7-1920

Soil Survey of Iowa, Report No. 13—Montgomery County

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35 Effects of Some Manganese Salts on Ammonification and Nitrification.  
43 The Effect of Sulphur and Manure on the Availability of Rock Phosphate in Soil.  
44 The Effect of Certain Alkali Salts on Ammonification.  
45 Soil Inoculation with Azotobacter.

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3 Muscatine County.  
4 Webster County.  
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8 Clinton County.  
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SOIL SURVEY OF IOWA
Report No. 13--MONTGOMERY COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson, M. E. Olson and L. L. Rhodes

A representative Montgomery County farmstead

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

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson, M. E. Olson and L. L. Rhodes

Montgomery county is located in southwestern Iowa, in the second tier of counties north of the Missouri line and separated by only one county from the Nebraska state line on the west. It is entirely within the Missouri loess soil area and by far the largest percent of the soils are loessial in origin.

The total area of the county amounts to 424 square miles, or 271,360 acres. Of this area, 256,232 acres, or 94.4 per cent, is in farm land. The total number of farms is 1,668 and the average size is 153.6 acres. The following figures from the Iowa Yearbook of Agriculture for 1917 show the utilization of the farm land of the county:

Acreage in general farm crops ........................................ 155,770
Acreage in pasture ................................................. 81,182
Acreage in gardens ................................................... 182
Acreage in orchards .................................................... 959
Acreage in farm buildings, feed lots and public highways ...... 10,367
Acreage in waste land ................................................. 1,178
Acreage in crops not otherwise listed .............................. 203

General farming is the type of agriculture which is practised most extensively in Montgomery county. The livestock industry is very important, however, especially the raising of hogs. The raising of beef cattle is practised to a limited extent also. The feeding of beef cattle is an important industry and the feeding of sheep is likewise of some importance. Dairying is followed on a small scale to supply the local demands. The raising of poultry is practised on practically every farm as a minor industry.

Gardens and orchards are maintained on most farms to supply, in part, the home demand. Apples, cherries, and pears are the leading fruits. Sweet potatoes, sweet corn, melons, millet, sorghum, soy beans, navy beans, strawberries and dewberries are some of the minor garden crops grown in the county for home use and to supply the local markets.

The area in waste land in the county is rather large and it is quite advisable that some method be adopted to reclaim such land. It is impossible to recommend general methods of treatment inasmuch as the conditions causing infertility are quite variable. The special treatments needed for individual soil types will be considered later in this report. Advice regarding the treatments necessary in special cases may be obtained from the Soils Section of the Iowa Agricultural Experiment Station, upon request.

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

*See Soil Survey of Montgomery county by A. M. O'Neal, Jr., of the U. S. Department of Agriculture and L. L. Rhodes of the Iowa Agricultural Experiment Station.
### TABLE I. ACREAGE, YIELDS AND VALUES OF FARM CROPS IN MONTGOMERY COUNTY*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percentage of total farm land in county</th>
<th>Bu. or tons per acre</th>
<th>Total bu. or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>106,000</td>
<td>41.40</td>
<td>40.0</td>
<td>4,240,000</td>
<td>$0.97</td>
<td>$4,012,800</td>
</tr>
<tr>
<td>Oats</td>
<td>22,800</td>
<td>8.80</td>
<td>44.4</td>
<td>1,013,000</td>
<td>$0.61</td>
<td>617,390</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>5,900</td>
<td>2.00</td>
<td>20.1</td>
<td>50,400</td>
<td>$1.54</td>
<td>82,776</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>3,000</td>
<td>1.10</td>
<td>14.0</td>
<td>42,000</td>
<td>$1.97</td>
<td>61,740</td>
</tr>
<tr>
<td>Barley</td>
<td>400</td>
<td>0.15</td>
<td>36.0</td>
<td>14,000</td>
<td>$1.15</td>
<td>6173</td>
</tr>
<tr>
<td>Rye</td>
<td>160</td>
<td>0.66</td>
<td>20.1</td>
<td>3,200</td>
<td>$1.97</td>
<td>6173</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,450</td>
<td>.96</td>
<td>84.0</td>
<td>50,400</td>
<td>$1.32</td>
<td>68,228</td>
</tr>
<tr>
<td>Tame hay</td>
<td>16,000</td>
<td>6.20</td>
<td>1.7</td>
<td>800</td>
<td>$14.79</td>
<td>11,832</td>
</tr>
<tr>
<td>Wild hay</td>
<td>400</td>
<td>.13</td>
<td>4.0</td>
<td>16,000</td>
<td>$18.82</td>
<td>27,108.8</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>3,000</td>
<td>1.10</td>
<td>2.5</td>
<td>7,500</td>
<td>$23.40</td>
<td>175,600</td>
</tr>
</tbody>
</table>

* *Iowa Year Book of Agriculture, 1917.

Corn is by far the most important crop, both in acreage and value, over 41 pet. of the total farm land of the county being devoted to this crop. Average yields of 40 bushels per acre are secured. Practically all the corn is used for feeding purposes for hogs, cattle or dairy cows. Much of the corn is used for ensilage.

Oats is the second crop in importance in the county and average yields of 45 bushels per acre are secured. Under favorable seasonal conditions the yield of oats may be very much greater. The greater proportion of the oat crop is fed on the farm but in some instances a part is marketed at local elevators.

Hay is produced on a considerable area, the crop consisting mainly of timothy and clover mixed. Some timothy is grown alone and some clover is also grown alone. All of the hay produced in the county is used for feeding and it is always necessary to add to the supply by purchasing some outside of the county. Considerable clover is harvested for seed. It is frequently customary to pasture the crop the first year. The area devoted to wild hay is small.

The fourth crop both in acreage and value is wheat. Spring wheat and winter wheat are produced on almost equal acreages. Formerly spring wheat was grown almost exclusively but the area in this crop is decreasing, while that in winter wheat is increasing rapidly. Average yields of 20 bushels per acre for the spring varieties and 14 bushels for the winter varieties are reported. Only a small part of the crop is used locally, the bulk being sold.

Alfalfa is being grown on a rather large acreage in the county and the area in this crop is increasing as its value is being more generally recognized. Average yields of 2½ tons per acre are secured and yields of 3 or 4 tons are not uncommon. Good yields are secured in many cases for five or seven years without reseeding and three or four cuttings are obtained each season.

Potatoes are grown on a considerable acreage and average yields of 84 bushels per acre are secured. Barley and rye are grown on small areas and are of minor importance. The rye is mainly grown for home use and the barley grain is largely used for feeding.

The character and extent of the livestock industry in Montgomery county are shown in the following figures taken from the Iowa Yearbook of Agriculture for 1917:
The raising of hogs is the most important industry throughout the county. The feeding of beef cattle is of considerable importance and the feeding of sheep is also of value. Considerable time is also devoted to the raising of cattle. Dairying is of only minor importance. In general, the largest sources of income from the livestock industry is the sale of hogs and beef cattle.

Land values in Montgomery county are somewhat variable, depending upon the improvements, the topography and the location with reference to towns and railroad facilities. Rough and strongly rolling land in the eastern section, at some distance from the railroad, sells for $100 to $150 per acre while the slightly rolling to undulating land in the same locality sells for $200 per acre. Near the railroads and larger towns, the land values range from $200 to $300. In general it may be said that throughout the county, farm land will average from $185 to $250 per acre.

The yields of farm crops and the incomes from the average farms in Montgomery county are in general, quite satisfactory. In some cases, however, improvements may be made in the methods of soil treatments practiced, with resulting increases in crop yields and larger money returns from the farms. The soils of the county are usually slightly acid in reaction and while deficiency in lime content is not great, small applications of lime would undoubtedly be of value in many cases, especially where legumes such as clover and alfalfa are to be grown. Perhaps the greatest need of the upland types in the county is for organic matter which may be supplied by applications of farm manure or green manures. Farm manure is of considerable value on these soils and applications of as large amounts as practicable should be strongly urged. When the amount of farm manure produced is insufficient to keep all the upland soils on the farm supplied, green manures should be employed to bring up the organic matter content of the soil.

The phosphorus supply in the soils of the county is not high and applications of phosphorus fertilizers may be of much value at the present time. Even if they are not needed now, they will certainly be needed in the near future. Complete commercial fertilizers are not recommended for general use in the county but it is possible that they may prove of value in some cases. Field tests are now being carried out on some of the more important soil types to determine the relative value of rock phosphate, acid phosphate and complete commercial fertilizers, in increasing crop production. Data from these experiments are being secured and it is hoped that after several years' results become available, definite advice can be given regarding the use of these materials. For the present it can merely be urged that experiments be carried out by individual farmers on their own soils to determine whether or not any of these fertilizers will prove profitable. If tests on a small area yield good results, then applications of the fertilizer may be made to large areas with the assurance of profit.
Drainage is necessary in a few instances but in general the soils of the county are well drained. The proper cultivation of the soil, the rotation of crops and the utilization of all crop residues produced on the farm are other well-known soil treatments which should be practiced in addition to those mentioned above, if crop production is to be increased and the soils of the county kept permanently productive.

THE GEOLOGY OF MONTGOMERY COUNTY*

The rock material underlying the soils of Montgomery county is so deeply buried under the coverings of drift and loess that it exerts practically no influence on the character of the soils of the county. Only in a few narrow ledges do the underlying rocks appear and even in these localities little effect is apparent in the character of the soil.

The county was covered at least once by a great ice sheet which on its retreat left behind a thick deposit of debris known as glacial drift or till. This glacial deposit is quite variable in thickness. In the central and southern tier of townships it ranges from 20 to 60 feet in depth. Near the Cass county line it varies from 65 to 95 feet in depth and in the highest parts of Lincoln township it has been estimated that the drift layer may be as much as 160 feet thick.

The drift material is quite variable in character but it consists in general of a blue boulder clay underlain by a yellow boulder clay. The former consists of a bluish-gray, tough, plastic clay carrying a small percentage of both fine and coarse sand. It also contains lime particles and concretions. Boulders are distributed to some extent through the upper part of this blue clay. The yellow clay varies from a yellow to green and brown in color. It contains lime concretions and many pebbles and small boulders. Throughout this upper layer, deposits of coarse sand are frequently found. This glacial drift is exposed only in the rougher portions of the county, chiefly where deep valleys have been cut through the lower slopes. Small areas are also exposed in other parts of the county on the tops of hills where the surface covering of loess has been removed. The soil derived from this glacial material is mapped as Shelby silt loam and it covers less than 4 per cent. of the total area of the county.

The greater portion of the upland of the county is covered by a layer of loess deposited by the wind at some previous geological time when climatic conditions were very different than at present. It ranges in color from a pale yellow to a yellowish-brown and is an even-grained material composed chiefly of silt. Under the process of weathering to which the loess has been subjected during the time that has elapsed since its deposition, it has lost most of its original content of lime and the accumulation of plant remains has led to a rather noticeable darkening in its color. The depth of this loess covering varies considerably, being usually somewhat greater in the western part of the county and gradually becoming thinner toward the east. In general, throughout the county the deepest deposits will not exceed 35 feet and the average depth will vary from 8 to 12 feet. The soil derived from the loess deposit is mapped as Marshall silt loam and covers two-thirds of the total area of the county.

Besides this loess soil and the small area of drift, there is a rather considerable area of terrace or second bottomland soil and of first bottomland soil. These are formed by the action of streams and are composed, therefore, of mixtures of loess and drift, and the deposits vary widely in thickness.

**PHYSIOGRAPHY AND DRAINAGE**

The upland of Montgomery county is, in general, a gently undulating plain cut by the rather shallow valleys of the larger streams and their tributaries. Along the Middle Nodaway and West Nodaway rivers and Seven Mile creek the topography is rather rough and broken. The slopes are steep and irregular and cultivation is difficult. Small areas of this rough land are found on the east side of the Nishnabotna, just north of Stennett and along the east side of Tarkio creek, just before it leaves the county. These rough areas extend back from the streams from one-half to three miles where they merge with the gently undulating upland. The hills thruout the upland are smooth and rounded. The slopes are gentle and uniform and the landscape, in general, has a gently rolling appearance. The ridges and valleys which occur in succession across the county are nearly parallel and extend approximately in a north and south direction. The lowlands vary from a few yards to two miles in width and are distributed quite irregularly along the various streams.

The drainage of the county is brought about by the East Nishnabotna, West Nodaway and Middle Nodaway rivers and Seven Mile, Tarkio, Walnut and Indian creeks and their tributaries. The larger streams have channels not
more than 200 to 250 feet in width and their banks rise from 10 to 20 feet above low water. The flood plains of these rivers lie 100 to 200 feet below the general level of the uplands. Numerous intermittent drainage ways branch throughout all parts of the county. The drainage of the county in general is, therefore, quite satisfactory and only in a few instances is it necessary to resort to the use of tile drains and ditches. The accompanying map shows the location of the drainage system of the county.

THE SOILS OF MONTGOMERY COUNTY

The soils of Montgomery county are grouped into four classes, according to their origin and location. These classes are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from material deposited by glaciers on their retreat and they contain material from various sources and sometimes 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 decrease in the volume of the stream which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow.

The extent and occurrence of these four groups of soils in Montgomery county are shown in table II.

By far the largest area of the county, over 66 pet., is covered by the loess soil. The swamp and bottomland soils are less extensive covering about 28 pet. of the total area of the county. The drift and terrace soils are comparatively small in area, covering 3.8 and 2.1 pet. of the total area of the county, respectively. In topography the loess and drift soils are undulating to gently rolling. The drainage is well established. The terrace types are level to very gently sloping but the drainage is entirely satisfactory. The swamp and bottomland soils are all level in topography and subject to overflow. The Wabash silt loam is particularly in need of drainage, some of the type being so level and impervious that it is known locally as "gumbo."

There are seven distinct soil types in Montgomery county and these with the colluvial phase of the Wabash silt loam, make a total of eight separate soil areas. There is one drift soil, two loess soils, two terrace soils and three swamp and bottomland types. These various soil types are distinguished on the basis of definite characteristics which are described in the appendix to this

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soil</td>
<td>10,968</td>
<td>3.8</td>
</tr>
<tr>
<td>Loess soils</td>
<td>179,520</td>
<td>66.2</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>5,760</td>
<td>2.1</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>75,712</td>
<td>27.9</td>
</tr>
<tr>
<td>Total</td>
<td>271,360</td>
<td></td>
</tr>
</tbody>
</table>
TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MONTGOMERY COUNTY

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRIFT SOIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Shelby silt loam</td>
<td>10,368</td>
<td>3.8</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>179,392</td>
<td>66.1</td>
</tr>
<tr>
<td>33</td>
<td>Knox fine sand</td>
<td>128</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>LOESS SOILS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>179,392</td>
<td>66.1</td>
</tr>
<tr>
<td>33</td>
<td>Knox fine sand</td>
<td>128</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>5,360</td>
<td>1.9</td>
</tr>
<tr>
<td>23</td>
<td>Hancock silt loam</td>
<td>400</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>39,104</td>
<td>27.1</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>34,496</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,112</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The drift soil is the Shelby silt loam and this is of minor importance in the county, covering only 3.8 pet. of the total area of the county and occurring in small areas on steep slopes and in narrow strips bordering the gentle slopes.

There are two loess types, the Marshall silt loam and the Knox fine sand. The Marshall silt loam is the most extensive soil type in the county, covering 66.1 pet. of the total area of the county. It is by far the most important type as it covers practically all of the upland of the county. The Knox fine sand is very minor in importance, covering only one-tenth of one percent of the total area of the county. It occurs in five small areas, the largest of which is just north of Morton Mills. There are two terrace types in the county, the Waukesha silt loam and the Hancock silt loam. Both of these types are of very minor importance, covering but 1.9 pet. and 0.2 pet. of the total area of the county, respectively.

The swamp and bottomland types are all of the Wabash series and are represented by the silt loam, colluvial phase of the silt loam and the silty clay loam. The silt loam is the largest in area and the colluvial phase is only slightly smaller in extent. Together these types cover 27.1 pet. of the total area of the county. The Wabash silty clay loam is of minor importance, extending over only 0.8 pet. of the total area of the county.

THE FERTILITY IN MONTGOMERY COUNTY SOILS

Samples were drawn from all the soils in the county with the exception of the Knox fine sand and the Hancock silt loam, both of which are of very little importance. The more important types were sampled in triplicate while only one sample was secured from the minor types. All the samples were taken with the greatest care, so that they should represent accurately typical soils and any variations due to local conditions or special treatments be eliminated. The
SOIL SURVEY OF IOWA

Sampling were made at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil respectively. Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were followed in the phosphorus, nitrogen and carbon determinations and the Veitch method was employed in the determination of the limestone requirement. The results given in the tables are the averages of duplicate determinations on all the samples of each type which were analyzed. Where more than one sample of a type was taken, the results are the averages of four or six determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The amount of phosphorus in the soils of the county is somewhat variable, ranging from 1,218 up to 2,092 pounds per acre. There is no relation apparently between the various soil groups and the phosphorus content of the soils, the drift, loess and terrace types containing almost the same amounts while the loess soils are just a trifle higher than the others. The average of the swamp and bottomland types is somewhat higher than in the other soil groups. This is due to the high content of the Wabash silt loam and the still greater content of the Wabash silty clay loam. The colluvial phase of the Wabash silt loam shows about the same amount of phosphorus as the upland soils. It might be expected that the bottomland types would be better supplied with this element inasmuch as crop growth has been less and there has, therefore, been less removal from the stock originally present in the soil. In general, it seems evident that while phosphorus is not actually deficient in the soils of Montgomery county at the present time, that element must be supplied in the near future, if the soil is to be kept fertile. It is, of course, quite possible that phosphorus fertilizers may prove of value in some cases at the present time, but it is impossible to make definite recommendations until the field experi-

TABLE IV. PLANT FOOD IN MONTGOMERY COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Shelby silt loam</td>
<td>1,359</td>
<td>3,346</td>
<td>39,238</td>
<td>512</td>
<td>2,402</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>1,332</td>
<td>3,980</td>
<td>43,438</td>
<td>388</td>
<td>2,935</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,238</td>
<td>3,818</td>
<td>59,196</td>
<td>414</td>
<td>1,601</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,590</td>
<td>5,059</td>
<td>85,758</td>
<td>322</td>
<td>2,535</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>1,218</td>
<td>3,260</td>
<td>40,532</td>
<td>428</td>
<td>1,601</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,092</td>
<td>6,198</td>
<td>78,510</td>
<td>310</td>
<td>1,601</td>
</tr>
</tbody>
</table>
ments now under way have given evidence of the value of such materials. Tests should be made on a small scale before large areas are treated with any phosphatic fertilizer.

The nitrogen content of the various soil types varies in much the same way as does the phosphorus. Thus the drift, loess and terrace types differ but little in nitrogen content, the loess soil having slightly the larger amount. The average of the bottomland types is greater than in the case of the other soil groups, as might be expected. The Wabash silt loam and the Wabash silty clay loam are both considerably higher in nitrogen than the upland or terrace soils but the colluvial phase Wabash contains about the same amount as the upland types. While the nitrogen supply of these soils is not low and in fact the amount present is sufficient to supply many crops, still this does not mean that nitrogen can be disregarded in systems of permanent fertility. A supply of this element must be maintained by the regular application of nitrogenous materials. Farm manure, green manures and crop residues are the natural nitrogenous fertilizers. Leguminous green manures furnish the best means of supplying nitrogen to the soil, because when well inoculated they secure a part of the nitrogen which they contain, from the atmosphere. These materials not only supply nitrogen but also organic matter to the soil and hence they have a double value. The organic carbon in the soil is a measure of the amount of organic matter present. If there is a large amount of organic carbon in the soil, there is usually an abundance of nitrogen present. Hence, there is ordinarily a definite relation between the amount of organic carbon and nitrogen present in soils.

The color of the soil indicates quite definitely the amount of organic matter present and shows roughly the organic carbon content and usually the nitrogen content. The heavier soil types and those darker in color usually contain the most organic matter and nitrogen. Deficiency in these constituents is rather clearly shown by a light colored soil.
The bottomland types contain, on the average, considerably more organic carbon than the upland or terrace types. The Wabash silt loam and the silty clay loam are particularly rich in organic matter as indicated by their color, while the colluvial phase Wabash is poorer in this element. Practically the same relations between the soil types occur in the case of the organic carbon, as were noted in the case of the nitrogen. In general, it may be said that the upland types are not abundantly supplied with organic matter and experimental evidence indicates that fertilizing materials supplying organic matter are particularly valuable on these soils. Indeed, farm manure gives increases in crop yields at the present time which are frequently rather large and always profitable. The value of manure in improving crop production in Montgomery county is definitely established.

All the soil types in the county show a small content of inorganic carbon but in no case is the amount sufficient so that the type does not show a lime requirement by the Veitch method. It is evident that the lime supply in these soils has been rather largely removed thru the weathering they have undergone and while no striking deficiency is found, such as frequently occurs in the soils of some other counties, the application of lime is becoming more generally necessary. This conclusion is borne out by the results of the limestone requirement tests which indicate a need of about one ton of limestone on all the soils of the county. As crop production continues on these soils, this deficiency in lime will become more and more apparent and while quite satisfactory crops may be secured at present without additions of lime, such applications will be found more and more necessary, especially if legumes are to be grown. Every soil in Montgomery county should, therefore, be tested from time to time and when a lime requirement is indicated, a proper application made, if the best crop production is to be secured.

THE SUBSURFACE SOILS AND THE SUBSOILS

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

TABLE V. PLANT FOOD IN MONTGOMERY COUNTY, IOWA, SOILS
Pounds per acre of four million pounds of subsurface soils (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 requirem’t</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>Shelby silt loam........</td>
<td>1,436</td>
<td>3,900</td>
<td>42,224</td>
<td>536</td>
<td>3,202</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam......</td>
<td>2,276</td>
<td>6,762</td>
<td>70,854</td>
<td>832</td>
<td>4,804</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam.....</td>
<td>2,304</td>
<td>10,112</td>
<td>94,072</td>
<td>648</td>
<td>3,202</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirem’t</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,568</td>
<td>7,601</td>
<td>119,709</td>
<td>650</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>2,436</td>
<td>6,838</td>
<td>84,900</td>
<td>700</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>4,252</td>
<td>8,392</td>
<td>165,884</td>
<td>1,216</td>
</tr>
</tbody>
</table>
The actual plant food content of the lower soil layers has very little influence on the fertility of the soil unless an unusually large amount of some constituent is present. There is no considerable quantity of any of the essential plant food constituents present in the subsurface soils and subsoils in Montgomery county. It is not necessary, therefore, to consider these analyses in detail. The needs of the soils as shown by the analyses of the surface samples are confirmed by the analyses of the samples at lower depths. Phosphorus will be needed in the future and phosphorus fertilizers might prove of value in some cases, even now. The organic matter and nitrogen content, while not extremely low is, on the other hand, sufficiently low to warrant applications of organic materials containing nitrogen. The lower layers of the various types show a little more lime than the surface soils but the amounts present are rather small and only in the case of the subsoil of the Wabash silty clay loam is there no limestone requirement.

It is evident that any deficiency in lime in the surface soil cannot be supplied from the lower soil layers. In fact it is questionable whether or not there is any moving upward of lime in the soil. However, if such a movement occurred, there would be little change in the lime requirements in the surface soils of this county. Lime must certainly be applied to these soils at regular intervals if the proper reaction is to be maintained and the best crop growth secured continuously.

**GREENHOUSE EXPERIMENTS**

In order to gain some information regarding the needs of the soils of Montgomery county and the value of various fertilizer treatments, two experiments were carried out in the greenhouse, one in 1918 and the other in 1919. The soil used in both the tests was the Marshall silt loam, the chief soil type in the county.

The soil treatments were the same in both cases, and consisted in the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The same amounts of these materials were employed as in

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**TABLE VI. PLANT FOOD IN MONTGOMERY COUNTY, IOWA, SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pounds per acre</td>
<td>Pounds per acre</td>
<td>Pounds per acre</td>
<td>Pounds per acre</td>
<td>Pounds per acre</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>-----------------</td>
<td>---------------</td>
<td>---------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>DRIFT SOIL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Shelby silt loam</td>
<td>816</td>
<td>2.922</td>
<td>46.842</td>
<td>978</td>
<td>1.200</td>
</tr>
<tr>
<td><strong>LOESS SOIL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TERRACE SOIL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,508</td>
<td>5.927</td>
<td>81.324</td>
<td>1.236</td>
<td>634</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,504</td>
<td>5.547</td>
<td>115.844</td>
<td>856</td>
<td>2.401</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>3,566</td>
<td>11.064</td>
<td>133.218</td>
<td>882</td>
<td>3,115</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>4,992</td>
<td>6.630</td>
<td>96.984</td>
<td>876</td>
<td>Basic</td>
</tr>
</tbody>
</table>
Fig. 3. Clover pot culture on Marshall silt loam indicated the value of manure

the field tests now under way and the results may be considered, therefore, to
indicate quite definitely what may occur in the field.

Lime was added in a sufficient amount to neutralize the acidity of the soil
as indicated by the Veitch test, and two tons additional were supplied to put
the soil in the best condition for the growth of crops. Manure was added at the
rate of 8 tons per acre, rock phosphate, 2,000 pounds per acre, and acid phos­
phate, 200 pounds per acre. A standard 2-8-2 brand of a complete commercial
fertilizer was applied at the rate of 300 pounds per acre. Wheat and clover
were grown on the pots in both these experiments, the clover being seeded
about one month after the wheat was up. In the test in 1918, the wheat crop
was destroyed by an attack by nematodes and no yields were secured. The
clover yields on these pots were secured, however, and these with the various
soil treatments are shown in table VII, the average results for the duplicate
pots being given. The average results for both the wheat and clover crops ob­
tained in 1919 are given in table VIII.

Considering first the experiment in 1918, it is apparent that the manure
brought about a distinct increase in the clover crop. The addition of lime with
manure, however, gave no influence on the crop. This is rather surprising, as
the soil showed a slight degree of acidity and an increase in the clover from the
application of lime would naturally be expected. Evidently the acidity in the
soil was not great enough to exert any appreciable injurious effect on clover
and hence liming proved of no particular value. In soils with a greater acidity,
lime would undoubtedly bring about a distinct increase in crops of legumes.
The rock phosphate when applied with manure and lime showed no influence
whatever on the clover crop but acid phosphate and commercial fertilizer both
brought about decided increases over the pots receiving the manure and lime.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>56.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>62.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>65.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock phosphate</td>
<td>65.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid phosphate</td>
<td>70.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Commercial fertilizer</td>
<td>66.5</td>
</tr>
</tbody>
</table>
The acid phosphate showed a particularly large influence. These results indicate rather definitely that manure is a valuable material to be used on this soil and acid phosphate may also prove profitable.

Table VIII, which gives the results of the test in 1919, shows some interesting results. The application of manure brought about a small increase in the wheat crop and when lime was added with the manure a still larger increase was shown. Rock phosphate and acid phosphate both brought about further increases in the wheat, the rock showing a greater effect than the acid phosphate. Owing to an injury to the crop in the pots treated with commercial fertilizer the yields of wheat and of clover on those pots were not secured.

The effects of the treatments on the clover crop were very similar to those on the wheat. The manure gave a decided increase in crop yield and lime applied with the manure showed no further gain. The rock phosphate and acid phosphate both gave pronounced increases over the manure and lime pots, the acid phosphate showing more effect than the rock. This is exactly the reverse of the results with the wheat, where the rock showed the greater effect. The differences in neither case, however, are large enough to warrant definite conclusions regarding the relative merits of the two materials. They may be considered merely to indicate that the influence of the two phosphates may be quite different on different crops on the same soil type. This indication, with the evidence thus far accumulated that the effects of the two materials may be different on different soil types, shows quite clearly the difficulties likely to arise in reaching a definite conclusion regarding the relative value of the phosphates in Iowa.

The lack of any effect of lime on the clover in this experiment is as surprising as in the preceding test and the same conclusion must be reached here, that the acidity in the soil was evidently not great enough to be injurious to the clover. In other cases on this same soil type, if the acidity were more pronounced, lime should be applied, if the best crop growth, particularly of legumes, is to be secured.

In general, these greenhouse experiments on the Marshall silt loam show that manure is a distinctly profitable material to be used. The soil is not high in organic matter and crop yields may evidently be increased considerably by the application of humus-forming materials. Manure should be used in as large amounts as practicable and care taken that the entire amount of this material produced on the farm is returned to the soil, without permitting it to undergo any losses prior to application. In most cases insufficient production of manure will probably necessitate the use of leguminous green manures if the organic matter content of the soil is to be brought up to and kept at the best for crop growth. The results of these tests also indicate that phosphate fertilizers
may prove profitable in Montgomery county. Whether acid phosphate or rock phosphate should be used will depend, however, upon the soil and the cropping conditions. Until more field experiments have been carried out and results secured over a long period of years, definite recommendations along this line cannot be made. Farmers of the county are urged to test the use of phosphorus on their own soils and thus determine for their own conditions which material may be employed the most profitably.

FIELD EXPERIMENTS WITH "GUMBO"

Within the state there are areas of soil popularly called "gumbo" which have received special attention for several years because of the difficulty in farming them, and their need for special treatment.

The term "gumbo" is not a recognized name for a particular class of soils, according to any accepted scheme of soil classification. It is a popular name for a group of soils which possess characteristics well known and dreaded by farmers. It is very different from the "gumbo" referred to in geological reports which includes almost impervious gray or yellow clay subsurface soils.

The soil that Iowa farmers call "gumbo" is a heavy, greasy, black clay soil, occurring in flat areas, either river bottoms or level uplands. It is usually inky black and is stickier and bakes more easily than any other type of soil in the state. If such soil is plowed when too wet it balls up before the plow point in such a way that the implement cannot be made to stay in the ground. On the other hand, if it becomes too dry it will turn up in clods which cannot be worked down during the whole season. Where such clods are formed, freezing and thawing is the only process which will restore the loose, mealy structure. This soil can, however, be put in excellent tilth, with a fine, mealy appearance and kept so during the entire season provided it is not cultivated when too wet.

The total area of "gumbo" in Iowa is probably about one percent of the entire state, occurring in small patches in various localities. The principal areas are in southeastern Iowa and along the Missouri river in western Iowa. The counties in which "gumbo" has been found are Muscatine, Washington, Louisa, Henry, Des Moines, Van Buren, Lee, Woodbury, Monona, Harrison and Pottawattamie.

There is one soil type in Montgomery county which is known locally as "gumbo" and this is the Wabash silty clay loam, a bottomland soil which covers 2,112 acres in the county or 0.8 percent of the total area of the county. The entire area of this type is not typical "gumbo" but it is all very heavy and impervious and much of it would respond to the treatments recommended for "gumbo" soils.

The management of "gumbo" may be profitably considered at this point, therefore, and the results of a field experiment presented. While this experiment was not carried on in this county, it yielded results applicable to "gumbo" soils everywhere in the state.

This experiment was located on a typical area of "gumbo" bottomland near Wapello, Louisa county. Two series of plots were laid out in 1908, one consisting of six plots which were undrained and one of ten which
TABLE IX. FIELD EXPERIMENT ON "GUMBO"

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. corn per acre 1909</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Rape (too wet)</td>
<td>24</td>
</tr>
<tr>
<td>102</td>
<td>Buckwheat</td>
<td>22</td>
</tr>
<tr>
<td>103</td>
<td>Clover</td>
<td>94</td>
</tr>
<tr>
<td>104</td>
<td>Check</td>
<td>77</td>
</tr>
<tr>
<td>105</td>
<td>Lime—10 tons per acre</td>
<td>68</td>
</tr>
<tr>
<td>106</td>
<td>Straw—4 tons per acre</td>
<td>47</td>
</tr>
<tr>
<td>107</td>
<td>Check</td>
<td>40</td>
</tr>
<tr>
<td>108</td>
<td>Manure—12 tons per acre (too wet)</td>
<td>33</td>
</tr>
<tr>
<td>109</td>
<td>Manure—6 tons per acre (too wet)</td>
<td>14</td>
</tr>
</tbody>
</table>

| Plots 201, 202, 203, 204 and 205 were green manured in 1908 with rape, buckwheat, clover and clover and timothy respectively. The clover and timothy on plots 201 and 202 had been a meadow for several years and produced a crop of hay in 1908 which made a yield of 2½ tons per acre. The aftermath was plowed under for green manure. All, except plots 205 and 206, were fall plowed in 1908, the treatments indicated being made prior to plowing.

In the fall plowing it was noticed that the clover and buckwheat plots worked much more easily than the others. The following season the plots which received manure dried out more slowly after a wet spell than the others. Further observations on the effects of treatment could not be made.

Great differences in yield occurred but these should undoubtedly be attributed to differences in drainage rather than to the effects of treatment. It was impossible to get a satisfactory outlet for the tile drain and on each side of the experiment field there was a swamplike place in which the water stood nearly all summer and this surely affected the results from the outside plots, (101, 108, 109).

Where the soil was fall plowed, a fine mealy seed bed was obtained for the corn which was planted on May 13. Surrounding undrained land which was not fall plowed could not be planted until about June 10. The undrained plots were too wet nearly all summer and the outside plots in the drained series were also too wet. In the latter part of the summer all of the plots dried out well at the surface and the undrained ones cracked open, leaving wide fissures to a depth of more than a foot. On the best drained plots, the fine crumbly surface soil prevented this cracking. On the hard, cracked ground the corn turned yellow and "fired" about the middle of August, but on the other plots it remained green at least three weeks longer.

The fall plowed plots were fairly clean of weeds and grass while the others were very foul. The lime treatment of plot 105 seemed to have no effect on the "gumbo".

This experiment shows very definitely the possibilities of "gumbo" soils when properly drained and fall plowed. The drainage of "gumbo" is more
readily accomplished than would be supposed. On the upland the tile should be laid 8 rods apart to secure good drainage, altho reports have been made of successfully drained "gumbo" when the tile was 10 to 12 rods apart. On the lowland "gumbo" the tile should be somewhat closer together, but the securing of a satisfactory outlet is the chief necessity for thorough drainage and in some cases it may be necessary to run an open ditch thru to the river, in which case a drainage district must be organized. When properly tiled out such "gumbo" soil is equal to any other soil in the state in producing power for general farm crops. Fall plowing improves the soil very decidedly and the use of clover or some other green manure is also of value.

The occurrence of "gumbo" on a farm need not be a cause of lower value of the farm. It may be made and kept productive thru the treatments mentioned above and is then equal in value to the best farm land.

THE NEEDS OF MONTGOMERY COUNTY SOILS INDICATED BY LABORATORY AND GREENHOUSE TESTS

The field experiments in Montgomery county have not been under way long enough to permit of conclusions being drawn from them. These tests include the use of manure, crop residues, lime, rock phosphate, acid phosphate and a complete commercial fertilizer on the Marshall silt loam under the livestock and grain systems of farming. The exact plan of the tests is given in Circular 51 of the Iowa Agricultural Experiment Station. The results secured from these experiments will be published in a supplementary report, just as soon as sufficient data has been accumulated to warrant conclusions. The treatments recommended in this report for the soils of the county are based on the laboratory and greenhouse experiments as well as on the experience of many farmers and no suggestions are given which have not been proven to be of value by practical experience.

MANURING

The soils of Montgomery county were shown by the laboratory analyses to be mainly in need of organic matter to put them in a better condition for crop growth. The greenhouse experiments confirmed this conclusion from the analyses and the practical experience of many farmers gives further proof to the statement that farm manure is a highly profitable material for use on the soils of the county. It is undoubtedly the most valuable fertilizing material to be used at the present time and should be applied even when other fertilizers are employed if these latter materials are expected to exert any large influence on crop yields.

The beneficial influence of manure is due to its physical, chemical and bacteriological effects on the soil. It improves the physical condition of soils making light, open soils more retentive of moisture, less open and porous and less apt to lose valuable plant food by leaching. It opens up heavy, impervious soils, making them better aerated, less retentive of excess moisture and putting
them in a better condition generally for the production of available plant food. Manure improves the soil chemically by the addition of plant food. It contains much of the plant food constituents which have been supplied to the animals in their feed and hence the "life" of the soil may be considerably lengthened by adding plant food in manure. There are many bacteria in manure and when it is applied to the soil there is brought about an immediate increase in the production of available plant food—the result of bacterial activities. Furthermore the large amount of organic matter in manure encourages greater bacterial action among those organisms already present in the soil and the change of unavailable plant food into an available form is still further facilitated. Increased crop production traceable to manure may be due to any one of its effects but in most cases it is undoubtedly due to all three.

The value of manure is so great when applied to soils that it is evident that great care should be exerted to prevent losses of its valuable properties, prior to its application. When properly stored and applied, manure may return 75 to 80 per cent of the plant food removed from the soil by the crops grown. But when stored in open piles, exposed to the weather and to a leaching or washing away of the liquid portion, 75 to 90 per cent of the value of manure may be lost. Every farmer should take the proper precautions to preserve the manure produced on his farm as nearly as possible without loss. He should keep it stored in a covered yard or pit, protected from the weather, moist and compact, or he should apply it to his land as it is produced. No one method of handling is applicable to all conditions but some one method should be chosen which will keep the manure as nearly as possible unchanged until it is applied to the soil.

On the average farm the production of manure is insufficient to permit of the application of excessive amounts, provided the total amount produced is distributed at all uniformly over the farm. The usual application is about 8 to 10 tons per acre and while this amount may be profitably increased in some cases, it is not advisable to apply more than 16 to 20 tons per acre for general farm crops. In market gardening or truck farming, when it is desired to force a crop much larger amounts of manure may, of course, be used to advantage.

On the livestock farm, the production of manure is usually not great enough to permit of applying more than 10 tons per acre once in a four-year rotation to all the soils on the farm, while on the grain farm, there is, of course, only a very small amount of manure produced. In both cases, therefore, green manures should be used either as a supplement to or a substitute for farm manure. Legumes are usually considered preferable to non-legumes for use as green manures, inasmuch as they not only supply much organic matter to the soil but, when well inoculated, as they always should be, they have the ability of drawing on the nitrogen supply of the atmosphere and thereby increasing the amount of this constituent in the soil. In some cases non-legumes may be used, however, to good advantage, when the addition of organic matter to the soil is the chief consideration. There are many legumes which may be used for green manures and which may be grown under a wide range of conditions and hence some one may be chosen which will fit almost any rotation.

Green manuring may be a very profitable farm practice in many cases in Montgomery county but it should not be practised blindly or carelessly for it
may not only be unprofitable but actually injurious. Advice along this line in the case of special soil conditions will be given by the Soils Section upon request.

In addition to the use of farm manure and green manures, the organic matter content of Montgomery county soils may be built up and kept up by the proper use of crop residues, such as straw and stover. Too often the value of these materials is not appreciated and they are burned or otherwise destroyed and no return is made to the soil. In livestock farming they should be used for feed or bedding and returned to the soil mixed with the manure. In this way the greatest effect on the soil is secured as the decomposition processes are encouraged. On the grain farm they may be stored and allowed to decompose partially or they may be applied directly but they should be returned to the soil just as carefully as on the livestock farm. It is even more important that they be all utilized as there is no manure produced to keep up the organic matter in the soil. Crop residues add much to the "life" of the soil because of the plant food which they contain but their chief value lies in the organic matter which they supply.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of Montgomery county is not large and phosphorus fertilizers might prove of value in many cases at the present time. They will undoubtedly be needed in the future in all cases. The greenhouse experiments on the Marshall silt loam gave evidence of a beneficial effect both of rock phosphate and of acid phosphate on wheat and clover. The relative effects of the two materials was different in the two experiments and also in the case of the two crops, so that no conclusions can be drawn along this line. The field tests now under way in the county will not yield results permitting of definite conclusions for several years and for the present specific recommendations cannot be made. Farmers should determine the need of their own soils for phosphorus and by the use of rock phosphate and acid phosphate, they may learn also which materials will be the most profitable under the particular conditions. Acid phosphate costs more than rock phosphate but it is readily available to crops. Rock phosphate must be used in much larger amounts than the acid phosphate but it is much cheaper. The choice of the material to be used under any particular conditions will depend therefore, very largely upon the actual crop increase and the economic return on the money invested in the fertilizer. Simple tests of these two materials may be carried out on any farm according to the directions given in Circular 51 and advice and information to any who are contemplating such tests will be given by the Soils Section upon request. A phosphorus fertilizer which has been shown to be profitable on a small area may then be applied to a large area with assurance of economic returns and without fear of injury to the soil.

The nitrogen content of Montgomery county soils is not especially low but neither is it high, and nitrogenous materials must evidently be added to these soils from time to time if they are to be kept supplied in this constituent. There is a large return of nitrogen to the soil by the use of crop residues and farm
manure but in spite of these natural fertilizers, there is a gradual decrease in nitrogen unless some other nitrogen-containing materials are employed. The use of well-inoculated legumes as green manures is a relatively cheap and efficient way of supplying nitrogen to the soil and the addition of commercial nitrogenous fertilizers cannot be recommended at the present time as an economical proposition. In small amounts as top dressings to encourage the early growth of some crops they may prove profitable but in general the nitrogen supply in the soil may be more economically maintained by leguminous green manures. If tests in the field on a small scale show any particular nitrogenous material to be of value, however, it may be used on a large area without fear of injury to the soil. It should be remembered that legumes, as green manures, have the double value of adding nitrogen and organic matter to the soil and if nitrogenous fertilizers are employed some materials must be used also to keep up the supply of organic matter in the soil.

The potassium content of the soils of the state has been shown to be abundant* and hence it is unlikely that potassium fertilizers would prove of value on the soils of Montgomery county. If the soil is kept in the best physical condition with regard to organic matter, moisture and aeration, sufficient potassium from the store present in the soil will undoubtedly be brought into an available form to keep crops supplied. In small amounts as top dressings to encourage the early growth of crops, potassium fertilizers might possibly be employed with profit. In trucking or gardening also it might be desirable to use potassium fertilizers but for general farm crops it is highly unlikely that they would prove of value.

Complete commercial fertilizers are being tested in the field experiments now under way in Montgomery county and until these tests have yielded definite results, positive recommendations along this line should not be made. It may be said, however, that the indications thus far are that phosphorus fertilizers give quite as large yields and hence are more economic. It would hardly be expected that complete brands of fertilizers containing nitrogen and potassium as well as phosphorus would prove as profitable as phosphorus fertilizers used with green manures to supply nitrogen and with proper soil treatment to keep up the best production of available potassium. Farmers may easily test the value of a complete fertilizer at the same time that they test the use of a phosphorus fertilizer and if some special brand proves profitable under the special conditions, it may be used without fear of injury to the soil. There is no objection to the use of complete commercial fertilizers provided they prove profitable and especially provided they prove more profitable than phosphorus fertilizers.

**LIMING**

The analysis of the soils of Montgomery county showed them all to be acid in reaction. In no case, however, was the extent of acidity large. For the best growth of crops, especially legumes, lime should be applied whenever necessary, even if the need is small. The lower soil layers showed no considerable amounts of lime present and the needs of the surface soils indicate quite defi-

*Bulletin 150, Iowa Agricultural Experiment Station.
nitely, therefore, the requirements of the soils to a depth of 40 inches. All the soils in Montgomery county should evidently be tested for acidity and when found to be acid, lime should be applied in the amount necessary to secure basic conditions. Farmers may test their own soils but it will be more satisfactory if they will send a small sample to the Soils Section and have it tested more accurately, free of charge. Thus the actual application of lime needed will be determined and an excess application or too small an amount will be avoided, both of which are highly undesirable. Practically all crops grow better when lime is present in the soil and as there is a constant loss of this material from cultivated land, applications must be made at regular intervals to keep up the supply. No general tests will serve to show the needs of a soil but each individual soil must be tested if the proper application is to be made. Soils vary widely in acidity and lime requirements and the results given earlier in this report should be considered merely to indicate the needs of the various soil types in the county. Further information regarding the use of lime on soils, the losses by leaching, and other points connected with liming are given in Bulletin 151 of the Iowa Agricultural Experiment Station. Circular 58 also gives some suggestions along this line, particularly where limestone may be secured and the cost of the material.

**DRAINAGE**

The soils of Montgomery county are generally very well drained and no difficulties are experienced from excessive moisture in the soil, except in a few instances. The Wabash silty clay loam, however, a minor bottomland type, is very poorly drained. In fact it is so impervious that it is known as "gumbo". In view of the fact that this type is subject to overflow, its poor drainage is especially injurious to crop growth. The installation of tile drains and ditches has brought about large increases in crop yields on this soil. It is the first treatment needed to make the soil type highly productive. In case small areas in any other soil types are poorly drained, tile should be installed. Satisfactory crops cannot be secured on any soil which is too wet and the expense involved in tiling is always well warranted by the increased crop yields secured from the land.

**THE ROTATION OF CROPS**

The continuous growing of any one crop is much less profitable in the long run than the rotation of crops, according to the results secured in many experiments and in much farm experience. Even if the one crop is a "money" crop, the decrease in yields from year to year will be so great that the actual income from the land will be increased by the use of other crops with the one in the rotation. For the permanent fertility of the soil it is absolutely necessary that a rotation of crops be practiced.

No special tests of rotations have been made in Montgomery county but there are various rotations in use throughout the state which are quite satisfactory and a choice suitable for the county may readily be made. If those given below do not fit the particular conditions, modifications may be made as desired. Indeed almost any rotation may be used provided that it contains a legume and includes the most profitable crops.
1—FOUR OR FIVE-YEAR ROTATION

First Year — Corn.
Second Year — Corn.
Third Year — Oats (with clover or with clover and timothy).
Fourth Year — Clover (if timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2—FIVE-YEAR ROTATION WITH ALFALFA

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

3—THREE-YEAR ROTATION

First Year — Corn.
Second Year — Oats or wheat (with clover seeded in the grain).
Third Year — Clover (only the grain and clover seed should be sold. In grain farming most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil).

THE PREVENTION OF EROSION

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

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

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

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

In Montgomery county erosion occurs to a considerable extent and most of the upland types are subject to the destructive action. The Marshall silt loam, Shelby silt loam, Wabash silt loam and colluvial phase Wabash are all apt to be badly washed in some localities and under some conditions. This is particularly true of the Marshall silt loam and the Shelby silt loam.

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 gullying, to large gullying, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

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

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

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

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in dead furrows.
Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

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

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

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

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

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

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

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

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

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.
Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water absorbing power of the soil and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

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

BOTTOMLANDS

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

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

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

HILLSIDE EROSION

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

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

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

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

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

**SHELBY SILT LOAM (93)**

The Shelby silt loam covers an area of 10,368 acres, or 3.8 pet. of the total area of the county. It occurs principally in the eastern part of the county but smaller areas are found in other sections. It usually occurs in narrow, ribbon-like bands bordering the slopes and none of the individual areas are of any considerable size.

The surface soil to a depth of 6 to 12 inches is a brown silt loam or fine loam. This changes abruptly into a light-brown to yellowish-brown silty clay, mottled with rusty-brown, yellow and gray, which constitutes the subsoil. Considerable gravel occurs throughout the subsoil and on the steeper slopes there is some at the surface. At three feet or more there is frequently found a layer of clay, gravel and small boulders and glacial boulders sometimes occur at the surface on hill-sides and in road cuts. On the steeper slopes the surface soil is shallower, varying usually from 4 to 6 inches in depth and in some areas, the surface soil is entirely washed away. Occasionally small areas show a high content of very fine sand and in a few cases, the subsoil at 24 inches or more is a steel-gray or bluish-gray plastic clay, entirely free of gravel and boulders. These areas are not typical Shelby silt loam but they are too small to be separated.

The topography of the type is gently sloping to steep, most of the areas being rather steep. Drainage is good and the steeper slopes suffer to a considerable extent from erosion.

About 85 pet. of the type is under cultivation or in pasture. The timbered areas support a growth of red oak, bur oak, cottonwood, walnut, maple, hackberry and mulberry. A large portion of the area in this type is in pasture, especially the steeper slopes where it is difficult to cultivate and where cultivation brings about extensive erosion. Corn is the chief crop grown on the cultivated areas. Oats, wheat, rye, alfalfa, timothy, clover and all kinds of garden crops are grown also.

The greatest care must be taken in handling this soil to prevent as far as possible the destructive washing action of water. The steeper slopes should undoubtedly be kept in pasture or timber and if the gentler slopes are cultivated, they should be terraced or at least prepared so that the furrows all run around the slopes and as little opportunity as possible is provided for the washing of gullies down the slopes. The soil should receive liberal applications or organic matter either as farm manure or green manures, as it is low in this material. It is acid in reaction and small applications of lime are needed. Phosphorus is not high and phosphorus fertilizers might be of value in some cases at the present time and they certainly will be needed in the near future. With these treatments, the gentler slopes may be made and kept more highly

*The descriptions of the individual soil types given in the Bureau of Soils report have been rather closely followed in this section of the report.*
Fig. 5. Frankfort Ridge. Flat colluvial soil in foreground

productive and indeed brought up to as high a crop yielding power as the upland loess soil.

**LOESS SOILS**

There are two loess soils in Montgomery county, the Marshall silt loam and the Knox fine sand. The former is very extensive while the latter is of very little importance. Together they cover over 66 pet. of the total area of the county.

**MARSHALL SILT LOAM (9)**

The Marshall silt loam is by far the most extensive soil type in the county. It covers 179,392 acres, or 66.1 pet. of the total area of the county. It occurs in large areas in all parts of the county.

The surface soil is a brown to dark-brown silt loam, 16 to 18 inches in depth. When thoroly wet, the richer areas frequently present a black appearance. The subsoil is a yellowish-brown silt loam, with iron stains and faint gray mottlings in the lower part.

The type is remarkably uniform over the entire area in color, texture and depth of surface soil. On the tops of the more level divides, however, the surface soil is sometimes 2 to 4 inches deeper and somewhat darker in color. This is noticeable near Wales and Wallin and on the "Frankfort Ridge". In some other areas where the topography is more rolling, particularly along the streams in the eastern part of the county, erosion has been more active and the surface soil is only 10 to 14 inches in depth and a lighter brown in color. Very small unimportant areas contain a noticeable amount of very fine sand.

The topography of the type is generally undulating to rolling. In the areas between the Nishnabotna river and Tarkio creek, the slopes are gentle and the topography appears rather level. Similarly near Wales, east of Grant, between
The Nishnabotna and Walnut creek and between Tarkio creek and the West Nodaway river, the land is very gently undulating. In the eastern part of the county, however, along the rivers and creeks, the topography is more strongly rolling and presents in general a rougher appearance.

The drainage of the Marshall silt loam is good and the use of tile drains is not necessary. The subsoil is retentive of moisture and crops seldom suffer from drought. The failure of crops in some seasons is due to a burning by the hot dry winds, rather than to a lack of moisture in the soil. In some of the rough sections the type is often subject to considerable destructive action by erosion.

Practically all of the type is under cultivation, probably less than 5 pet. being in timber and almost none in waste land. The tree growth on the timbered areas consists of soft maple, cottonwood, black walnut, red oak, bur oak, elm and hickory. The most important crops grown are corn, wheat, oats and hay. Corn is grown on the largest acreage and yields of 35 to 80 bushels per acre are secured. Wheat is second in importance and gives yields of 15 to 20 bushels per acre. Oats is almost as important as wheat and yields at the rate of 40 to 60 bushels per acre. Hay consists mainly of alfalfa, clover and timothy and yields of 1 to 2½ tons are commonly secured. Rye is grown on a small area and yields 15 to 25 bushels per acre. Apples grow well on the type and it is also well suited for growing tomatoes, beets, cabbage, parsnips, potatoes, beans, eggplants, onions and strawberries. None of these crops are grown to any extent at present, but only in gardens for home use.

The Marshall silt loam is a good producing soil for general farm crops but its productivity may be increased by proper methods of treatment. Its chief need is for the application of manure. Increases in crop yields from the use of this material are always large. If farm manure cannot be supplied, then green manures should be used to build up and keep up the organic matter in this soil. The soil is sometimes acid in reaction and when this is the case, lime should be added in the amount shown to be necessary by the test. Tests should be made at regular intervals to determine the soil reaction, particularly when legumes are to be grown. The greenhouse tests showed indications of value from the use of phosphorus fertilizers and as the content of the soil in phosphorus is not high, it should undoubtedly be concluded that phosphorus fertilizers would probably prove of value in many cases now. Their use will certainly be necessary in the future. Farmers should test the value of both rock and acid phosphate and select that material which gives the best and most profitable results. This type is subject to erosion in some areas and care should be taken to prevent its occurrence, by following proper methods of soil treatment, particularly as to plowing and cultivation. In cases where gullies have been formed, they should be checked and filled by the adoption of some one of the methods described earlier in this report.

KNOX FINE SAND (33)

The Knox fine sand is a very minor type in the county, covering only 128 acres or 0.1 pet. of the total area of the county. It occurs in several small areas, the largest of which is about 1½ miles north of Morton Mills on the east
side of the Nodaway valley, where it occupies the crest of a hill and the slope toward the bottomland. A second area is found along the east bank of the Nishnabotna, 3 miles south of Red Oak and there are four small bodies along the east side of the West Nodaway between Villisca and Tenville.

The sand in the largest area is a pale yellow in color and varies from 1 to 10 feet in depth. In the other areas, it consists of a brown to brownish-yellow fine sand to a depth of 3 feet or more.

The sand is scattered considerably over the surrounding land and modifies to some extent the soil conditions there. The type is of little agricultural value, especially in the largest area. If the smaller areas were treated with farm manure, lime and a complete commercial fertilizer and a legume grown for a green manure, the latter might then be turned under and would build up the soil in fertility and it might be made satisfactorily productive.

**TERRACE SOILS**

There are two terrace soils in Montgomery county, the Waukesha silt loam and the Hancock silt loam. Both of these soils are of only minor importance, the Hancock silt loam being much the smaller in area. Together they cover only 2.1 per cent of the total area of the county.

**WAUKESHA SILT LOAM (75)**

The Waukesha silt loam is not very large in area, covering only 5,360 acres or 1.9 per cent of the total area of the county. The largest areas of this type are found along the Nishnabotna near Red Oak and Elliott and along the West Nodaway north of Villisca. Three small areas occur along the Walnut, Tarkio and Seven Mile creeks, but with the exception of these, the type is confined to the second bottoms or terraces of the Nishnabotna, West Nodaway and Middle Nodaway rivers.

The surface soil of the Waukesha silt loam is a brown to dark-brown silt
loam, 15 to 18 inches in depth. The subsoil to a depth of 36 inches or more is a yellowish-brown heavy silt loam, faintly mottled with gray and showing some iron stains. The type is quite uniform both in color and texture. There is a small area west of Red Oak, however, which has a very dark-brown to black subsoil. This area is really Bremer silt loam but owing to its small extent it is included with the Waukesha.

In topography the type is level to very gently sloping. It lies about 15 to 20 feet above the normal level of the streams and 1 to 6 feet above the first bottoms. It is not subject to overflow and is generally well drained. The subsoil holds water well and the soil is not apt to suffer from drought.

Practically all of this type is under cultivation or in pasture. Corn is the principal crop grown and yields of 35 to 75 bushels per acre are secured. Oats is produced to a large extent and yields 25 to 40 bushels per acre. Wheat is grown also on a considerable acreage and yields 15 to 25 bushels per acre. Timothy and clover grown either separately or together constitute the main hay crop, yields of 1 to 3 tons being secured. About one-third of the total area of the type is kept in pasture and grass grows well. Alfalfa is grown on a small area and satisfactory yields are obtained.

This soil is about as productive as the best areas of the Marshall silt loam and the crop yields secured are generally very satisfactory. It is sometimes acid in reaction, however, and when such is the case, it should receive an application of lime. Additions of manure always prove profitable and green manures should be used when farm manure is not available in sufficient amounts. Phosphorus is not high in the soil and phosphorus fertilizers would probably prove of value now and will undoubtedly be necessary in the near future. With these treatments the soil can be made more productive than it is at present and it can be kept in a high state of fertility.

HANCOCK SILT LOAM (23)

The Hancock silt loam is a very minor type in the county, covering only 400 acres or 0.2 pet. of the total area of the county. It occurs only in two small areas on the Pottawattamie county line. These areas are very much like the Waukesha silt loam and were included with that type in the Bureau of Soils report but they are separated here in order to join up with the Hancock silt loam mapped in Pottawattamie county.

The surface soil is a brownish-black silt loam, extending to a depth of 12 to 15 inches. It then grades into a lighter subsoil from chocolate-brown to mottled yellowish-brown in color. It ranges in texture from a silt loam to a silty clay loam and in some places layers of fine sandy material are found.

The type is level in topography but in general it is well drained.

Corn is the chief crop grown. Oats, wheat, timothy, clover and alfalfa are all grown also to some extent. Satisfactory yields of these crops are ordinarily secured. Crop yields may be increased however, by the use of manure, by the application of lime when the soil shows acidity, and probably also by the use of phosphorus fertilizers, the same treatments recommended for the Waukesha silt loam.
SWAMP AND BOTTOMLAND SOILS

There are three swamp and bottomland soils in Montgomery county, all classed in the Wabash series. They are the Wabash silt loam, the colluvial phase of this same type and the Wabash silty clay loam. The two former types are quite extensive in area and together cover over 27 pet. of the total area of the county. They are about equal in area, the typical Wabash silt loam being slightly the larger. The Wabash silty clay loam is very much smaller in area and is of minor importance.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland type and it covers 39,104 acres or 14.4 pet. of the total area of the county. It occurs in broad areas along the Middle Nodaway, West Nodaway and Nishnabotna rivers and Seven Mile, Tarkio and Walnut creeks. Narrow areas are also found along some of the other creeks. The largest areas occur near Elliott and south of Red Oak where the bottoms of the Nishnabotna have a width of 1\frac{1}{2} to 2\frac{1}{2} miles.

The surface soil is a dark-brown to very dark-brown mellow silt loam extending usually to a depth of 14 to 18 inches. In some places however, it is 22 inches in depth. The subsoil to 3 feet or more is a very dark-brown to black heavy silt loam to silty clay loam. In some places where the areas are depressed or on a lower level, the surface soil is a very dark-brown to black and the subsoil is heavier, ranging from a heavy silt loam to a silty clay. Throuout these areas the soil in a few patches consists of Wabash silty clay loam. Where the drainage is poor, a heavy, plastic clay, bluish-gray to mottled grayish-brown and yellow in color is often found below 30 inches. North of Sciola the surface soil is somewhat lighter in color and frequently the subsoil below 24 inches is a black, heavy silty clay. In many places along the streams there are very small areas of fine sandy loam and fine sand which would have been mapped Riverwash had they been of sufficient size to show on the map.

In topography, the soil is level, lying 8 to 15 feet above the normal level of the streams. It is subject to overflow. Drainage is generally quite inadequate. In areas adjoining the uplands the type is somewhat higher and subject to overflow only at times of very high water. Here the drainage is more satisfactory. Along some of the sharper bends of the rivers and creeks, the type suffers much from erosion.

About 85 pet. of the type is under cultivation or in pasture. There are a few timbered areas along the streams and the tree growth consists mainly of willow, cottonwood, box elder, ash and walnut. Corn is the crop grown the most extensively and yields of from 35 to 60 bushels are secured. Oats is the second crop of importance on the type and yields 38 to 50 bushels per acre. Wheat is grown to some extent and yields of 16 to 25 bushels per acre are obtained. A large acreage is devoted to grass which is either cut for hay or used for pasture. Yields of 1 to 3 tons of hay are secured. Potatoes grow well on this soil, yielding 60 to 100 bushels per acre. Other garden crops such as tomatoes, beans, cabbage, onions, etc., are grown very successfully in small areas.

The crop yielding power of this soil is naturally high and quite satisfactory crops are secured in normal seasons but many failures occur owing chiefly to
overflow or to excessive water retained in the soil. Drainage is the first treatment needed for the type and tile drains or open ditches would prove very profitable in many cases. The soil should then be protected from overflow if crops are to be secured regularly. The use of lime is sometimes necessary as the soil is often slightly acid in reaction. Manure would prove of value on this soil and phosphorus fertilizers might also give profitable returns. Even if these latter materials are not needed now, they will certainly be required in the future. With these treatments and especially drainage and protection from overflow, this bottomland soil may be made highly productive.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is almost equal in area to the typical Wabash silt loam. It covers 34,496 acres or 12.7 pet. of the total area of the county. It occurs in strips along the smaller creeks, branches and drainageways, varying in width from 50 feet to a quarter of a mile.

The surface soil is a brown to dark-brown, mellow silt loam, 15 to 18 inches in depth, resting upon a subsoil of a darker brown silt loam to a depth of 3 feet or more. Frequently the dark-brown, chocolate-colored silt loam extends for 3 feet practically unchanged. There are many small areas of the silt loam and the silty clay loam included in this type which cannot be shown separately owing to their small size. There are also included in the type a few small, narrow bands of material washed from the uplands. These occur at the foot of the more gentle slopes.

In topography the type is level to gently sloping. Drainage is poor and the water frequently stands in depressions for long periods.

About 60 pet. of the type is under cultivation, the remainder being in pasture. A few timbered areas occur along some of the streams, willow, cottonwood, elm, red oak and walnut making up the tree growth. The crops grown and
the yields obtained are about the same as on the typical Wabash silt loam. Corn is the most important crop and yields 35 to 70 bushels per acre. Oats yield 25 to 40 bushels per acre, wheat 15 to 25 bushels and hay 1 to 2 1/2 tons.

The needs of the soil for treatment are very much the same as in the case of the typical silt loam. Drainage is needed first of all and tile drains or ditches prove of much value. Protection from overflow is also required. Lime should be used when the soil is acid. Manure is always a profitable material for use on this soil. Phosphorus fertilizers may be of value now and they certainly will be required in the future.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering only 2,112 acres or 0.8 per cent of the total area of the county. It occurs in small areas throughout the bottoms of the Nishabotna and West Nodaway rivers and Walnut creek. The largest areas occur near Villisca and along the Nishabotna south of Red Oak.

The surface soil to a depth of 12 to 16 inches is a very dark-brown to black heavy silty clay loam. The subsoil is a black to bluish-black heavy, tenacious silty clay which becomes lighter in color and somewhat more plastic at the lower depths. When wet the surface soil is intensely black. When not properly plowed the soil turns up in clods which crumble very slowly. Frequently it bakes, and crevices 1 to 2 feet in depth, appear. The type is known locally as "gumbo".

The topography of the soil is level and it occurs 10 to 15 feet above the normal level of the streams. Drainage is quite inadequate and the soil is subject to overflow.

About 95 per cent of the type is under cultivation or in pasture. A small area is timbered and the tree growth consists of willows with a few oaks, cottonwoods and elms. Corn, wheat, oats and hay are the principal crops grown. Corn yields 35 to 70 bushels per acre, wheat 18 to 26 bushels, oats 35 to 55 bushels and hay 1 to 2 1/2 tons. A large acreage is devoted to pasture and natural grasses grow luxuriantly.

The needs of this type have been considered in the section of this report dealing with "gumbo" soils and hence they will not be discussed at length here. Drainage, protection from overflow and fall plowing are the treatments most needed by this type. Manure would prove valuable in increasing crop production, lime is often needed and should be applied whenever tests show any acidity present, and phosphorus fertilizers will be needed in the future if, indeed, they do not prove of value now.
APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

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

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

**PLANT FOODS IN SOILS**

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

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

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

**THE "SOIL DERIVED" ELEMENTS**

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

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

**AVAILABLE AND UNAVAILABLE PLANT FOOD**

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied
for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

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

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

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

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

Calculating Nitrogen (N) at 16c (Sodium Nitrate \((\text{NaNO}_3)\)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride \((\text{KCl})\))

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Food Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn crop</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
<td>17.76</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td>9.21</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>34</td>
</tr>
<tr>
<td>Oats crop</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
<td>7.76</td>
</tr>
<tr>
<td>Barley grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5.5</td>
<td>13</td>
</tr>
<tr>
<td>Barley straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley crop</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
<td>5.20</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>25.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye crop</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
<td>6.62</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

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

### Removal from Iowa Soils

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

This loss of fertility is unequally 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.

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

*Bulletin 150, Iowa Agricultural Experiment Station.*
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 crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

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

CULTIVATION AND DRAINAGE

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

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

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

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

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

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.
Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop, if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

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

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

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

**MANURING**

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

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

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

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

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

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

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin 151, referred to above.
There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig 9.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called “glacial till” or “drift” and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or “nigger-heads.” Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

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

Fig. 9. Map showing the principal soil areas in Iowa
It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1: 1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose. 2. The topography or lay of the land. 3. The structure or depth and character of the surface, subsurface and subsoil. 4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain. 5. The texture or porosity, granulation, friability, plasticity, etc. 6. The color of the strata. 7. The natural drainage. 8. The agricultural value based upon its natural productiveness. 9. Native vegetation. 10. The ultimate chemical composition and reaction. The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

Fine Sand—More than 25 per cent very coarse, coarse and medium sand, less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

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

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

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

Gravels—More than 50 per cent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all the soil types but also of the streams, roads, railroads, etc. The completed map is therefore, 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 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 topographical 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 type are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.