The application of a phosphate fertilizer would be desirable, and tests of superphosphate are recommended.

CASS SILT LOAM (106)

The Cass silt loam is a minor type, covering 0.3 percent of the total area. It occurs in narrow strips in the flood plains of the Turkey and Volga rivers. There are a number of small areas of the type.

The surface soil of the Cass silt loam is a very dark grayish-brown or black heavy silt loam to a depth of 15 inches. The subsurface soil is a grayish-brown loam or fine sandy loam. At about 28 inches there is an abrupt change into a brown sand, containing coarse sand, gravel and small rock fragments. This is the typical subsoil of the Cass silt loam. The surface of the type in most places is flat, but there are a few low ridges and mounds rising above the general level. The soil is subject to overflow at every rise of the river, but the water rapidly recedes.
A large part of the soil is in cultivation, almost exclusively to corn. Yields are good in favorable seasons. The type is in need of protection from overflow if it is to be satisfactorily cultivated. The addition of farm manure would be of value, and the use of a phosphate fertilizer would undoubtedly prove worth while. Tests of superphosphate are recommended. In some areas the type is probably acid and in need of lime. When there is acidity in the soil lime should be applied if legumes are to be grown.

WABASH LOAM (49)

The Wabash loam is a minor type covering 0.3 percent of the total area. It occurs in very small areas along the Turkey and Volga rivers and a few of their tributaries and along the tributaries of the Maquoketa River in the southwestern corner of the county.

The surface soil of the Wabash loam is a very dark grayish-brown friable loam, extending to a depth of 18 inches. The subsoil is a dark grayish-brown or brown clay loam, containing considerable of the coarser grades of sand. In small areas along the Maquoketa River there are sandy loam phases of the type. These differ from the typical soil only in the sandy loam texture of the surface soil. The soil is subject to overflow at frequent intervals and hence varies somewhat in texture.

Very little of the type is cultivated, the greater part being used for pasture land. For the best growth of cultivated crops, it must first be protected from overflow. Additions of farm manure would be of value. The soil is acid and in need of lime, and the use of a phosphate fertilizer would be desirable. Tests of superphosphate are recommended.

CASS SANDY LOAM (19)

The Cass sandy loam is a minor type, covering 0.2 percent of the total area. It is found developed on the first bottoms of the Turkey and Volga rivers. The largest areas occur near the point where Turkey River enters the county.

The surface soil of the Cass sandy loam is a very dark grayish-brown sandy loam 10 inches in thickness. The subsurface soil is a brown coarse sandy loam containing a large percentage of coarser grades of sand and fine gravel. At a depth of 28 inches the subsoil is encountered, consisting of a bed of very loose and porous coarse sand and gravel.
Included with this soil there is a finer textured variation occurring in Marion and Highland townships in areas too small to be indicated separately on the soil map. This included area of soil is a very dark grayish-brown fine sandy loam from 12 to 14 inches in thickness, and containing considerable silt. Underlying this there is a grayish-brown or brown fine sandy loam containing much coarse sand and some gravel. The soil is less inclined to be drouthy than the typical Cass sandy loam. The texture averages a fine sand, but many spots are quite loamy.

The principal areas of this soil are under cultivation. Corn is the chief crop grown, small grains being produced occasionally. The soil is subject to overflow, and unless protected from flooding crop yields are apt to be quite unsatisfactory. Applications of farm manure would be of value to cropped areas. In some of the areas the type is acid in reaction and in need of lime. In other cases there is no need for additions of lime. The application of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

SARPY VERY FINE SANDY LOAM (28)

The Sarpy very fine sandy loam is a minor type, covering 0.1 percent of the total area. Small areas are mapped along the upper Turkey River and upper Volga River, the largest being ¼ mile northeast of Volga.

The surface soil of the Sarpy very fine sandy loam is a grayish-brown very fine sandy loam 15 inches in thickness. It is underlaid by a grayish-brown very fine sandy loam or fine sand. There are many variations in the soil, especially at the surface and in places there are thin layers of varying texture making up the entire soil. The sandy phase is found in a few small areas northeast of Volga. On account of its small total acreage, it is included with the Sarpy very fine sandy loam.

The soil occurs on the bottoms bordering the stream channels and is subject to periodic overflow. Only a small part of this soil is under cultivation. Corn is the chief crop grown. Yields are fair in favorable seasons, but the soil is subject to overflow and hence yields are uncertain. The type is chiefly in need of protection from overflow if it is to be made productive. It will respond to applications of farm manure. In some areas it may be acid in reaction, in which case it would need to be limed. Other areas are not in need of lime. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended.

MUCK (21a)

There is a small area of muck, covering 0.1 percent of the total area. It occurs in small areas in the southwestern corner of the county, southeast of Strawberry Point. Muck consists of a dark brown or black partly decomposed vegetable matter derived from an accumulation of the remains of plants. Varying amounts of mineral material washed in from the surrounding uplands are mixed with the plant remains. The material in most

\[ \text{SARPY VERY FINE SANDY LOAM} \]

\[
\begin{array}{c}
\text{A} \quad \text{Grayish brown very fine sandy loam} \\
\text{B} \quad \text{Grayish brown very fine sandy loam or fine sand} \\
\text{C} \quad \text{Yellowish brown fine coarse sand} \\
\end{array}
\]
places ranges in thickness from a few inches to 3 feet. The areas of muck are used entirely for pasture. They are poorly drained and if they are to be cultivated must first of all be thoroughly drained. For the growth of cultivated crops on drained areas of muck, applications of muriate of potash and superphosphate, each at the rate of 200 pounds per acre, would prove of value.

Residual Soils

There are three residual soils in the county, classified in the Sogn and Dubuque series. These, together with the area of rough stony land make up the four residual soil areas. Together they cover 7 percent of the area.

ROUGH STONY LAND (78)
There is a rather considerable area of rough stony land in the county, covering 6.7 percent of the total area. It consists of non-agricultural land of little value even for grazing. It occurs on steep slopes where the streams have removed the greater part of the loess, and the underlying lime rock or the weathered soil is exposed. It includes the almost perpendicular limestone ledges which are found along the large streams.

There is a thin residual soil overlying the rock in a considerable part of these areas, and this is formed from the weathering of the limestone and consists of a black heavy silt loam 3 inches thick. It is underlaid by a thin layer of black silty clay, which in turn is underlaid by gray or gray and brown mottled clay resting on the rock. This material may be 3 inches or more in thickness, but as a rule the entire thickness of the weathered soil is only a few inches. On the lower slopes the deeper soil consists of a material which has slipped down from above. On the upper slopes there is practically no soil. In places the silty material has been washed down from the loess soils and forms a thin covering over the rocks of the residual soils. Small areas of silty material are similar to the steep areas of the Fayette and Clinton silt loams. Such areas were too small to show on the map.

The greater part of this land is in timber. The tree growth consists of oak, hickory, elm, ash, birch and other hardwoods and patches of underbrush. It is too rough and stony to be used for cultivated crops, and the best use seems to be for growing timber.

SOGN LOAM (237)
There is a small area of Sogn loam, covering 0.1 percent of the total area. It occurs only in a few small areas, principally in sections 13, 14 and 23 of Sperry Township in the southwestern part of the county and along the road leading from Strawberry Point to Elkader, about 3 to 5 miles southwest of Osborne.

The surface soil of the Sogn loam is a rich black loam containing much coarse sand and clay and extending to a depth of 10 inches. Below this to a depth of 15 inches, there is a dark brown or black silty clay loam or silty clay, changing abruptly into the subsoil which consists of a pale grayish-yellow clay loam containing considerable coarse sand. At 24 inches this subsoil becomes a heavy, tough, residual, blue-gray silty clay or clay, beneath which the hard limestone rock is found.

In topography the Sogn loam is gently rolling. The type is naturally productive and general farm crops are grown with yields very similar to those secured on the Carrington loam. The type is eroded to some extent.
The chief need of the soil to be made more productive is the addition of organic matter, which would increase the fertility of the soil and reduce the danger of erosion. In some areas the type may be acid in reaction in the surface soil, in which case lime is necessary if legumes are to be grown. The use of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are recommended.

SOGN CLAY LOAM (164)

The Sogn clay loam is a minor type, covering 0.1 percent of the total area. It occurs in several small areas in association with the Sogn loam.

The surface soil of the Sogn clay loam consists of a black, heavy clay loam about 7 inches in thickness. Below this there is a black calcareous silty clay or clay. At a depth of 12 inches there is a heavy bluish-gray clay, faintly mottled with yellowish-brown. This typical subsoil rests on the limestone bedrock from which the soil is derived. The depth of soil above the limestone varies, and in many places the rock is exposed in small patches.

A brown residual soil has been included with the Sogn clay loam because of its small extent. This type consists of a brown clay loam 5 inches thick, underlaid by a yellowish-brown tough clay which rests directly on the limestone at a depth ranging from 12 to 15 inches. This variation from the typical soil occurs over only a small total area and is relatively unimportant. Several small areas of the variation are found in the west central part of the county near the Turkey and Volga rivers.

One of the largest areas is 3 miles northwest of Elkader, others occur ½ mile south of Osborne, 2 miles west of Osborne, and others are scattered over this general region along the Volga River.

The Sogn clay loam is generally somewhat rolling in topography. The area near the Turkey River lies on a bench-like position and has a flat surface. The soil on the flat areas is poorly drained. On the more sloping areas, the drainage is more nearly adequate. The low lying areas are in cultivation, and general farm crops are grown. Corn yields from 30 to 50 bushels per acre and oats from 20 to 40 bushels. Clover and timothy do well on the better drained areas.

The chief need of this soil to be made more productive is for adequate drainage. It will then
be benefited by applications of farm manure. The use of a phosphate fertilizer will undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

**DUBUQUE SILT LOAM (183)**

The Dubuque silt loam is a minor type, covering 0.1 percent of the total area. It occurs on steep slopes or edges of bluffs along the larger streams where the covering of loess has been removed. There are a number of small areas of the type.

The Dubuque silt loam surface soil consists of a grayish-brown mellow silt loam underlaid by a yellowish-brown silty clay loam beneath which there is a yellowish-brown or reddish moderately stiff gravelly clay. This in turn rests on limestone. The total thickness of the soil above the bedrock ranges from 6 to 30 inches. The surface soil is formed largely or entirely from loess and the underlying clay is residual from limestone. In places the loessial soil rests directly on the rocks at a slight depth. There are many variations in the color of the surface soil and in the texture of the various soil layers.

Very little of this type has been cultivated. All of it was formerly covered with a growth of oak, hickory, elm and walnut. Smoother areas may be profitably utilized for pasture. The rougher areas should undoubtedly be left in timber.
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 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 types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various
PLANT FOOD IN SOILS

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

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

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.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications 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 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.

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 superphosphate, 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
### TABLE I. PLANT FOOD IN CROPS AND VALUE

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Plant Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats, crop</td>
<td>------</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td>barley, crop</td>
<td>------</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>------</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>50</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300</td>
<td>27.7</td>
<td>144</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

### 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 may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

### 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 yields of certain crops are not being
obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops, and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the 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 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 control the moisture in the soil.

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage, and the amount of water present in the soil may be conserved during the 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.

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.

There are a number of explanations 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 proper rotations the time between two different crops of the same plant is long enough to allow the "toxic" substances to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

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

MANURING

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

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

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

THE USE OF PHOSPHORUS

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

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

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and superphosphate 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.

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 force which brought about the formation of the various soil areas.

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 of "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 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 the 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 stone. 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 is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division 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

Map showing the principal soil areas in Iowa.
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 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 Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessal, alluvial, colluvial or residual.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and 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 decomposed vegetable and animal material.
- Stones—over 32 mm.*
- Gravel—32—2.0 mm.
- Very coarse sand—2.0—1.0 mm.
- Coarse sand—1.0—0.5 mm.
- Medium sand—0.5—0.25 mm.
- Fine sand—0.25—0.10 mm.
- Very fine sand—0.10—0.05 mm.
- Silt—0.05—0.00 mm.

**Inorganic matter**
- Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.
- Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.
- Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.
- Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.
- Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.
- Clay Loams—20 to 30 percent clay and less than 50 percent 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 30 percent.
- Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.
- Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 30 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, 20 to 30 percent silt and clay.
- Sand—More than 25 percent very coarse, coarse and medium sand, less than 20 percent fine sand, less than 20 percent silt and clay.

* 25mm. equals 1 in.  † Bureau of Soils Handbook.
Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.
Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.
Gravels—More than 50 percent very coarse sand.
Stony Loams—A large number of stones over 1 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 the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all 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 and by 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 of 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 map of the county.