Soil Survey of Iowa, Report No. 20—Hamilton County Soils

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SOIL SURVEY OF IOWA
Report No. 20—HAMILTON COUNTY SOILS

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

One of Hamilton county’s lake areas

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

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

Hamilton county is located in central Iowa, just north and slightly west of the exact center of the state. It is entirely within the Wisconsin drift soil area and the soils of the county are all derived from this drift material. The total area of Hamilton county is 570 square miles, or 364,800 acres. Of this area 347,116 acres, or 95.1 percent, is in farm land. The total number of farms is 2,120 and the average size is 163 acres. The following figures, taken from the Iowa Yearbook of Agriculture for 1919, show the utilization of the farm land of the county:

- Acreage in general farm crops ...................................................... 257,386
- Acreage in pasture ..................................................................................... 70,567
- Acreage in farm buildings, feed lots, and public highways ........... 16,576
- Acreage in waste land ............................................................................... 2,058
- Acreage in crops not otherwise listed .................................................. 156

The type of agriculture practiced in Hamilton county is principally general farming, combined to a greater or less extent with the raising and feeding of hogs and other livestock. In fact, in most instances a considerable portion of the grain produced on the farm is fed to the livestock and it may even be considered that livestock farming is becoming the more important type of agriculture in the county. The raising of hogs is the most important livestock industry, although considerable numbers of beef cattle are raised and fed on the farms. Only a small number of sheep are raised. Some horses are raised, chiefly for use on the farms.

Orchards are commonly found on the farms of the county, but orcharding is not practiced on a commercial scale. Apples, cherries and plums are the chief fruits grown. Strawberries are also produced successfully.

There is a rather considerable area of waste land in the county and some method should be adopted for its reclamation. No treatment can be recommended as adapted to all conditions, inasmuch as the causes of unproductiveness are various. In a later section of this report, methods which should be followed in the case of certain individual soil types will be mentioned, and in special cases advice may be secured by communicating with the Soils Section of the Iowa Agricultural Experiment Station.

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

- Corn is by far the most important crop, both in acreage and value. Over 37 percent of the total farm land of the county is devoted to this crop and average yields of 45.0 bushels per acre are secured. The varieties of corn grown are chiefly Reid’s Yellow Dent, Boone County White, White Silver Mine and Silver King, the yellow varieties being grown most extensively. The bulk of the corn

SOIL SURVEY OF IOWA

TABLE I—AVERAGE YIELD AND VALUE OF CROPS GROWN IN HAMILTON COUNTY, IOWA*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm land of county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>131,110</td>
<td>37.8</td>
<td>45.0</td>
<td>5,899,950</td>
<td>$1.17</td>
<td>$6,902,941.50</td>
</tr>
<tr>
<td>Oats</td>
<td>97,491</td>
<td>28.1</td>
<td>41.9</td>
<td>3,997,131</td>
<td>.64</td>
<td>2,558,163.84</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>802</td>
<td>.23</td>
<td>13.0</td>
<td>10,426</td>
<td>1.98</td>
<td>20,648.48</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>2,649</td>
<td>.75</td>
<td>12.0</td>
<td>31,758</td>
<td>1.89</td>
<td>60,079.32</td>
</tr>
<tr>
<td>Barley</td>
<td>510</td>
<td>.147</td>
<td>24.0</td>
<td>12,240</td>
<td>1.11</td>
<td>13,586.40</td>
</tr>
<tr>
<td>Rye</td>
<td>92</td>
<td>.026</td>
<td>18.0</td>
<td>1,656</td>
<td>1.33</td>
<td>2,202.48</td>
</tr>
<tr>
<td>Hay (tame)</td>
<td>18,830</td>
<td>5.4</td>
<td>2.1</td>
<td>39,543</td>
<td>18.37</td>
<td>726,494.91</td>
</tr>
<tr>
<td>Hay (wild)</td>
<td>5,313</td>
<td>1.5</td>
<td>1.2</td>
<td>6,376</td>
<td>16.48</td>
<td>105,076.48</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>135</td>
<td>.039</td>
<td>...</td>
<td>418</td>
<td>23.09</td>
<td>9,651.62</td>
</tr>
<tr>
<td>Potatoes</td>
<td>454</td>
<td>.13</td>
<td>55.0</td>
<td>24,970</td>
<td>1.94</td>
<td>48,441.80</td>
</tr>
<tr>
<td>Pasture</td>
<td>70,507</td>
<td>20.3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

produced is fed to the livestock and only a small portion is sold out of the county.

Oats rank next to corn, both in acreage and value, about 28 percent of the total area of farm land being devoted to this crop. Average yields of 41.0 bushels per acre are secured. The varieties grown are mainly Early Champion, Kherson, Green Russian, Iowa 105, Iowa 103. In general the white and later maturing oats are favored, altho a considerable quantity of early oats is produced. Some farmers believe that the early oats do not grow so rank and are not so apt to lodge as the late variety. Oats are very largely a cash crop and most of the production is marketed at local elevators.

The third crop of importance is hay, over 5 percent of the total farm land of the county being devoted to tame varieties. Timothy and clover make up the bulk of this crop and are usually grown together. Occasionally, however, they are grown separately for seed. Some farmers grow clover alone for hay as well as for seed, and very little difficulty is experienced in securing a satisfactory crop. The average yield of timothy and clover mixed amounts to one ton per acre. There is a rather considerable area in wild hay, amounting to 1.5 percent of the total farm land. Practically all of the hay produced is fed on the farm.

Wheat is grown to some extent, the spring varieties being the most generally used. Some winter wheat has been sown recently and is gaining in favor. Average yields of spring varieties amount to 12.0 bushels per acre and 13.0 bushels per acre is the average for the winter varieties.

Barley is grown on a rather considerable area and average yields of 24.0 bushels per acre are secured. It is largely used for feeding purposes. Potatoes are grown to some extent, chiefly for home use, and average yields amount to 55 bushels per acre. Buckwheat, rye, flax and millet are other crops which are grown in a few instances. Buckwheat and flax are used on newly reclaimed land, while millet is often used where corn has been drowned out, as well as on reclaimed peat, muck or alkali land.

Alfalfa has been grown recently on a small scale and has proved a successful crop, altho special soil treatment has been found very necessary. It is particularly important that the soil be well drained, that lime and farm manure be

*Iowa Yearbook of Agriculture, 1919.*
applied and that the soil be inoculated. Alfalfa makes valuable forage and its use in the county will undoubtedly increase. Sweet clover is not grown to any extent at present, but its occurrence along roads, railroads, ditches and fence-lines in a wild state indicates that it might prove a profitable crop.

The character and extent of the livestock industry in Hamilton county are shown by the following figures taken from the Iowa Yearbook of Agriculture for 1919:

- Horses (all ages) .................................................. 15,826
- Mules (all ages) .................................................. 698
- Swine (on farms July 1, 1918) .................................. 94,448
- Cattle (cows and heifers kept for milk) ...................... 10,388
- Cattle (other cattle not kept for milk) ....................... 29,827
- Cattle (total all ages) .................................................. 39,715
- Sheep (all ages on farms) ......................................... 3,103
- Sheep (total pounds wool clipped) ......................... 16,099

The raising of hogs is probably the most important livestock industry in the county. In many cases all the corn produced on the farm is fed to hogs. The leading breeds are the Poland China, Duroc Jersey and Chester White. The beef cattle industry is also of considerable importance, most of the animals fed during the fall and winter being raised locally. Some feeders are shipped in from Kansas City, Omaha, and other market centers. Most of the stock is grade Shorthorn or Angus. The raising of sheep and horses are minor industries, and dairying is also of minor importance. By far the largest source of income from the livestock industry in the county comes from the sale of hogs and beef cattle.

Land values in Hamilton county are variable, depending on improvements, topography, soil conditions, and location with reference to railway facilities and to towns. Values in 1918 ranged from $175 to $300 per acre. Since that time there has been an increase to a much larger figure in many instances and some farms have sold for considerably more than $300 per acre.

The yields of general farm crops in Hamilton county are very satisfactory and farm incomes have been generally rather considerable. Greater yields of many crops could undoubtedly be obtained, however, by better methods of soil treatment and such increases in crops would lead naturally to larger incomes. Some of the soils are acid in reaction and where this is true, lime should be applied if the most satisfactory production of legume crops, such as clover and alfalfa, is to be secured.

Applications of farm manure are highly desirable on many of the soils, small amounts proving of value even on those types which are apparently well supplied with organic matter. The value of farm manure in increasing crop production has been definitely shown by much farm experience. The soils of the county are not strikingly deficient in nitrogen, but some return of this element must be made from time to time if the supply in the soil is to be kept up. The most satisfactory method of supplying nitrogen is by the use of inoculated legumes as green manures.

The phosphorus supply in the soils of the county is rather low and there is evidence that phosphorus fertilizers would prove of value in many cases at the present time. They will undoubtedly be needed in the near future. Farmers are urged to test the value of rock phosphate or acid phosphate on their soils.
and thus determine for their own conditions the need of phosphorus and which phosphorus carrier should be employed. Field experiments in other counties on similar soil types have given indications of value from phosphorus fertilizers and it is hoped that the tests now under way in Hamilton county will permit of definite recommendations along this line in the near future. For the present, it can merely be urged that tests be carried out on individual farms.

Complete commercial fertilizers are not recommended for general use on the soils of the county, inasmuch as phosphorus carriers would probably give as satisfactory results at a lower cost. If tests are carried out on the farm, however, and any complete brand proves satisfactory, it may be employed without fear of injury to the soil. It should be emphasized that the relative value or economic returns from the use of any complete fertilizer should be determined by comparison with a phosphate carrier before applications are made to any considerable area.

Many of the soils of the county are in need of drainage and in some instances this is the first treatment required to make them properly productive. Many acres in Hamilton county have been reclaimed by the installation of tile and drainage ditches. There are still many areas, however, that will give profitable crop increases upon being thoroly drained. The proper cultivation of the soil, the rotation of crops and the utilization of all crop residues produced on the farm, are other methods of soil treatment which should be practiced in addition to those mentioned, if crop production in the county is to be increased and the soils kept permanently fertile.

THE GEOLOGY OF HAMILTON COUNTY*

Hamilton county lies entirely within the Wisconsin drift soil area and the soils are derived practically entirely from this material. At least twice during the glacial age, great glaciers swept over the county and, upon their retreat, left behind vast deposits of debris which covered to considerable depths the original bed rock material. The soils of the county are, therefore, not affected by the character of the rock material underlying the glacial deposits and it is unnecessary to consider the geological history previous to the deposition of the drift material.

The earliest drift material which was deposited in the county is known as the Kansan. It is seen only in railway cuts and on river banks, and does not appear at the surface anywhere in the county. In thickness this drift material is extremely variable, being reported to depths of 50 to 150 feet. It consists of a bluish, gritty clay containing numerous pebbles and boulders and is known as blue clay. When exposed in cuts, oxidation changes the color to yellow or brown, but when not exposed to weathering, it is distinctly blue in color and is well known as typical of the Kansan drift.

The second great glacier which invaded the county is known as the Wisconsin and upon its retreat a considerable layer of Wisconsin drift material was deposited. The depth of this surface deposit is variable, averaging from 6 to 16 feet. In many places the deposit is undoubtedly much thicker than these

figures would indicate. The original Wisconsin drift material consisted of a whitish or pale yellowish calcareous pebbled clay. Numerous pebbles and boulders of varying dimensions are present and in many cases calcareous material is found. Under the influence of weathering, much of the calcareous material disappears and with the accumulation of organic matter from plant residues, the soils formed are mainly loams or clay loams, dark brown to black in color, still containing, however, numerous pebbles and boulders. Where this surface deposit is deep, the lower layers still retain many of the characteristics of the drift deposit and are grayish to drab or greenish yellow in color. This gray drift material is hard and compact, but not tough in texture like the blue clay of the underlying Kansan.

The upland soils of Hamilton county are chiefly loams and clay loams, derived from the weathering of the Wisconsin drift. On the more level areas where the accumulation of organic matter has been greater and drainage less extensive, the Webster soils are developed. On the more rolling areas the soils are somewhat lighter in color and also in texture and are classed in the Carrington, Clarion and Miami series. Throughout the surface soils of all these types, gravel and boulders occur, the latter sometimes being two or three feet in diameter.

The remaining soils of the county occur on the terraces or narrow bottoms and are derived from the wash from the upland drift soils. They are variable in character, but resemble in many ways the upland drift types. The terrace soils and bottomland soils together are rather inextensive, the total area which they cover being comparatively small. They consist mainly of loams and fine sandy loams and are uniformly dark brown to black in color.

PHYSIOGRAPHY AND DRAINAGE

The topographic condition of Hamilton county may be described as level to very gently undulating, but locally there are many variations from this typical condition and the level prairies are broken by precipitious slopes such as are found along the Boone river, extensive valleys, prominent hills and numerous low swells. Many so-called "morainic hills" occur, ranging from 50 to 75 feet in height. These are rather regular in shape and resemble artificial mounds. They are believed to have been formed at the extreme edge or near the edge of the glacial deposits. Probably the most striking occurrence of these morainic hills is found south and east of Stratford. There is also a series of knobby mounds extending north from Wall Lake, east and north from Jewell, north of Randall and then north thru scattered swells and knobs and in the higher hills at the east of what was formerly Iowa lake. A similar chain of hills begins at the southwest corner of the county and extends across it in the vicinity of Stanhope, Kamrar and Blairsburg.

Throughout the upland there are found shallow, marshy lakes, the largest of which, Mud lake, situated north of Jewell, was artificially drained with partial success. Iowa lake in Rose Grove township has also been drained and it will probably eventually be possible to secure satisfactory crop growth on the peaty material which covers this area. At the present time its decomposition has not been sufficient. Wall lake, just north of Jewell, covers an area of one-half a square mile and is a shallow body of water, generally little more than a marsh.
Goose lake just east of Jewell is hardly more than a slough and less than one-fourth of a square mile in area.

The prevailing slope of the county as a whole is to the south and the more or less adequate drainage system flows in that direction. Many areas are inadequately drained and there are numerous low sags and ponded areas which will not be properly productive until drained. The areas between the various streams are level to almost flat in many cases and, owing to this topographic condition, as well as to the impervious character of the soil and subsoil, drainage is inadequate in many instances. Roughly, there are three of these more level areas in the county, where drainage is poor. The first occupies the east central part of the county between the Skunk river on the west and a rough area across the northeastern portion of the county. The second area extends between the Skunk river and the Boone river as far south as Stanhope. The third area is found west of the Boone river, covering the northwestern part of the county.

Drainage is brought about by the Boone river, the Skunk river and a few tributaries to the Iowa river on the east, Kegley creek, Crooked creek and

Fig. 1. Map showing natural drainage system of Hamilton county
Squaw creek on the south. The Skunk river extends thru the eastern central portion of the county, draining that area. Dick creek and Bear creek drain the area in the remaining southwestern portion of the county. In the northeastern part, several small tributaries to the Iowa river bring about fairly adequate drainage. The Boone river with several branches drains the western central part of the county. The most important tributaries of this river are Fox creek, Buck creek, Lyons creek and Brewers creek. In the southern part, the drainage is brought about by Kegley creek, Crooked creek and Squaw creek. These streams are all characterized by rather narrow flood plains, that of the Skunk river being less than one-fourth of a mile in width. The flood plain of the Boone river is somewhat wider, but in general these streams have narrow bottoms. Many of the tributaries are hardly more than intermittent drainage-ways, and flow thru upland soils. The drainage of the county as a whole is naturally somewhat inadequate, as will be evident from an examination of the drainage map shown in fig. 1. Artificial drainage has been established in many instances, drainage ditches being installed to carry away the surplus water from the level uplands. The use of such ditches and the extensive tiling which has taken place in some sections of the county has brought about large increases in crop production and has permitted of large crop growth on areas formerly entirely unproductive.

THE SOILS OF HAMILTON COUNTY

The soils of Hamilton county are grouped into three classes, according to their origin and location: Drift soils, terrace soils, and swamp and bottomland soils. Drift soils are those deposited by glaciers upon their retreat. They contain material from various sources, also sand and pebbles and frequently boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams or a deepening of the stream channel. Swamp and bottomland soils are those which occur in low-lying, poorly-drained areas or along streams, and they are subject to more or less frequent overflow. The extent of the occurrence of these groups of soils in Hamilton county is shown in table II.

By far the largest portion of the county, over 96 percent of the total area, is covered by the drift soils. The terrace and bottomland types cover very small areas, the former only 1.8 percent and the latter 2.1 percent of the total area of the county.

The drift soils vary considerably in topography features, the more extensive types being rather level, but the soils of the Carrington series are rolling and there is an area of the steep phase Carrington which is found along the streams.

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>350,464</td>
<td>96.1</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>6,592</td>
<td>1.8</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>7,744</td>
<td>2.1</td>
</tr>
<tr>
<td>Total</td>
<td>364,800</td>
<td></td>
</tr>
</tbody>
</table>
and, as the name indicates, is steep in topography. The terrace types are level, as are also the bottomland types, the latter being poorly drained and subject to overflow.

There are eleven distinct soil types in the county and these, together with the steep phase Carrington loam and the areas of peat, muck and meadow, make a total of fifteen separate soil areas. There are nine drift soils, two terrace types and four areas of swamp and bottomland. These various soil types are distinguished on the basis of certain definite characteristics, which are described in the appendix to this report. The type names which are given to the individual soils denote certain group characteristics, which will be described later. The areas of the different soil types in the county are given in table III. The occurrence of each of these individual soil types is shown on the map and the description of each type, together with recommendations and treatments needed in each case, is given later in the report.

THE FERTILITY IN HAMILTON COUNTY SOILS

In order to determine the plant food content of the various soil types in the county, samples were drawn from all the soils, with the exception of the Carrington gravelly loam, which is small in area, and the area of meadow, which is also small in area and so variable that sampling would be difficult. The larger types were sampled in triplicate, while the minor types were represented by only one sample. The samples were all taken with the greatest care that they should represent the soil type accurately and that any variations due to local conditions or special treatments should be eliminated. The samplings were made at three depths, 0"-6 2/3", 6 2/3" to 20" and 20"-40", representing the surface soil, the subsurface soil and the subsoil respectively. The total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirements were determined on all samples. The official methods were fol-

<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>55</td>
<td>Webster loam</td>
<td>211,520</td>
<td>58.0</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>54,464</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>3,520</td>
<td>15.8</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>43,712</td>
<td>12.0</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>31,040</td>
<td>8.5</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>2,752</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1,728</td>
<td>0.5</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>1,408</td>
<td>0.4</td>
</tr>
<tr>
<td>59</td>
<td>Carrington gravelly loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>139</td>
<td>Hancock very fine sandy loam</td>
<td>3,466</td>
<td>0.9</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>3,136</td>
<td>0.9</td>
</tr>
</tbody>
</table>

<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>49</td>
<td>Wabash loam</td>
<td>4,480</td>
<td>1.2</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>2,112</td>
<td>0.6</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>768</td>
<td>0.2</td>
</tr>
<tr>
<td>20</td>
<td>Meadow</td>
<td>384</td>
<td>0.1</td>
</tr>
</tbody>
</table>
followed in the case of the nitrogen, phosphorus and carbon determinations, and the Veitch method was used for the determinations of the limestone requirement. The results given in the tables are the average of the duplicate determinations on all the samples of each type. When more than one sample was taken, the results are the averages of four or six determinations.

**THE SURFACE SOILS**

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

The phosphorus content of the soils of the county is quite variable, ranging from 929 pounds per acre to 1963 pounds, and going up to 2100 pounds in the case of peat. There is no definite relation evidenced between the phosphorus content of the various types in the different soil groups. Some of the drift soils are rather well supplied with this constituent, while others are rather poorly supplied. In the case of the two terrace soils the phosphorus content is about the same, and the average for these two types is slightly higher than that for all the drift soils. There does, however, seem to be some relation in the case of the drift soils between texture and phosphorus content. The Webster clay loam, for instance, contains the largest amounts of the element of any of the drift types. The silt loams stand next to the clay loams. These are followed by the loams, while the lowest is the fine sandy loam. In the case of the terrace types, however, we find that the Hancock very fine sandy loam is somewhat better supplied with phosphorus than is the Waukesha loam. This fact may have some relation to the high lime content of the soil. In general it seems evident, therefore, that the phosphorus content of the soils of the county varies considerably, depending upon the texture and also, apparently, to some extent upon the soil origin, which is indicated in the series name.

While in general the phosphorus supply of the most extensive soil types of the county is not extremely low, neither is it very high, and this element will

**TABLE IV—PLANT FOOD IN HAMILTON 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>Lime- stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,452</td>
<td>4,792</td>
<td>86,948</td>
<td>0</td>
<td>1,200</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,160</td>
<td>4,872</td>
<td>61,050</td>
<td>0</td>
<td>3,147</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>929</td>
<td>1,760</td>
<td>26,420</td>
<td>28,420</td>
<td>Basic</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>1,152</td>
<td>2,680</td>
<td>30,636</td>
<td>12,493</td>
<td>Basic</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>1,563</td>
<td>8,609</td>
<td>75,980</td>
<td>8,750</td>
<td>Basic</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>1,590</td>
<td>2,154</td>
<td>32,220</td>
<td>0</td>
<td>2,402</td>
</tr>
<tr>
<td>4</td>
<td>Rogers silt loam</td>
<td>963</td>
<td>1,836</td>
<td>24,500</td>
<td>0</td>
<td>1,201</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>1,754</td>
<td>23,800</td>
<td>242,417</td>
<td>87,913</td>
<td>Basic</td>
</tr>
</tbody>
</table>

**TERRACE SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime- stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>139</td>
<td>Hancock very fine sandy loam</td>
<td>1,440</td>
<td>2,984</td>
<td>50,520</td>
<td>12,660</td>
<td>Basic</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,387</td>
<td>3,018</td>
<td>35,640</td>
<td>0</td>
<td>3,693</td>
</tr>
</tbody>
</table>

**SWAMP AND BOTTOMLAND SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime- stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,455</td>
<td>3,080</td>
<td>53,740</td>
<td>18,820</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>2,100</td>
<td>46,836</td>
<td>701,000</td>
<td>12,600</td>
<td>Basic</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>1,720</td>
<td>33,388</td>
<td>460,140</td>
<td>0</td>
<td>Basic</td>
</tr>
</tbody>
</table>
undoubtedly be needed in the future for maintaining permanent fertility. It is possible that phosphorus fertilizers might prove of value in some cases at the present time. Such materials should not be applied on a large scale, however, until tests have been made on small areas and the value of the phosphate material definitely shown for the particular soil type. When field tests which are being established in this county have been carried on for a period of several years, it may be possible to make definite recommendations for the individual types. For the present, however, it can merely be urged that phosphate materials be tested on small areas on individual farms.

The soils of the county are much better supplied with nitrogen than with phosphorus. With the exception of two minor types, the supply of nitrogen is not particularly low. In the case of the Webster clay loam it is rather high and in the Rogers silt loam, which is a rather abnormal soil, the supply is extremely large. The peat and muck are, of course, very high in this constituent. There seems to be no relation between the soil group and the nitrogen content and very little between the soil texture and the supply of this constituent, except that the Webster clay loam is well supplied and the Carrington fine sandy loam is low in this constituent. In fact the relation, if any, between the nitrogen supply and the soil type seems to depend primarily upon the series in which the soil type is classified.

In general it should be noted that the soils of the county are fairly well supplied with nitrogen and only in a few cases is the amount of this constituent so low that it should be considered actually deficient. This does not mean, however, that nitrogen should not be considered in systems of permanent fertility. If the nitrogen supply of the soil is to be kept up, regular applications of nitrogenous materials must be made. Farm manure, green manures and crop residues are the natural means of supplying nitrogen to soil. Farm manure and crop residues, however, merely return to the soil a portion of the nitrogen removed by the crop grown on the land and hence cannot build up the nitrogen supply in the soil. Leguminous crops, however, when well inoculated are able to utilize the free nitrogen of the atmosphere and, when turned under in the soil as green manures, may increase considerably the nitrogen content. They also increase the supply of organic matter; hence, the effect of green manuring with legumes may be distinctly profitable and the soils may be built up in nitrogen content and kept permanently fertile, as far as that constituent is concerned.

The amount of organic carbon present in soils indicates the quantity of organic matter present and this, in turn, gives some idea of the nitrogen content, so that there is usually a rather definite relation between the organic carbon and the nitrogen in soils. The color of the soil indicates rather definitely the amount of organic matter present and thus gives a rough idea of the nitrogen supply. Darker-colored soils, especially those heavier in texture, are generally better supplied with organic carbon and nitrogen than light-textured, light-colored types.

There is a wide variation in the organic carbon content of the soils of Hamilton county, the Rogers silt loam showing the largest amount of any of the soil types. This soil was also the highest in nitrogen content. The peat and
muck are naturally much higher in both of these constituents than any of the
other soil types. The Webster series soils stand next to the Rogers silt loam in
content of organic matter, and these are followed by the Wabash soils. There
seems to be very little relation between organic matter supply and the topo­
graphic position of the type; neither is there any very definite relation be­
tween the soil texture and organic carbon content. The relations which exist
seem to be dependent chiefly upon the soil series and the textures within series.

"It is necessary for the continued fertility of these soils that organic matter
be supplied from time to time and in many instances applications of farm
manure prove distinctly profitable, even on those soils which seem to be
abundantly supplied with organic matter. Farm manure is undoubtedly the
most important source of organic matter for use on the soils of the county,
altho crop residues and green manures, as noted above, supply considerable
organic matter. If farm manure is not available, leguminous green manures
should be employed for maintaining the supply of organic matter in the soil.

Several of the soil types are well supplied with inorganic carbon. In fact, in
the case of many of them, the amount of inorganic carbon present is so large
that the soils will effervesce with hydrochloric acid. The Rogers silt loam con­
tains a very large amount of inorganic carbon, a characteristic of the Rogers
series. The Clarion loam and Hancock very fine sandy loam are also well
supplied with lime, which is characteristic of these soil series. The Wabash
loam shows considerable lime in the surface soil, indicating that this soil should
probably have been classed as Lamoure rather than Wabash, if this lime content
is uniform. It is possible, however, that other samples of the same type would
not show as large amounts of lime present. The steep phase Carrington loam
shows considerable lime present, which indicates that this type should have
been classed as Clarion loam, steep phase. The Webster clay loam is basic in
reaction and contains considerable lime in the surface soil, whereas the Webster
loam shows a slight acidity and no lime content in the surface soil. This type,
however, becomes basic in the subsurface soil and subsoil, where considerable
lime is found.

It is interesting to note that the soils which are acid in reaction show the
need of only small applications of lime to put them in the best condition for
crop growth, but it should be emphasized that even altho they are only slightly
in need of lime, the application of this material will prove very profitable in
increasing crop growth, particularly of legumes. It is necessary that soils of
the Carrington, Webster, Miami, Waukesha and Wabash series be tested for
lime requirement and lime applied as shown to be necessary by the tests, if the
soils in those series are to be made satisfactorily productive. The amount of
lime which should be applied to any of these soils must be determined by indi­
vidual tests. No general recommendations can be givn and the figures in the
table should be considered as merely indicating the approximate lime require­
ments of the soils. Tests should be made in the case of every soil to ascertain
the exact amount of lime needed.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and the subsoils are given
in tables V and VI. They are calculated on the basis of 4,000,000 pounds of
TABLE V—PLANT FOOD IN HAMILTON COUNTY, IOWA, SOILS
Pounds per acre of four million pounds of subsurface soils (6 2/3"-20")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,750</td>
<td>7,401</td>
<td>106,781</td>
<td>2,469</td>
<td>Basic</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,769</td>
<td>7,144</td>
<td>57,320</td>
<td>0</td>
<td>4,802*</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,520</td>
<td>5,152</td>
<td>54,290</td>
<td>69,560</td>
<td>Basic</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>1,949</td>
<td>2,860</td>
<td>23,573</td>
<td>103,645</td>
<td>Basic</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>2,520</td>
<td>5,152</td>
<td>54,290</td>
<td>21,220</td>
<td>Basic</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>1,200</td>
<td>3,000</td>
<td>16,380</td>
<td>69,660</td>
<td>Basic</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1,360</td>
<td>3,000</td>
<td>39,320</td>
<td>0</td>
<td>800</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>2,562</td>
<td>30,000</td>
<td>175,085</td>
<td>412,615</td>
<td>Basic</td>
</tr>
</tbody>
</table>

DRIFT SOILS

subsurface soil and 6,000,000 pounds of subsoil. The plant food present in the lower soil layers may exert some influence on the fertility of the soil, but unless the amount of a particular constituent is very much higher or very much lower than that present in the surface soil, the needs of the soil as indicated by the analyses of the surface soil are little modified. It is evident from tables V and VI that there is no excessive supply of plant food constituents in the lower layers of the soils of this county, and neither is there any striking deficiency. It seems hardly necessary, therefore, to consider these results in detail.

The conclusions drawn from the analyses of the surface soil are very largely confirmed by these results. Phosphorus fertilizers might prove of value in

TABLE VI—PLANT FOOD IN HAMILTON COUNTY, IOWA, SOILS
Pounds per acre of six million pounds of subsoil (20"-40")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>2,400</td>
<td>5,172</td>
<td>43,067</td>
<td>97,489</td>
<td>Basic</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>2,190</td>
<td>5,853</td>
<td>56,667</td>
<td>0</td>
<td>3,503</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>3,200</td>
<td>7,134</td>
<td>88,200</td>
<td>32,640</td>
<td>Basic</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>2,923</td>
<td>1,920</td>
<td>16,759</td>
<td>157,888</td>
<td>Basic</td>
</tr>
<tr>
<td>56</td>
<td>Webster clay loam</td>
<td>2,670</td>
<td>3,774</td>
<td>51,720</td>
<td>56,670</td>
<td>Basic</td>
</tr>
<tr>
<td>58</td>
<td>Miami silt loam</td>
<td>1,620</td>
<td>1,764</td>
<td>22,860</td>
<td>0</td>
<td>10,809</td>
</tr>
<tr>
<td>4</td>
<td>Carrington fine sandy loam</td>
<td>1,980</td>
<td>3,514</td>
<td>26,640</td>
<td>2,334</td>
<td>Basic</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>3,456</td>
<td>33,600</td>
<td>360,552</td>
<td>216,543</td>
<td>Basic</td>
</tr>
</tbody>
</table>

TERRACE SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>139</td>
<td>Hancock very fine sandy loam</td>
<td>2,640</td>
<td>5,944</td>
<td>62,760</td>
<td>50,240</td>
<td>Basic</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,600</td>
<td>3,518</td>
<td>66,760</td>
<td>0</td>
<td>8,808</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,920</td>
<td>9,444</td>
<td>124,800</td>
<td>6,280</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>4,160</td>
<td>84,136</td>
<td>1,258,120</td>
<td>7,400</td>
<td>Basic</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>2,840</td>
<td>65,252</td>
<td>860,012</td>
<td>0</td>
<td>Basic</td>
</tr>
</tbody>
</table>

<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>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2,220</td>
<td>5,520</td>
<td>94,410</td>
<td>3,050</td>
<td>Basic</td>
</tr>
<tr>
<td>21</td>
<td>Peat</td>
<td>5,760</td>
<td>116,430</td>
<td>1,638,258</td>
<td>20,262</td>
<td>Basic</td>
</tr>
<tr>
<td>21a</td>
<td>Muck</td>
<td>3,120</td>
<td>36,656</td>
<td>483,480</td>
<td>0</td>
<td>Basic</td>
</tr>
</tbody>
</table>
some cases at the present time and will undoubtedly be needed in the future for permanent fertility. Organic matter and nitrogen will be needed on these soils for continued fertility and in some instances could be added with profit at the present time. Many of the soils of the county are abundantly supplied with lime in the lower soil layers. Except in the case of the Webster loam and the Carrington fine sandy loam, the reaction of the lower soil layers is very much the same as that of the surface soil and if lime is needed at the surface, it should be applied. It should be noted that even if a large supply of lime occurs in the subsoil, any acidity in the surface soil should be neutralized for the best crop growth, inasmuch as there is little movement of lime upward in the soil. Emphasis should be placed upon the need of testing the soils of certain series as listed above for their lime requirements.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on Hamilton county soils to secure some indications of the value of various fertilizing materials. One of these experiments was carried out with the Carrington loam and the second experiment with the Webster loam.

The soil treatments were the same in both experiments and consisted of the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts which were used were the same as are employed in the field experiments now under way; hence, the results of the greenhouse tests may be considered to indicate the character of the results which may be expected in the field. Manure was applied at the rate of 8 tons per acre. Lime was added in an amount sufficient to neutralize the acidity of the soil, as indicated by the Veitch test, and supply two tons additional. Rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in both these experiments, the clover being seeded about one month after the wheat was up.
The results of the experiment on the Carrington loam are given in table VII, the results being the average of the duplicate pots. It is evident that the application of manure was of considerable value on this soil, the wheat and clover both being increased in yield to a considerable extent. Lime in addition to manure brought about a further increase, which was small in the case of the wheat crop, but considerable in the case of the clover. It would be expected that the effect of lime would be evidenced to a larger extent on clover than on wheat, and these results bear out the assumption. The addition of rock phosphate with manure and lime had no effect on either crop and the same is true for the acid phosphate. The commercial fertilizer, however, gave a small incomplete commercial fertilizer brought about a still larger increase in the case of both crops.

These results show quite definitely that manure is a particularly valuable fertilizer for use on this soil. They show also the value of lime, especially on the clover crop. The results do not indicate any particular value from the phosphorus carriers, except in the case of the complete fertilizer.

The results of the second greenhouse experiment are given in table VIII.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover grain in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>9.62</td>
<td>43.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>11.93</td>
<td>65.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>12.79</td>
<td>79.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>12.45</td>
<td>72.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>12.56</td>
<td>78.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>13.61</td>
<td>93.0</td>
</tr>
</tbody>
</table>
TABLE VIII—GREENHOUSE EXPERIMENT, WEBSTER LOAM, HAMILTON COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>13.15</td>
<td>59.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>13.77</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>17.61</td>
<td>70.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>13.94</td>
<td>74.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>18.01</td>
<td>80.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>20.31</td>
<td>82.0</td>
</tr>
</tbody>
</table>

The yield of clover on the manure treated pots is not given, inasmuch as the results were evidently very abnormal, for some reason. The effect of manure is evidenced by a slight increase in the yield of wheat. Lime in addition to manure increased the wheat yield considerably. This combination of lime and manure also increased the clover to a large extent. Rock phosphate had no effect on the wheat, but showed a slight increase in the case of the clover. Acid phosphate increased both the wheat and the clover rather definitely and the complete commercial fertilizer brought about a still larger increase in the case of both crops.

It is apparent from this experiment that the addition of lime to the Webster loam when it is acid will lead to increases in crop growth, particularly of legumes. The test also indicates the desirability of determining the value of phosphorus fertilizers on this soil type by field experiments, as a rather distinct crop increase from the use of phosphate carriers is shown.

Fig. 4. Lime in addition to manure brought about a marked increase in wheat on the Webster loam
Fig. 5. The effect of various fertilizers on clover grown on Webster loam

These greenhouse experiments as a whole indicate that for the more rolling upland of the county, the application of farm manure is strongly to be recommended, and this material should be employed in liberal amounts. On the heavier, more level types, the additions of small amounts of manure may prove of value, but large applications should be avoided, as there is a tendency to cause small grains to lodge. The tests show also the desirability of applying lime when soil is acid and indicate that phosphorus fertilizers may be of considerable value. Tests of these materials on individual farms should yield very definite and valuable data, in that they will show not only the value of applications of phosphorus, but also which phosphorus fertilizer should be employed.

FIELD EXPERIMENTS

Until recently it has not been possible to carry on field experiments in Hamilton county. Some tests are now under way, but they must be continued for at least five years before data of any general value will be secured. The results of these experiments will be published at a later date as a supplement to this report.

The Webster loam is one of the main types in Hamilton county and it occurs on a large area, also, in Webster county. A field experiment was laid out in Webster county several years ago and the results of this experiment may be given here as indicating what the effects of treatment may be on this soil type in Hamilton county.

THE LUNDGREN FIELD

This experiment is near Lundgren on an area of Webster loam, which is typical of this soil type, wherever it occurs. The field is permanently located by the installation of corner stakes and care is taken in the application of fertilizers and in the harvesting of crops, to be certain that the results secured are accurate.
On this field a series of plots has been arranged to include a test under the livestock system of farming and under the grain system. In the former, manure is applied, while in the latter, crop residues are utilized as a source of organic matter. In addition to these materials, rock phosphate, acid phosphate and a complete commercial fertilizer are tested. Manure was applied at the rate of 4 tons per acre in 1918, when the experiment was started, a larger application being undesirable, as oats was to be grown. Rock phosphate is applied at the rate of 2,000 pounds per acre once in a four-year rotation, acid phosphate at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. On the grain system plots, the second crop of clover is to be plowed under in all cases. The corn stalks are cut with a disc and plowed under and the threshed straw from the small grains is returned to the soil. There are thirteen plots in the experiment, three of which are untreated or check plots. These are numbered 1, 7 and 13. Plots 1 to 7, inclusive, are therefore included in the livestock system, while plots 7 to 13 are in the grain system. These plots are 155 feet 6 inches by 28 feet, or 1/10 of an acre in size.

The results of the experiment in 1918-19-20 are given in table IX. The yield on the check plot is not given in the case of the oats in 1918, owing to its very evident abnormality. In 1918 there is some evidence of value from the application of the acid phosphate and the complete commercial fertilizer to the oats, the increase being particularly noticeable in the case of the acid phosphate on the crop residue plots. In 1919 the acid phosphate and commercial fertilizer again show a slight effect on the livestock system plots, but the effect is much more pronounced with these materials in the case of the crop residue plots. The increase on the corn from the use of commercial fertilizer, as shown in plot 12, is quite pronounced. In 1920, again, the phosphorus fertilizers show some value, the greatest increase in the corn being found from the use of the commercial fertilizer with manure on plot 6. Rock phosphate and acid phosphate both gave distinct increases on the residue plots, while the commercial fertilizer showed less effect. Manure was applied to the soil previous to the seeding in 1920, but showed little effect on the corn yield. Rock phosphate proved of some effect on the corn in 1920, whereas in the preceding years it had practically no effect.

This experiment indicates rather definitely the desirability of testing phos-

**TABLE IX—FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. per acre oats 1918</th>
<th>Bu. per acre corn 1919</th>
<th>Bu. per acre corn 1920</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>59.0</td>
<td>63.8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>85.0</td>
<td>63.8</td>
<td>62.4</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>86.2</td>
<td>69.6</td>
<td>65.3</td>
</tr>
<tr>
<td>4</td>
<td>Manure + rock phosphate</td>
<td>85.0</td>
<td>61.3</td>
<td>69.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure + acid phosphate</td>
<td>91.4</td>
<td>65.1</td>
<td>74.2</td>
</tr>
<tr>
<td>6</td>
<td>Manure + complete commercial fertilizer</td>
<td>89.2</td>
<td>65.1</td>
<td>74.2</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>54.0</td>
<td>59.7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>82.9</td>
<td>63.3</td>
<td>59.7</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues</td>
<td>85.0</td>
<td>63.5</td>
<td>57.7</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + rock phosphate</td>
<td>87.1</td>
<td>65.9</td>
<td>68.9</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + acid phosphate</td>
<td>97.7</td>
<td>69.7</td>
<td>68.6</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + complete commercial fertilizer</td>
<td>93.5</td>
<td>73.9</td>
<td>65.2</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>80.7</td>
<td>54.2</td>
<td>57.7</td>
</tr>
</tbody>
</table>
Phosphorus fertilizers on the Webster loam to determine their value and to learn which material may be applied most economically. The application of manure proved of little effect, but this material should be employed in small amounts at regular intervals on this soil to keep up its supply of organic matter. The soil was not acid in reaction; hence, no lime was used. Whenever this soil is acid, however, it would be desirable and distinctly profitable to apply lime. Phosphorus fertilizers may prove of value, and certainly should be tested.

The Ames Field

The Carrington loam is the second largest type in Hamilton county and it also occurs extensively in the different counties throughout the Wisconsin drift soil area. Some of the experimental plots at Ames are located on this soil and the results of the experiments on these plots may be considered as directly applicable to conditions in Hamilton county on the same soil type.

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

The experiment was carried out on five series of plots, two of which contained 12 plots, one-tenth of an acre in size, two series contained 11 plots of the same size and the fifth series contained 12 plots, three-twentieths of an acre in size. These plots were laid out in the usual way, with division strips of 6½ feet and a cropped border 6½ feet wide around each series of plots.

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

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

Cowpeas were sown in the corn at the last cultivation, as the legume catch crop. In some seasons they were plowed under in the fall and in others disked down in the spring. Manure was applied at the rate of 8 tons per acre once in the four-year rotation to the clover sod, in the fall just before plowing. This represents about the amount which should be applied if all the crops produced on the land were fed and the manure returned to the soil. Phosphorus was applied as steamed bone meal, at the rate of 800 pounds per acre, on the clover sod once in the four-year rotation. Potassium was applied, either as muriate of potash or as potassium sulfate, at the rate of 400 pounds per acre, also on the clover sod once in the rotation.

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

*Bulletin 161, Iowa Agricultural Experiment Station—Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa.
The general plan of the experiment was to remove all the regular crops grown on the land except the corn stalks. These were usually plowed under, but in seasons where the growth was heavy and the moisture conditions were not favorable, they were removed. Two cuttings of clover were removed, except in very dry years, when the second crop was practically a failure and was plowed under.

The weight and value of each of the crops grown during the two separate four-year periods was determined and calculation made for the eight-year period. In making the calculation, the corn was figured at 45 cents per bushel, the oats at 35 cents and the clover at $8.00 per ton. The cost of fertilizers was as follows:

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

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

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

### THE ROTATION EXPERIMENTS

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

When phosphorus was added with the manure, almost the same yield was secured as with the manure alone, but the cost of the phosphorus reduced the net returns considerably. Potassium applied with the manure and phosphorus brought about no appreciable increase in the yield and the cost of the material lowered the value of the treatment to an actual loss. The phosphorus and potassium treatments were not cost-effective.

### TABLE X—CORN YIELDS, CARRINGTON LOAM, AMES FIELD

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Average yield in bu. per acre</th>
<th>Inc. or Dec. in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatment per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>60.2</td>
<td>-1</td>
<td>$.05</td>
<td>$1.25</td>
<td>$-1.30</td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>60.1</td>
<td>-1</td>
<td>$.05</td>
<td>$.80</td>
<td>4.89</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>72.4</td>
<td>12.2</td>
<td>5.49</td>
<td>4.90</td>
<td>1.59</td>
</tr>
<tr>
<td>4</td>
<td>Manure + cowpeas</td>
<td>68.3</td>
<td>8.1</td>
<td>3.65</td>
<td>2.05</td>
<td>1.60</td>
</tr>
<tr>
<td>5</td>
<td>Manure + cowpeas + phosphorus</td>
<td>73.1</td>
<td>12.9</td>
<td>5.51</td>
<td>5.05</td>
<td>0.76</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas + phosphorus</td>
<td>64.9</td>
<td>4.7</td>
<td>2.12</td>
<td>4.25</td>
<td>-2.13</td>
</tr>
<tr>
<td>7</td>
<td>Manure + phosphorus</td>
<td>72.1</td>
<td>11.9</td>
<td>5.36</td>
<td>3.80</td>
<td>1.56</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas + phosphorus + potassium</td>
<td>72.1</td>
<td>11.9</td>
<td>5.36</td>
<td>3.75</td>
<td>-1.39</td>
</tr>
<tr>
<td>9</td>
<td>Manure + phosphorus + potassium</td>
<td>72.7</td>
<td>12.5</td>
<td>5.63</td>
<td>6.30</td>
<td>-6.67</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus + potassium</td>
<td>69.9</td>
<td>9.7</td>
<td>4.35</td>
<td>5.50</td>
<td>-1.14</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>59.1</td>
<td>-1.1</td>
<td>-5.0</td>
<td>3.00</td>
<td>-3.50</td>
</tr>
</tbody>
</table>

Average gain for manure .................................................. 8.8 bushels
Average gain for phosphorus ............................................. 2.1 bushels
Average gain for potassium .............................................. 6.2 bushels
potassium together increased the yield of corn, but to a less extent than the manure alone, and again the applications proved uneconomical.

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

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

Evidently, when manure is available it is the best fertilizing material for use on this soil and the application of other fertilizers with it may not give large gains.

The result of the experiment with oats, as given in table XI, reveal the fact that with all the treatments except manure, the cost of the fertilizers considerably exceeded the value of the increases which they brought about in yields. Greater increases in yields were obtained in several cases from the combined treatments than were obtained from the manure alone, but the cost of the other fertilizers made the treatments uneconomical.

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

Table XII gives the results of the tests with clover for the eight-year period, and again the manure alone gave the largest net returns on the investment for the treatment and the other applications proved of less value. Gains in yield were shown for several other treatments and the average gains for the manure, phosphorus and potassium were 0.284 tons, 0.215 tons and 0.433 tons, respectively. The results for the clover crop were somewhat different from those secured with the corn and oats, in that they showed a larger influence from

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Average yield in bu. per acre</th>
<th>Inc. or Dec. in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatm't per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>55.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>56.4</td>
<td>1.4</td>
<td>$.49</td>
<td>$1.25</td>
<td>$.76</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>61.9</td>
<td>6.9</td>
<td>2.42</td>
<td>.80</td>
<td>1.62</td>
</tr>
<tr>
<td>4</td>
<td>Manure + cowpeas</td>
<td>67.9</td>
<td>2.9</td>
<td>1.03</td>
<td>2.65</td>
<td>-1.02</td>
</tr>
<tr>
<td>5</td>
<td>Manure + cowpeas + phosphorus</td>
<td>62.5</td>
<td>9.1</td>
<td>3.18</td>
<td>5.05</td>
<td>-1.87</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas + phosphorus</td>
<td>62.5</td>
<td>7.5</td>
<td>2.63</td>
<td>4.25</td>
<td>-1.62</td>
</tr>
<tr>
<td>7</td>
<td>Manure + phosphorus</td>
<td>62.4</td>
<td>7.4</td>
<td>2.59</td>
<td>3.80</td>
<td>-1.21</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas + phosphorus + potassium</td>
<td>63.9</td>
<td>8.9</td>
<td>3.12</td>
<td>6.75</td>
<td>-3.63</td>
</tr>
<tr>
<td>9</td>
<td>Manure + phosphorus + potassium</td>
<td>65.3</td>
<td>10.3</td>
<td>3.61</td>
<td>6.30</td>
<td>-2.69</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus + potassium</td>
<td>55.8</td>
<td>.2</td>
<td>-0.07</td>
<td>5.50</td>
<td>-5.57</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>57.9</td>
<td>2.9</td>
<td>1.03</td>
<td>3.00</td>
<td>-1.97</td>
</tr>
</tbody>
</table>

Average gain for manure ........................................... 5.0 bushels
Average gain for phosphorus .................................... 3.9 bushels
Average gain for potassium .................................... 0.4 bushels
TABLE XII—CLOVER YIELDS, CARRINGTON LOAM, AMES FIELD

Eight-year period—1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Average yield in tons per acre</th>
<th>Inc. or Dec. in tons per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatm't per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>2.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>2.65</td>
<td>.40</td>
<td>$3.20</td>
<td>$1.25</td>
<td>$1.95</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>2.82</td>
<td>.57</td>
<td>4.56</td>
<td>.80</td>
<td>3.76</td>
</tr>
<tr>
<td>4</td>
<td>Manure+cowpeas</td>
<td>2.54</td>
<td>.29</td>
<td>2.32</td>
<td>2.05</td>
<td>.27</td>
</tr>
<tr>
<td>5</td>
<td>Manure+cowpeas+phosphorus</td>
<td>3.11</td>
<td>.56</td>
<td>6.88</td>
<td>5.05</td>
<td>1.83</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas+phosphorus</td>
<td>2.71</td>
<td>.46</td>
<td>3.68</td>
<td>4.25</td>
<td>-.57</td>
</tr>
<tr>
<td>7</td>
<td>Manure+phosphorus</td>
<td>2.85</td>
<td>.60</td>
<td>4.80</td>
<td>3.80</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas+phosphorus+potassium</td>
<td>3.35</td>
<td>1.10</td>
<td>8.50</td>
<td>6.75</td>
<td>2.05</td>
</tr>
<tr>
<td>9</td>
<td>Manure+phosphorus+potassium</td>
<td>3.06</td>
<td>.81</td>
<td>6.48</td>
<td>6.30</td>
<td>1.8</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus+potassium</td>
<td>2.90</td>
<td>.65</td>
<td>5.20</td>
<td>5.50</td>
<td>-.30</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>2.45</td>
<td>.20</td>
<td>1.60</td>
<td>3.00</td>
<td>-1.40</td>
</tr>
</tbody>
</table>

Average gain for manure ................................ .................................. 0.284 tons
Average gain for phosphorus ..................................................... 0.215 tons
Average gain for potassium ..................................................... 0.433 tons

The application of potassium. The greatest net returns were secured with the manure alone, inasmuch as the cost of the potassium was very large. Cowpeas exerted some effect on the clover crop, but their influence was less than that of the manure.

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

THE CONTINUOUS CORN EXPERIMENT

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

The yields of corn under continuous growing were very much smaller than those secured in the four-year rotation, indicating that the continuous growth of corn is injurious to the soil. The plant food is used up too rapidly, the humus or organic matter content becomes depleted and the physical condition
TABLE XIII—CONTINUOUS CORN YIELD, CARRINGTON LOAM, AMES FIELD
Eight-year period—1906-1913

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil treatment</th>
<th>Average yield in bu. per acre</th>
<th>Inc. or Dec. in bu. per acre</th>
<th>Value of increase per acre</th>
<th>Cost of treatm’t per acre</th>
<th>Net returns per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>42.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cowpeas</td>
<td>44.2</td>
<td>1.5</td>
<td>$.68</td>
<td>$1.25</td>
<td>$.57</td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>53.9</td>
<td>11.2</td>
<td>5.04</td>
<td>.80</td>
<td>4.24</td>
</tr>
<tr>
<td>4</td>
<td>Manure + cowpeas</td>
<td>55.4</td>
<td>10.7</td>
<td>4.82</td>
<td>2.05</td>
<td>2.77</td>
</tr>
<tr>
<td>5</td>
<td>Manure + cowpeas + phosphorus</td>
<td>56.4</td>
<td>13.7</td>
<td>6.17</td>
<td>5.05</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>Cowpeas + phosphorus</td>
<td>46.5</td>
<td>3.3</td>
<td>1.71</td>
<td>4.25</td>
<td>-2.54</td>
</tr>
<tr>
<td>7</td>
<td>Manure + phosphorus</td>
<td>54.9</td>
<td>12.2</td>
<td>5.49</td>
<td>3.30</td>
<td>1.69</td>
</tr>
<tr>
<td>8</td>
<td>Cowpeas + phosphorus + potassium</td>
<td>55.5</td>
<td>12.8</td>
<td>5.76</td>
<td>6.75</td>
<td>-1.99</td>
</tr>
<tr>
<td>9</td>
<td>Manure + phosphorus + potassium</td>
<td>54.2</td>
<td>11.5</td>
<td>5.18</td>
<td>6.30</td>
<td>-1.12</td>
</tr>
<tr>
<td>10</td>
<td>Phosphorus + potassium</td>
<td>49.2</td>
<td>6.5</td>
<td>2.93</td>
<td>5.50</td>
<td>-2.57</td>
</tr>
<tr>
<td>11</td>
<td>Phosphorus</td>
<td>43.6</td>
<td>.9</td>
<td>.41</td>
<td>3.00</td>
<td>-2.59</td>
</tr>
</tbody>
</table>

Average gain for manure .......................................................... 9.3 bushels
Average gain for phosphate ...................................................... 1.8 bushels
Average gain for potassium ....................................................... 4.6 bushels

of the soil is injured. A longer period for the experiment would undoubtedly have shown a much greater decrease in yield than was apparent here, but these results indicate clearly the superior value of a rotation of crops.

The relative value on corn of the various treatments appeared to be practically the same whether the corn is grown continuously or in rotation. Manure was of the greatest value in both cases, potassium gave smaller gains and phosphorus and cowpeas showed only small effects. Furthermore, none of the treatments except the manure yielded profitable net returns.

PEAT SOILS

Peat is partially rotted vegetable matter, which consists either of swamp grasses, sedges, rushes and flags, or of sphagnum moss, the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed increase from year to year and with the long continuance of swampy conditions may become of considerable depth. When the glacier which once covered north central Iowa, retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places lakes, ponds and marshes were formed because of the heavy, impervious character of the subsoil, and the formation of peat followed. It is mainly in the Wisconsin drift soil area, therefore, that peat occurs in Iowa. Hamilton county is located in this soil area and has several peat areas, aggregating 2,112 acres or 0.6 percent of the county’s area.

A complete discussion of peat soils in Iowa and a report of certain experiments which have been carried out to determine their needs have been given elsewhere1 and no extended consideration of them need be entered upon here.

There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value

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1Bulletin 157, Iowa Experiment Station—Improving Iowa’s Peat and Alkali Soils.
pointed out. They are composed of fibrous, fairly dry vegetable matter, extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer, therefore, only to the shallow peats and are not at all applicable to deep peats.

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

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

FIELD EXPERIMENTS IN PEAT SOILS

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story counties, respectively, and these tests were considered at length in the bulletin previously mentioned. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination in the amounts in which such materials are generally applied to soils. In no case was there any profitable increase in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and the untreated soils were only such as might well occur between duplicate plots.

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

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

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

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

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

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

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

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

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

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat and aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.
Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes and potatoes all gave excellent results on the experiment plots near Ontario. Cabbage, beets, turnips and other crops might also prove of value. The use of such crops on newly-reclaimed peat soils should be encouraged.

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

"ALKALI" SOILS

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

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

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

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

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned and more in detail in a later publication, and it is apparent from the studies which have been carried out that the salts which occur are variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amounts of these latter salts which make up the "alkali" content of Hamilton county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium bicarbonate which always occurs, may prove injurious.

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

TREATMENT FOR ALKALI SOILS

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

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

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

The general treatments recommended in this report for the soils of Hamilton county are based upon the laboratory, greenhouse and field experiments reported in the previous pages. They are based also, however, upon the general experience of farmers and only those suggestions which have been proved by practical experience to be of value are offered. The field experiments which are under way in this county must be carried on for several years before definite conclusions can be drawn from them. The field data which are given show, however, what may be expected from similar treatments of the Webster loam and the Carrington loam in the county and are presented to emphasize the importance of testing phosphorus fertilizers on these soils. Until the field data is available, definite recommendations cannot be made regarding the relative merits of rock phosphate and acid phosphate and it is urged that farmers test the value of these two materials on their own soils and determine for their own conditions which material will yield the greater economic value.

In spite of the limitations of the experimental results available at the present time, the following general statement may be given regarding the needs of the soils of the county and the suggestions offered should be of value in increasing crop production in the county.
DRAINAGE

In the Wisconsin drift soil area, drainage has been one of the most important farming operations and is often the first treatment needed to make the soils productive. Ponds, lakes and swamps were at one time common throughout this area and the soils where these occurred have been particularly benefited by drainage. Many acres of land in that area, where crop production was limited or entirely prevented by excessive moisture conditions, have been made highly productive by the use of tile drains and drainage ditches.

Hamilton county is in the Wisconsin drift area and while much drainage work has been done in the county, there are still areas where the soils are too wet and tiling would be of value.

The Webster loam, the most extensive soil type in Hamilton county, covering one-half of the total area, is frequently in need of tiling in order to permit of proper drainage conditions. Dredged ditches have been installed and, where these have been given the proper fall, the laterals laid not more than four rods apart and the main tile carrying water to the dredged ditch is sufficiently large, thorough drainage of the soil has been accomplished. In some instances one or the other of these precautions has not been observed and where such is the case, the drainage is not satisfactory. The Webster clay loam, an important soil type in the county covering 8.5 percent of the total area, is particularly in need of drainage and, when drained, becomes highly productive. The Wabash loam, the Rogers silt loam and the area of peat and muck are likewise in need of drainage. This is particularly true in the case of the peat, as has been noted. Much of the land in Hamilton county has been drained and the results secured give definite evidence of the value of the operation. In many
cases where drainage is not adequate, the first treatment necessary is the installation of tile and frequently the location of dredged ditches. Altho the cost of draining may be considerable, the increased value from the crops secured will more than warrant the expense involved. The method of installation of tile is quite generally understood, but definite advice along this line will be given upon request by the Soils Section of the Iowa Agricultural Experiment Station.

MANURING

The soils of Hamilton county are not strikingly low in organic matter and in several instances they seem to be very well supplied. The Webster soils of the upland are black in color, hence high in organic matter content. The Carrington loam is fairly well supplied with organic matter, as is the Clarion loam also. The other types of the Carrington series are, however, low in organic matter and the Miami silt loam and terrace soils are likewise relatively low in organic matter. On these latter types applications of farm manure would be particularly valuable and liberal applications should be made. Farm experience indicates, however, that manure is of value, when applied in small amounts, on the dark-colored, upland types, as well. In general it seems to be the most valuable fertilizing material for use on the soils of the county and, while on the richer types small applications may prove more profitable than larger applications, on the poorer soils liberal amounts of manure are distinctly profitable. It should be emphasized that even where other fertilizers are employed, it is very desirable that at least small applications of manure be made if the organic matter content of the soil is to be maintained. The greenhouse and field tests bear out the conclusions from the analyses and from farm experience in showing the beneficial effects of applications of manure to the more important upland types in the county.

Manure has a definite influence on the physical, chemical and bacteriological conditions in the soil, even on soils which are apparently well supplied with organic matter. It opens up heavy, impervious soils and makes them better aerated, less retentive of moisture and in a better condition in general for the production of available plant food. It makes light, open soils less porous, less apt to suffer from lack of moisture and less subject to loss of valuable plant food by leaching. Its chemical influence on the soil is due to the fact that it contains a considerable amount of plant food, derived from the feed of the animals. Hence it may serve to prolong the life of the soil by lengthening the time before any one of the essential elements will become entirely deficient.

Manure also has important bacterial effects. It contains enormous numbers of bacteria which, when introduced into the soil, will stimulate decomposition processes and bring about a greater production of available plant food. The organic matter supplied by the manure in addition to the bacteria stimulates still further bacterial development and is indirectly responsible for greater available plant food production. Probably in many cases the beneficial effect of manure on dark-colored soils, well supplied with organic matter, is due chiefly to the bacterial effects, the stimulation of decomposition and greater plant food production. In general, however, the value of manure should
probably be attributed to a combination of physical, chemical and bacterial effects.

Manure is such a valuable fertilizing material that it is very important that it be properly stored and applied. If it is not carefully stored it may suffer much loss in value. The liquid portion may be washed away and decomposition may reduce the content of valuable plant food. In extreme cases where manure is exposed to the action of the weather and leaching, 75 to 90 percent of the total value of its constituents may be lost. Not only will its immediate effect on soils be reduced, but its effect in prolonging the life of the soil will be cut down to a minimum. If properly stored and applied to the soil, 75 to 80 percent of the plant food contained in the crops used for feed may be returned to the soil where they were grown.

Manure may be stored in a covered yard or a pit or in some other like manner. No definite method of storing can be recommended for use under all conditions, but any method which keeps the manure moist and compact and protected from the weather may prove satisfactory. Any difficulty or expense involved in the proper storing of manure will be well warranted by the greater value of the material when applied to the soil.

In general, the production of manure on the average farm is insufficient to permit of any excessive applications to the soils, and the average amount used is about eight to ten tons per acre once in a four-year rotation. Occasionally this amount may be increased to some extent with additional profit, but it is not generally advisable to apply more than 16 to 20 tons per acre for ordinary farm crops. In market gardening or truck farming much larger applications of manure may be made with profit, but for the soils of Hamilton county the most satisfactory results will generally be secured by the application of normal amounts.

On the livestock farm the amount of manure produced may be sufficient to permit of regular applications to all of the soils of the farm, but in general this is not the case. In grain farming there is only a small production of manure and some other means must be resorted to in order to make up the deficit. Green manuring is the practice which should be employed on the grain farm and as a supplement to farm manuring on the livestock farm. Legumes or non-legumes may be used as green manures, but the former are considered preferable, inasmuch as when thoroly inoculated they are able to utilize the free nitrogen of the atmosphere and thus to increase the supply of that element in the soil. Legumes have a double value as green manure and are a cheap source of nitrogen in comparison with commercial nitrogenous fertilizers. Occasionally non-legumes may be employed instead of legumes, when the organic matter supply is of most importance and nitrogen is secondary, but in general legumes should be employed, as even on the livestock farm it is often necessary to provide some means of maintaining the nitrogen supply.

Many legumes may be used as green manures and, as these may be grown under a wide range of conditions, it is possible to select a legume which will fit in with almost any rotation. It may often be desirable to turn under the second crop of clover and this may be considered as a partial green manuring practice. Clover seed may be removed and the remainder of the crop returned
to the soil, thus giving practically all the effects of a green manure crop. It may be possible under some conditions to seed a legume in the corn at the last cultivation.

Some of the soils of Hamilton county may respond to green manuring, but it should not be practiced carelessly nor blindly, as it may prove distinctly undesirable when carried out under improper conditions. Suggestions regarding the following of this practice in special cases will be given by the Soils Section upon request.

It is very important that all crop residues be returned to the soil, as they provide a valuable means of keeping up the organic matter supply. Too often the straw and stover are burned or otherwise destroyed and their value lost. On the livestock farm they may be utilized for feed or bedding and returned to the soil with the manure. Their use in this way probably brings about the greatest effect because of the greater decomposition of the organic matter which occurs. On the grain farm such materials may be applied directly to the soil, or they may be stored and allowed to decompose partially before application, but it is particularly important in this case that all the residues be returned to the soil, owing to the scarcity of manure as a source of organic matter. Crop residues not only add organic matter to the soil, but also supply plant food, and when they are properly utilized the life of the soil is considerably lengthened.

By the proper use of all crop residues, the application of farm manure and in some instances the use of inoculated legumes as green manures, the soils of Hamilton county may be kept up in content of organic matter and nitrogen, and crop production will not be dependent upon these constituents. In most cases at the present time, applications of manure are distinctly valuable and the addition of small quantities of this material even to soils black in color and apparently well supplied with organic matter, often brings about considerable increases in crop yields.

**LIMING**

The analyses of the soils of Hamilton county show that several of the types are slightly acid in reaction and, where this is true, lime should be applied if the best crop growth is to be secured. The Carrington loam shows acidity in all cases throughout the soil section and the same is true of the Miami silt loam and the Waukesha loam. The Webster loam is sometimes acid in reaction, but not always. The Webster clay loam is practically always basic in reaction and the Clarion loam and the Hanoeck very fine sandy loam always contain lime. It is necessary, therefore, that the soils of the Carrington, Webster, Miami and Waukesha series be tested for acidity, especially if legumes are to be grown.

The actual acidity in any of the soils of the county is not large, but the application of only small amounts of lime to slightly acid soils has been found to be of large value in increasing crop growth. It should be noted that the inorganic carbon content of some of the soils which give a basic reaction, is not large, and even though lime is not needed at present, it will become necessary in the near future.

Farmers may test their own soils for acidity, but it will be much more satisfactory if they will send a small sample to the Soils Section of the Iowa Agri-
cultural Experiment Station and have it tested more accurately free of charge. They may thus apply the exact amount of limestone needed and avoid any excessive application or insufficient amount, either of which is highly undesirable.

Soils which are cropped continually lose their lime content, so that it is necessary to test them at regular intervals to determine their reaction or need of lime. Even if the reaction is basic at present, lime may soon become a limiting factor of growth and it is desirable to test soils at least once in a four-year rotation, preferably just prior to seeding for clover, and thus determine definitely whether the soil conditions are at the best for the growth of that crop. Even after lime has been applied to the soil it is necessary that tests be made at regular intervals in order that the lime content may be kept up.

The actual amount of lime which should be used on any soil must be determined for that particular soil, inasmuch as the lime requirement of soils varies widely even on samples of the same type. The results given in this report should not be considered to show definitely the needs of the individual soil types as they occur in the county, but they should be looked upon merely as indicating the average acidity of the types or the average lime requirement. Farmers should test the soils from the various fields on their farms in order to determine how much lime should be applied to each field. It is not sufficient merely to test the soil from one area. Further information regarding the loss of lime from soil, the need of lime for the best crop growth, the use of lime, and other points connected with liming in general, are given in Bulletin 151 and Circular 58 of the Iowa Agricultural Experiment Station.

**THE USE OF COMMERCIAL FERTILIZERS**

The analyses of the soils of Hamilton county given earlier in this report do not show any extremely large amounts of phosphorus present and it seems quite probable, therefore, that phosphorus fertilizers might be applied to advantage in some cases. Even if they do not prove profitable at the present time, they will undoubtedly be needed in the near future as the phosphorus supply gradually decreases. The greenhouse experiments on two of the most important soil types in the county indicate the possibility of beneficial effects from the use of rock phosphate or acid phosphate on wheat and clover. The field experiments on these same types give indications of influence from these materials on general farm crops. Farmers are urged to test these materials on their own farms and determine which should be used for their particular conditions.

Acid phosphate is more expensive than rock phosphate, but it contains the phosphorus in an available form and may bring about a greater immediate effect. The benefits must be much larger, however, than those secured by the use of rock phosphate if the material is to prove economically more valuable. Simple experiments comparing the use of these materials may be carried out on any farm on a small area. When results are secured on a small scale, then applications may be made to large areas with the assurance of profit. Directions for the carrying out of such tests on the farm are given in Circular 51 and additional advice and information will be supplied by the Soils Section.
upon request. It is very desirable that the farmers of Hamilton county test
the value of phosphorus carriers on their soils.

The nitrogen content of the soils of Hamilton county is not extremely high,
except in one or two instances, and in some cases it is rather low. Any system
of permanent fertility to be of value in this county must, therefore, consider the
addition of nitrogen to the soils. Crop residues and farm manure aid materially
in keeping up the nitrogen, but they merely return a part of that which has
been removed by the crops. Inoculated legumes, when used as green manures,
prove an inexpensive and very satisfactory means of increasing the nitrogen in
the soil. Such materials have a double effect in that they also supply organic
matter. Commercial nitrogenous fertilizers cannot, therefore, be recommended
at the present time as economical. They may prove of value when used in small
amounts as top dressings, by stimulating the early growth of some crops, but
in general they should be used as supplements to leguminous green manures.
It is always advisable in any case to test such materials on a small scale before
any large applications are made.

Analyses of many of the soils of the state have shown the supply of potassium
to be so large that it seems hardly likely that potassium fertilizers would prove
of value on any of the soils of Hamilton county. If the best physical conditions
are maintained in the soil and it is well supplied with organic matter, available
potassium should be produced in a sufficient amount to keep the crops sup-
plied. Potassium fertilizers might be applied with profit as top dressings, but
for the growth of general farm crops it is quite unlikely that they would prove
of value.

The field experiments now under way in the county include the use of a com-
plete commercial fertilizer, but from the results secured in other counties, it
seems probable that phosphorus fertilizers will prove quite as valuable in in-
creasing crop yields as the more expensive complete brands. If nitrogen can
be supplied more cheaply by the use of green manures, and potassium is unnecessary, it would seem that a phosphorus fertilizer would prove more profitable than a complete brand. Farmers may test the value of a complete commercial fertilizer on their own soils while they are testing phosphate materials and, if some particular brand proves profitable under special conditions, it may be used without fear of injury to the soil. The complete brand tested should be chosen from among those recommended by the fertilizer companies for the particular crop and soil conditions. There is no objection to the use of complete commercial fertilizers if they prove profitable, but in interpreting the results of tests on a small scale, care should be taken to determine whether or not the complete brands are more profitable than the phosphate materials. In deciding upon their use, the actual cost of the two materials should be considered. At the present time it seems probable that the phosphate materials will prove of more value on the soils of Hamilton county than any complete brands.

THE ROTATION OF CROPS

Many experiments have shown that the fertility of the soil is very rapidly reduced by the continuous growing of any one crop. It is always advisable, therefore, that some sort of a rotation be practiced on every farm. Not only is the fertility of the soil kept up more readily with a good rotation, but a rotation proves actually more profitable than the continuous growing of any one crop, even if the latter is a "money" crop. Various rotations are in use throughout the state and while no special test of them has been made in Hamilton county, from among those suggested below a choice of one which will prove satisfactory may readily be made. These rotations suggested may be modified as seems desirable, provided that the rotation contains a legume and the most profitable crops. With these points in mind, almost any rotation may be planned which will prove satisfactory for conditions in this county.

1—FOUR OR FIVE-YEAR ROTATION

First year: Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second year: Corn.
Third year: Oats (with clover or with clover and timothy).
Fourth year: Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

2—FOUR-YEAR ROTATION WITH ALFALFA

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

3—THREE-YEAR ROTATION

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

DRIFT SOILS

There are nine drift soils in Hamilton county, altogether covering 350,464 acres or 96.1 percent of the total area of the county.

WEBSTER LOAM (55)

The Webster loam is by far the largest soil type in the county, covering more than one-half the total area, 58 percent. It occurs in extensive areas, the largest developments occurring roughly in three areas running north and south thru the county, the middle area developing into a large area of Webster extending to the western edge of the county. The most typical areas are found southwest of Webster City, west of Randall and in that portion extending from Williams south to Ellsworth.

The surface soil of the Webster loam consists of about 14 inches of black mellow heavy loam underlaid by a black to dark drab clay loam, which at 22 inches passes into gray, drab and greenish-yellow or greenish-drab plastic clay, somewhat mottled. The subsoil is compact and impervious, but below the three-foot level, typical drab and yellow mottled drift material is encountered.

The variations in this soil are largely the result of somewhat varying drainage conditions, which bring about differences in color and texture. Typically, the type is flat and poorly drained, but when the topography is gently undulating and drainage is developed to some extent, the soil becomes lighter colored and coarser than the typical, the subsoil less compact, more greenish-yellow mottled with drab in color, and less gray. Under the latter topographic conditions the subsoil is more like that of the Carrington series and in many instances it is rather difficult to draw a distinct boundary line between the two types.

Typically the Webster loam is flat in topography, but it may be slightly undulating in certain cases. The drainage is naturally poor and the soil is quite generally in need of tiling before it can be made properly productive. The value of draining the soil has been shown in many cases by the results secured on various areas where tiling and ditching have been practiced.

Practically all of the Webster loam is under cultivation, general farm crops being grown. It is probably a little better suited to corn than to oats, but the yields of both are satisfactory, corn yielding 50 bushels per acre and oats 45. Timothy and clover give good yields of hay, averaging 1 1/2 tons per acre. In general it may be said that crops mature a little later on this soil than on the Carrington loam.

Crop yields on this soil are quite satisfactory in favorable seasons, but they may be injured in wet seasons if the soil is not properly drained. The yields may undoubtedly be increased in many cases by the utilization of proper methods of soil treatment. Drainage is a most important consideration and any of this type that is not well drained should be tiled out. Without this preliminary treatment, the crop yields will not be satisfactory and may be very seriously reduced in unfavorable seasons. The soil is well supplied with organic matter, but it will respond to applications of small amounts of manure, par-

*The descriptions of the soil types given in the Bureau of Soils Report have been rather closely followed in this section of the report.
particularly when it is newly drained. It is acid in reaction, at least in the surface soil, and applications of lime in small amounts are needed for the best growth of legumes. Large applications are unnecessary, however, inasmuch as the lower soil layers of the type are fairly well supplied with lime. The soil is not particularly well supplied with phosphorus and it will probably respond to applications of phosphorus fertilizers. It is quite desirable that such materials as rock phosphate and acid phosphate be tested on the Webster loam to determine their relative value and the actual returns which may be secured from the use of phosphorus.

**CARRINGTON LOAM (1)**

The Carrington loam is the second largest soil type in the county, covering 54,464 acres and, together with the steep phase, which covers only 3,520 acres, makes up 15.8 percent of the total area. It occurs in all parts of the county, altho no extensive individual areas are found. It is the chief soil type on the rougher areas of the county along the larger streams. Thus it is found following the course of the Boone river, the Skunk river and the various creeks which enter the county from the southwest, the southeast and the northwest.

The surface soil of the Carrington loam consists of about 15 inches of dark brown to black mellow friable loam, grading into a brownish, more compact clay loam, which in turn passes into a brownish-yellow or greenish-yellow gritty clay loam at 24 inches. The surface soil usually contains some gravel and boulders and the subsoil still larger amounts. Yellow glacial till is encountered below the three-foot section. In the rougher areas the surface soil is slightly lighter in color and the subsoil is also lighter and sandier in texture. In some of the areas the subsoil is quite gravelly. As the type more nearly approaches the Webster in topography, the soil becomes darker and the dark color extends to a greater depth. The subsoil in these flat areas is a greenish-yellow clay. In topography the typical soil is undulating to rolling and drainage is everywhere quite adequate.

Practically all of the Carrington loam is under cultivation, general farm crops being grown. Corn yields 40 to 45 bushels per acre and oats 40 to 45 bushels. It is claimed that corn is not so frequently injured by frost as on the Webster soils and oats have less tendency to lodge. Crops in general seem to mature somewhat earlier than on the Webster loam. Timothy and clover yield one to one and one-half tons per acre. Spring wheat and winter wheat are grown to some extent, yielding 15 bushels per acre on the average. Barley is grown on a few areas, the yields being somewhat less than those of oats.

The Carrington loam is naturally a rather productive soil, but it would be improved by certain methods of soil treatment. Applications of farm manure have proved of great value on this type in increasing crop growth. Where such material is not available in sufficient amounts, green manure crops should be used to increase the organic matter and nitrogen content of the soil. It is recommended that farm manure be applied to this type in as large amounts as practicable, in order to increase crop growth and to maintain the soil at a high state of productivity. The soil is acid in reaction and should be tested and the lime shown to be necessary should be applied. The use of lime is particularly needed where legumes are to be grown. The soil will probably respond
to phosphorus fertilizers in practically all cases, as there are indications from experimental data that rock phosphate or acid phosphate may be used with profit. Just what the returns will be and which material would be preferable must be determined by tests on individual farms. If phosphorus does not prove of value at the present time, it will undoubtedly be needed in the near future.

CARRINGTON LOAM (Steep Phase) (57)

The steep phase of the Carrington loam occupies only a small area in the county, amounting to less than 1 percent of the total area. It is found on the eroded slopes and bluffs along the Boone river and some of its tributaries. The largest development of this type is along Prairie creek.

The surface soil of this phase of the Carrington loam is a black or dark brown friable loam 6 to 12 inches in depth, resting on a yellowish-brown compact clay loam. In many places the surface soil has been entirely removed and the heavy subsoil is exposed. At the lower parts of some of the slopes there are accumulations of the surface material washed from the higher land and the surface soil is rather deep and may be considered colluvial in origin.

Owing to its steep topography this soil is not under cultivation, some of the slopes being so steep that they are of no use agriculturally. Originally the land was forested, but now much of it is in use as pasture. It supports a luxuriant growth of blue grass in most areas. On some of the lower slopes there are small areas which are under cultivation, corn and oats being grown. The soil is best adapted for use as pasture, as in this way erosion is prevented and it is desirable also to retain much of the tree growth to aid in preventing bad washes.

CLARION LOAM (138)

The Clarion loam is the third largest soil type in the county, covering 12 percent of the total area. It occurs in all parts of the county in association with the Carrington loam, the largest individual areas being found southeast of Webster City. There are rather considerable areas in the southwest portions of the county and also in the southeast. It is usually found as an irregular and discontinuous boundary around the larger areas of Carrington loam, occurring on slopes bordering the flatter areas of that type. It does not extend over the steep slopes where erosion has exposed sandy and gravelly drift.

The surface soil of the Clarion loam is a very dark brown to black mellow friable loam to a depth of 12 inches. The upper subsoil is a brown or yellowish-brown clay loam or clay. Below 24 to 30 inches it is yellow in color, becoming gray in the lower depths. The texture is very similar to that of the surface soil. The high lime content of this gray layer is characteristic of the soil type. The surface soil is in general darker in color than the typical Carrington soils. The upper subsoils are very similar in the two series, but the lower subsoil of the Clarion differs from the Carrington because of its gray color and large proportion of lime. Gravel and boulders are found in the surface and throughout the soil section. In topography this soil type is undulating to gently rolling and it has a good natural drainage.

The Clarion loam is practically all under cultivation and the same crops are grown and very much the same yields are secured as in the case of the Carrington loam. The soil will be improved by the treatments suggested in the
ease of the Carrington. Applications of farm manure in considerable amounts will always give profitable returns and when farm manure is not available, leguminous green manures should be used. The surface soil is usually acid in reaction and applications of lime are necessary if legume growth is to be satisfactory. The phosphorus content is not high and applications of phosphorus fertilizers will probably prove of value. These materials will undoubtedly be needed in the near future, even if they do not prove profitable now.

WEBSTER CLAY LOAM (56)

The Webster clay loam is the fourth largest soil type in the county, occupying over 31,000 acres or 8.5 percent of the total area. It occupies low-lying, poorly drained areas and is associated with the Webster, Clarion and Carrington loams. The larger areas were formerly sloughs or lake beds. This was undoubtedly the origin of the areas west of Randall and north of Stanhope, which are the largest individual areas of the type in the county. Smaller areas are found in all parts of the county, occurring in many cases in narrow depressions in the level uplands, following what are known as the intermittent drainage lines. Many areas were found which were too small to show on the map.

The surface soil of the Webster clay loam consists of about 12 inches of a black clay loam, which is rather crumbly and granular in structure to a depth of about 4 inches. Below 12 inches the soil becomes a black fine-grained plastic clay, changing at about 22 inches to a dark drab plastic clay, which grades into a drab or gray heavy clay. The subsoil contains considerable lime in the form of nodules or lime concretions and generally the surface soil is also calcareous. There are some variations from the typical soil occurring in various parts of the county. The depth of the plastic soil may vary from 22 inches to as much as three feet. There are also some areas, too small to map, of a plastic, tenacious clay which is locally called gumbo. In areas which were formerly narrow sloughs in sections of Williams, Liberty and Clear Lake townships, the soil varies somewhat from the typical, in that there is a gravelly layer several feet in thickness which is encountered in the lower part of the three-foot section. Where this variation occurs the drainage of the soil is very satisfactory. In these areas the surface soil is somewhat lighter in texture, approaching a loam.

In topography, the Webster clay loam is flat to depressed and, as typically developed, is poorly drained. Largely due to this lack of drainage the soil has become very high in organic matter, hence, black in color, and, as has been noted, usually shows considerable accumulation of lime.

Formerly this type was used entirely for pasture and wild hay production, but as the areas have been drained general farm crops have been more largely grown. Corn yields very much the same as on the Webster loam, but the crop matures more slowly. The yields of oats are somewhat greater than on the loam, but with many varieties there is danger of lodging. The Iowa 103 and Iowa 105 varieties of oats are particularly desirable on this type, owing to the fact that they do not lodge.

This soil is a very productive one when properly drained, which is the first and most important treatment needed. Care should also be taken in cultivating it, as it has a tendency to puddle and bake. Fall plowing is particularly
desirable and in general it should be said that the soil should never be plowed when it is too wet. Small applications of manure would probably be desirable on newly drained areas of the soil in order to stimulate the decomposition processes. The phosphorus supply, while somewhat higher than in some of the other upland soils, is not very large and phosphorus fertilizers will be needed in the near future. They may prove of value at the present time in individual cases.

MIAMI SILT LOAM (58)

The Miami silt loam is one of the minor upland soils in the county, covering less than 1 percent of the total area, or 2,752 acres. It occurs in several small areas bordering the bluffs and steep slopes of the Boone river, the largest of these being north of Stratford and three miles north of Webster City.

The surface soil of the Miami silt loam consists of about 12 inches of a light brown to gray compact silt loam, which at 20 inches becomes a gray compact silt loam and changes abruptly into a dull brown or brownish-yellow compact clay loam subsoil. The surface soil when dry is rather coarsely granular and usually light gray in color. In some instances the surface two or three inches is rather dark, with a light gray silt immediately beneath it. In topography this soil is level to gently sloping and the drainage is entirely adequate.

Formerly this type was forested, but much of it has been cleared and is now under cultivation, general farm crops being grown. The yields of corn are somewhat lower than on the dark-colored upland soils and this crop may be injured by drouth. Yields of oats and clover are also less on this type. The soil is very low in organic matter and is particularly in need of applications of farm manure or the use of leguminous green manures in order to make it more productive. It is acid in reaction and applications of lime should be made as shown to be necessary by tests. In the lower subsoil below the three-foot depth, there is considerable calcareous material, but this does not affect the need of lime in the surface soil and when the latter is acid, lime should be applied. The phosphorus supply of the soil is very low and phosphorus fertilizers would probably prove of value at the present time. They will undoubtedly be needed in the near future.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor upland type in the county, covering only 1728 acres or 0.5 percent of the total area. It is found only in scattered areas along the Skunk river south of Ellsworth, the largest of these occurring just east and north of Randall.

The surface soil of this type is a dark brown medium sandy loam to fine sandy loam to a depth of 10 inches, below this point becoming a rather light yellow or yellowish-brown fine sandy loam. At 4 to 6 feet below the surface, a loose, pale yellow, incoherent sand is encountered. In topography this type is rolling to rough, occupying ridges or hills, some of which are 50 to 75 feet in height. The type is drouthy, owing to the loose texture of the surface soil and the underlying layer of sand. For satisfactory crop growth on these areas, applications of farm manure would be necessary or the use of leguminous crops as green manures in order to build up the content of organic matter in
the soil. It is acid in reaction and should be limed. It is low in phosphorus and applications of phosphorus fertilizers would undoubtedly be profitable.

**ROGERS SILT LOAM (140)**

The Rogers silt loam is a minor soil type in the county, covering 1408 acres or 0.4 percent of the total area. It occurs only in one area, occupying the basin of what was originally Mud lake, occurring north and west of Jewell.

The surface soil of this type is a gray silt loam, extending to a depth of 18 inches. It is high in organic matter and in soluble salts, which in many places appear on the surface as a white deposit. The subsoil is a gray silt loam containing so much organic matter that it has a spongy constituency. It is also very high in lime and other soluble salts. The material extends to a depth of 8 to 10 feet without any pronounced change in appearance. The area occupied by this type is a wide, hummocky flat and the ground is soft, yielding and spongy. The type has been partly drained by dredged ditches, but the growing of crops has not been successful. Much of the area supports a heavy growth of giant rag weed. This soil could be made to produce satisfactory hay crops or pasture grasses by more thorough drainage, which is the chief treatment needed. If it were cultivated, small applications of farm manure would prove of value and phosphorus fertilizers would be needed eventually.

**CARRINGTON GRAVELLY LOAM (59)**

This is a very minor soil type in the county, covering only 320 acres. It occurs mainly on smoothly rounded hills, although there are some areas on a level prairie south of Stanhope and southeast of Randall along the south county line. There are many areas of this type too small to map separately.

The surface soil of the Carrington gravelly loam is a dark gray to black friable loam to sandy loam 10 inches in depth, underlain by a brown or grayish-brown loose loam or clay loam, which at 22 inches passes into a pale yellow fine sandy loam or sand. Below the three-foot section, yellow sand is encountered. The subsoil is generally high in lime content and the type should probably have been correlated in the Clarion series.

The greater part of this type is used for pasture, inasmuch as cultivated crops are apt to suffer from drought. When cultivated it is particularly in need of organic matter, and should receive liberal applications of manure. Phosphorus fertilizers would also undoubtedly prove of value.

**TERRACE SOILS**

There are two terrace soils in the county, belonging in the Hancock and Waukesha series. Together they cover 6,592 acres or 1.8 percent of the total area.

**HANCOCK VERY FINE SANDY LOAM (139)**

The Hancock very fine sandy loam is a minor soil type in the county, covering 3,456 acres or 0.9 percent of the total area. It occurs on low terraces along the Boone river and is found in narrow strips, none of which are individually of any considerable size. The soil is 20 to 30 feet above the river level.

The surface of the Hancock very fine sandy loam consists of 16 to 18 inches of a black, brown or dark gray mellow very fine sandy loam, underlain by dull brown or gray very fine sandy loam. Generally the color and texture of the
soil changes very little throughout the three-foot section, although occasionally the grayish layer may appear nearer the surface. The type includes small areas of fine sandy loam, and loam, and occasionally the subsoil is gravelly.

Part of this type supports a forest growth, but most of it is under cultivation. Corn is the leading crop grown and yields compare favorably with those on the upland types. Oats are also grown to some extent and produce satisfactory yields. This type could be made more productive by the use of organic matter, either as farm manure or as green manures, and would probably also respond to phosphorus fertilization. Applications of lime are not necessary, as the soil is well supplied with this constituent.

**WAUKESHA LOAM (60)**

This type is about the same in area as the Hancock very fine sandy loam, covering 0.9 percent of the total area of the county. It is found on narrow terraces bordering the Boone river. The largest areas are found in the vicinity of Webster City and north to the county line.

The surface soil of the Waukesha loam is a dark brown to black friable crumbly loam, extending to a depth of 12 inches. Below this point it becomes somewhat lighter in color and coarser in texture. The subsoil material contains some gravel and is a light brown in color. In topography this soil is level to gently undulating and the natural drainage is quite adequate. Practically all of it is under cultivation and general farm crops produce satisfactory yields in favorable seasons. The soil is generally acid in reaction and should receive applications of lime when needed in order to permit of the best growth of legumes. The use of farm manure will increase crop growth and the application of phosphorus fertilizers will also undoubtedly prove of value.

**SWAMP AND BOTTOMLAND SOILS**

There are four areas of swamp and bottomland soils in the county, together covering 7,744 acres or 2.1 percent of the total area.

**WABASH LOAM (49)**

The Wabash loam is the largest bottomland soil, covering 4,480 acres or 1.2 percent of the total area of the county. It occurs in the bottomlands along the Skunk river, Squaw creek, and along some of the small creeks tributary to the Boone river. The largest area is found southeast of Jewell.

The surface soil of the Wabash loam consists of a black fine-textured loam to a depth of 10 inches, underlaid by a black heavy crumbly loam. Below 20 inches a black to dark drab stiff heavy silty clay is encountered which extends to a depth of 6 feet. South of Jewell the soil is gray or ashy gray and sometimes quite heavy and the texture also varies in other locations, being sometimes a silt loam and sometimes a sandy loam.

This soil is used almost entirely for pasture and hay production. Much of it in its native state is forested. When drained some areas might be utilized for cultivated crops, although the type is all subject to overflow. It is not high in organic matter and if cultivated should receive liberal applications of manure. It should be tested for acidity and when acid, lime should be applied. It would probably also respond to phosphorus fertilization.
There are several areas of peat scattered throughout the county, varying in size from one acre to a square mile or more, the total area amounting to 2,112 acres or 0.6 percent of the total area of the county. The largest area is found on what was originally Iowa lake.

Peat consists of brown to black partly decomposed vegetable matter. It is loose, porous and spongy in character and in the smaller areas extends to a depth of 6 to 20 inches. In some of the larger bodies it may be 4 to 6 feet in thickness. The subsoil is a black or drab plastic silty clay. It is high in lime content.

The first treatment needed to make peat soils productive is drainage and when this is accomplished it is preferable to seed to timothy and alsike clover, which may be utilized for hay or pasture for several years. This will permit of the decomposition of the peat and later corn and small grains may be produced. These crops will not produce satisfactory yields on newly reclaimed peat. Vegetable crops may sometimes be grown satisfactorily on drained peat areas. General suggestions regarding the handling of peat soils have been given in a previous section of this report.

Small areas of muck are found in all parts of the county, the total area amounting to 768 acres. There are no large areas of this material.

Muck consists of organic matter which has been partly decayed and is derived from peat. It consists of a loose black fluffy mass of well-decomposed vegetable material. It varies in depth from 6 to 20 inches and rests upon a plastic black clay, which in the lower part of the three-foot section changes to a drab plastic clay. Drainage is the chief treatment needed for making muck soils productive.
and when this is accomplished, the soil may be used satisfactorily for pasture or hay crops. Vegetable crops may also be grown on these areas profitably. The general treatments recommended for peat soils apply very largely to muck.

MEADOW (20)

There is a small area of meadow in the county, amounting to 384 acres. It is mapped along the Boone river in small areas of non-agricultural land consisting of sand bars, sand banks and riverwash. The material is composed of brown and gray loose incoherent sand. In some places there may be layers of clay or silty material and occasionally there is a surface deposit of silty material. These areas are extremely variable and are non-agricultural.
APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions

Fig. 9. Map of Iowa showing the counties surveyed
signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

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

**PLANT FOOD IN SOILS**

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

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

Knowledge of the nitrogen content of soils is important in showing whether sufficient green 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 or in soils, and then a fertilizing material containing the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium is frequently lacking in 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 alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

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

**AVAILABLE AND UNAVAILABLE PLANT FOOD**

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

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be unavailable. Plants cannot take up food unless it is in solution; hence available plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble are unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.
Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td>Nitrog'n</td>
<td>Phos'phorus</td>
<td>Potass'm</td>
</tr>
<tr>
<td></td>
<td>16c</td>
<td>12c</td>
<td>6c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
</tr>
<tr>
<td>Corn, crop</td>
<td>……</td>
<td>111</td>
<td>17.25</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>……</td>
<td>57.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>12.5 T.</td>
<td>15.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Oats, crop</td>
<td>……</td>
<td>48.5</td>
<td>8</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Barley, crop</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>25.4</td>
<td>6</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>……</td>
<td>41.4</td>
<td>9</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
</tr>
</tbody>
</table>

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.

*Bulletin 150, Iowa Agricultural Experiment Station.
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 soil production, largely because they help to control the moisture in the soil.

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought by thorough cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be 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 through proper drainage, and one of the most important farming operations is the laying of drainage 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, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

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

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

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

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

**THE USE OF PHOSPHORUS**

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

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

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

LIMING

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

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:

Organic matter
- All partially destroyed or undecomposed vegetable and animal material.

Stones—over 32 mm.*
Gravel—32—2.0 mm.
Very coarse sand—2.0—1.0 mm.
Coarse sand—1.0—0.5 mm.
Medium sand—0.5—0.25 mm.
Fine sand—0.25—0.10 mm.
Very fine sand—0.10—0.05 mm.
Silt—0.05—0.00 mm.

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 percent or more of organic matter, sometimes mixed with more or less sand or soil.

**Peaty Loams**—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

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

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

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

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

**Silt Loams**—20 percent clay and more than 50 percent silt mixed with some sand.

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

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

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

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

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

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

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

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

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*25 mm. equals 1 in.  †Bureau of Soils Field Book.  ‡Loc. cit.