Soil Survey of Iowa, Report No. 22—Palo Alto County

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SOIL SURVEY OF IOWA
PALO ALTO COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 22
June, 1922
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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3 Muscatine County.

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5 Lee County.

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7 Van Buren County.

8 Clinton County.

9 Scott County.

10 Ringgold County.

11 Mitchell County.

12 Clay County.

13 Montgomery County.

14 Black Hawk County.

15 Henry County.

16 Buena Vista County.

17 Linn County.

18 Wapello County.

19 Wayne County.

20 Hamilton County.

21 Louisa County.

22 Palo Alto County.
These bottomland soils are in the Cass series.
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Palo Alto county is located in the second tier of counties from the Minnesota state line and in the fourth tier east of the Nebraska state line. It is entirely within the Wisconsin drift soil area and its soils are therefore all derived from this material, either in its original location on the uplands or as it has been carried by the streams and reworked and deposited on the terraces and bottomlands.

Palo Alto county has an area of 561 square miles or 359,040 acres. Of this area 326,821 acres, or 91.0 percent, is in farm land. The total number of farms is 1,743 with an average size of 187 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

- Acreage in general farm crops: 268,799
- Acreage in pasture: 66,070
- Acreage in farm buildings, feed lots and public highways: 17,336
- Acreage in waste land: 3,562
- Acreage in crops not otherwise listed: 194

The type of agriculture practiced in Palo Alto county at present is very largely general farming, with some raising and feeding of hogs and beef cattle and some dairying. The income of the county is derived partly from the sale of corn and oats and partly from the sale of hogs, beef cattle and dairy products. The livestock industry and the dairy industry are gradually becoming more important and the amount of corn and oats sold out of the county is decreasing as these crops are more largely fed. At present a large part of the corn crop and probably two-thirds of the oats crop are used for feed on the farms.

There is a considerable area of waste land in the county and it is very important that some method of treatment be adopted which will permit of the reclamation of these areas. General recommendations for the treatment of such soils cannot be given because the causes of infertility are various, and treatments needed in one case would be of little or no value in other instances. Special treatments which will prove valuable under individual soil conditions will be mentioned later in this report. Advice regarding treatments most desirable in special cases may be obtained from the Soils Section of the Agricultural Experiment Station upon request.

The general farm crops grown in Palo Alto county in the order of their importance are corn, oats, hay, potatoes, barley, wheat, alfalfa, and rye. The average yield and value of these crops in 1920 are given in table I.

Corn is by far the most important crop, both in acreage and value. It is grown in all parts of the county and average yields of 45 bushels per acre are secured. This yield is considerably higher than the average for the state and apparently the soil conditions are quite satisfactory for the growth of this crop. A large part of the corn produced in the county is fed to cattle, hogs and work stock on the farms. Some is utilized for ensilage and the remainder is either

*See Soil Survey of Palo Alto County by A. M. O'Neal, Jr., of the United States Department of Agriculture, and F. M. Russell, C. E. Watts and G. H. Arlis of the Iowa Agricultural Experiment Station.
TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN PALO ALTO COUNTY, IOWA.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percentage 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>140,000</td>
<td>42.8</td>
<td>45.0</td>
<td>6,300,000</td>
<td>$0.47</td>
<td>$2,961,000</td>
</tr>
<tr>
<td>Oats</td>
<td>89,300</td>
<td>27.3</td>
<td>43.0</td>
<td>3,839,900</td>
<td>$0.36</td>
<td>1,382,364</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>0</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>840</td>
<td>0.2</td>
<td>13.0</td>
<td>10,900</td>
<td>1.35</td>
<td>14,715</td>
</tr>
<tr>
<td>Barley</td>
<td>1,370</td>
<td>0.4</td>
<td>27.0</td>
<td>36,990</td>
<td>0.63</td>
<td>23,303</td>
</tr>
<tr>
<td>Rye</td>
<td>430</td>
<td>0.1</td>
<td>19.0</td>
<td>8,170</td>
<td>1.17</td>
<td>9,558</td>
</tr>
<tr>
<td>Hay (tame)</td>
<td>17,325</td>
<td>5.3</td>
<td>1.2</td>
<td>20,790</td>
<td>16.24</td>
<td>337,143</td>
</tr>
<tr>
<td>Hay (wild)</td>
<td>18,760</td>
<td>5.7</td>
<td>1.1</td>
<td>20,636</td>
<td>12.89</td>
<td>261,870</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>180</td>
<td>0.05</td>
<td>3.5</td>
<td>630</td>
<td>19.23</td>
<td>12,014</td>
</tr>
<tr>
<td>Potatoes</td>
<td>594</td>
<td>0.1</td>
<td>119.0</td>
<td>70,686</td>
<td>1.22</td>
<td>86,236</td>
</tr>
<tr>
<td>Pasture</td>
<td>66,070</td>
<td>20.2</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
</tr>
</tbody>
</table>

sold to local elevators for shipment to outside markets or is shipped direct by the grower. Chicago is the principal market.

Oats is the second crop in the county in acreage and in value. It is grown on practically every farm and average yields of 43 bushels per acre are secured. Most of the oats produced is fed on the farms, the remainder, probably amounting to about one-third of the crop, being sold to elevators and shipped to outside markets.

Rather a considerable area in the county is devoted to hay and the value of the tame hay and the wild hay produced is considerable. Wild hay is produced on a somewhat larger area than the tame varieties, nearly all the river bottomland and the poorly drained areas along the streams being devoted to this crop. Practically all of the wild hay crop is baled and shipped. The tame hay consists either of clover and timothy mixed or of timothy alone, and average yields of 1.2 tons per acre are secured. Some clover is grown alone, in which case it is usually seeded with oats as a nurse crop. The general practice followed in handling clover or clover and timothy mixed is to utilize it to some extent for pasture the same year the grain crop is harvested. The next year the clover is cut twice for hay. A few farmers make only one cutting and turn the second crop under as a green manure. This practice is very desirable for improving the soil condition. Where timothy is grown the land usually remains in hay for several years. Practically all of the tame hay produced on the farms is used in feeding the work stock and beef cattle.

Potatoes are grown to some extent and rank fourth in crop value in the county. Average yields of 119 bushels per acre are secured and in 1920 the total production amounted to over 70,000 bushels. Small areas are devoted to this crop on practically every farm and the entire production is utilized for home use or sold at local markets.

Barley is grown on a number of farms in the county and the total value of this crop is considerable. Most of it is used for feeding hogs, altho a small portion is sold at the local elevators. Average yields of 27 bushels per acre are secured.

Spring wheat is grown on a small area and average yields of 13 bushels per acre are obtained. It is all sold and shipped to Chicago.

Alfalfa is grown on a small acreage in an experimental way and very satisfactory yields are secured. The value of this crop is considerable and it will
undoubtedly be grown much more extensively after its desirability is more widely recognized. With proper care in preparing the soil, liming, inoculating and selecting the seed, there should be no difficulty in securing a satisfactory growth under the conditions in this county.

Rye is grown on a small area in the county and is relatively unimportant. Flax is produced to some extent, being planted on sod ground and generally utilized the first year on reclaimed swamp and bottomland. All of the flax seed produced is shipped out of the county, chiefly to Minneapolis. A small area is devoted to popcorn, but most of this product is used locally. Sweet corn, millet, sorghum and sugar beets are crops of minor importance in the county.

Apple orchards are maintained on most farms but yields are not very satisfactory. Apparently little care has been taken of the apple trees. Strawberries and all kinds of garden crops are grown throughout the county and help to supply the home demand.

THE LIVESTOCK INDUSTRY IN PALO ALTO

The livestock industry of the county includes the raising and feeding of hogs and beef cattle, and dairying. A few sheep are kept, but this is not an important industry. The poultry industry has developed to some extent and there is a rather considerable income from the sale of poultry and eggs.

The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the character and extent of the livestock industry in Palo Alto county:

| Horses, all ages | 11,008 |
| Mules, all ages | 467 |
| Swine on farms July 1, 1920 | 60,479 |
| Swine on farms, Jan. 1, 1921 | 48,038 |
| Cattle (cows and heifers kept for milk) | 10,389 |
| Cattle (other cattle not kept for milk) | 19,888 |
| Cattle (all ages) | 30,277 |
| Sheep (all ages on farms Jan. 1, 1921) | 3,945 |
| Sheep (shipped in for feeding, 1920) | 1,446 |
| Sheep (total pounds of wool clipped) | 15,052 |
| Poultry (total number on farms Jan. 1, 1921) | 211,480 |
| Poultry (number dozen eggs received 1920) | 666,323 |

Hogs are raised on practically every farm and this is the principal livestock industry in the county. The number of hogs per farm varies from 60 to 100 head. There are a few breeders of purebred stock, as well as a few who raise and feed hogs on an extensive scale. The most popular breeds are the Duroc Jersey, Chester White, Poland China and Hampshire. The home and local markets are supplied by the hogs raised in the county and there is a large sale either by the growers or by the buyers to the Chicago markets.

Dairying is a rather important industry in the county and in 1920 there were 8 cooperative creameries. The income from the sale of dairy products, exclusive of home use, was estimated in 1920 at almost half a million dollars. Dairy herds usually contain from 6 to 20 cows. The Holstein and Jersey cattle are preferred, although grades of these are the most common. Many of the farms are equipped with silos.

On a number of the farms small herds of beef cattle are maintained and a few animals are fattened each year for the market. Some feeders are shipped into the county from Omaha and Sioux City, fed a few months and then shipped
to Chicago. Favorite breeds of beef cattle on the farms are Shorthorns and Aberdeen Angus.

At the present time there are only a few flocks of sheep in the county. Some western sheep are bought and turned into the corn fields to forage until cold weather and are then sold and shipped. Poultry products are providing considerable income on the farms. A few horses and mules are raised, largely for supplying the home demand.

**LAND VALUES**

The value of land in Palo Alto county is extremely variable, depending upon many factors, such as location, drainage, topography and the improvements on the farms. The average value of farm land in 1920 was about $200 per acre. Along the river where the drainage is poor, the price ranges from $75 to $125, while in other sections where the land is improved, the value ranges from $175 to $200. Well improved farms located near the principal towns are valued at $250 per acre. More recently prices of improved farm land have gone even higher.

**DRAINAGE IS NEEDED ON MANY FARMS**

Crop yields in Palo Alto county are in general fairly satisfactory, but in many cases larger crops would be secured if better methods of soil treatment were practiced. There are many cases where drainage is unsatisfactory and satisfactory crop yields are impossible. The first treatment needed to bring many of the soils of the county up to a high state of production is tiling and ditching. Many farmers have reclaimed considerable areas by straightening and deepening the channels of various creeks, by cutting ditches and by laying tile lines. The county has aided in this work by straightening and deepening the channels of the river. There is still much land, however, which is not being utilized for the growing of general farm crops owing to its lack of adequate drainage. The expense involved in draining these areas is frequently considerable, but the value of the crops produced after such land is drained more than makes up for the outlay.

A few of the soils of the county are acid and in need of lime, but many of them are well supplied with lime and in some cases so well supplied that there should be no need of applying this material for many years to come.

**PALO ALTO SOILS ARE GENERALLY FERTILE**

The soils of the county are quite generally high in organic matter and high in nitrogen and there is not the great need for applications of manure that is evident in so many parts of the state. Small applications of farm manure, however, would be of value on newly drained reclaimed land in order to stimulate available plant food production. Large applications of this material are not needed on most of the soils of the county. Care should be taken, however, to keep up the supply of organic matter in the soils and when they are brought under cultivation the utilization of farm manure in small amounts at regular intervals is a very necessary practice.

**PHOSPHORUS CONTENT OF SOILS IS NOT HIGH**

The phosphorus content of the soils of the county is not high in any case and neither is it extremely low. There is a possibility, therefore, that phosphorus
fertilizers may prove of value in some cases at the present time. At all events, these materials will be needed in the near future, especially as the crop production on the soils is increased. Tests on individual farms with the use of rock phosphate or acid phosphate are recommended at the present time, and if either of these materials show profitable crop increases, then that material may be applied to large areas on the farm with the assurance of profit. It may be that acid phosphate will prove more profitable on newly reclaimed land and later when decomposition processes are more vigorous, owing to better physical soil conditions, rock phosphate may give more profitable returns. This is a question which can only be settled by special tests. Field experiments now under way in the county include tests of these materials and when the results of these tests become available it is hoped that the solution of the problem will be provided. The indications from the greenhouse experiments and from the field tests in other counties on the same soil types point very strongly to the need of phosphorus fertilization for the best growth of general farm crops.

Complete commercial fertilizers are probably unnecessary on the soils of the county at the present time but field tests may include the use of these materials and they may show value in some cases. When the returns secured from their use are sufficient to warrant the expense involved in their purchase, there can be no objection to the use of complete commercial fertilizers. It should be emphasized, however, that such materials should always be compared with phosphorus fertilizers if satisfactory economic comparisons are to be made.

THE GEOLOGY OF PALO ALTO COUNTY

The rock formations underlying the soils of Palo Alto county are so deeply buried under the subsequent deposits of drift that they exert no influence whatever upon the soils of the county and need not be considered.

At least twice during the glacial age great ice sheets swept over the county and upon their retreat vast deposits of glacial drift or till were left behind. The earlier glaciation, known as the Kansan, covered the entire surface of the land, burying the original bed rock and the covering of pre-Kansan sand and gravel found occurring infrequently over the surface. The surface of this drift deposit was considerably modified by the time the later glacier, the Wisconsin, appeared. The Kansan drift deposit is extremely variable in depth ranging from 1 to 300 feet and this variation in depth is probably due to the varying erosive action which occurred during the centuries which elapsed after the deposition and before the invasion by the Wisconsin glacier. The Kansan drift material is generally known as blue clay, indicating the characteristic color and texture of the unweathered material. It is extremely tough and impervious and is made up of a fine-grained compact clay containing some sand, pebbles and boulders of various sizes and shapes. When weathered the color of the drift changes to a yellow or reddish-yellow. The older deposits of sand and gravel which are occasionally found beneath the blue clay are known as the Buchanan gravels and they extend for a depth of 20 feet.

Above the Kansan blue clay there appear layers of sand and gravel which are known as the Wisconsin gravels. These were deposited during the retreat of the Wisconsin glacier, particularly in the old valleys and drainage channels,
and may now appear at a considerable distance from the present drainage system, in isolated mounds on the sides of hills or in low ridges on level plains. These gravel deposits have been covered by the heavier material of the typical Wisconsin drift and while they occasionally are sufficiently near the surface to influence the character of the soil, in general the covering of the Wisconsin drift deposit is so deep that the gravels are not encountered in the three foot section.

The Wisconsin glacier descending from the northwest covered the entire area of the county and left behind a deposit which at the present time varies from a few inches to 80 feet or more in thickness. On the tops of hills, where erosion has occurred, the drift deposit is quite thin, while in the more level portions of the county the deposit extends for many feet.

The Wisconsin drift is a mixture of boulders, sand, silt and clay. A few large limestone boulders are found, but the principal part of the limestone occurs in a finely divided state. Surface boulders, sometimes 3 to 4 feet in diameter, are found on the lower gentle slopes and through the flatter areas. During the time which has elapsed since its deposition, much of the lime content, and in many cases practically all, has been leached out of the soil. The surface soils of the county are frequently acid, but in most instances lime is found in considerable amounts in the lower soil layers.

The original drift material was yellowish or buff colored and even occasionally whitish in color. During the ages which have elapsed since the glacier retreated, there has been an accumulation of organic material in the surface soil and under the characteristic topographic conditions in the county, this accumulation has been particularly rapid and the burning out of organic matter and leaching have been slow. The surface soils, and in many cases the subsurface soils of the county are dark brown or even deep black in color. The lower layer or subsoil is usually the typical grayish or yellowish color of the original Wisconsin drift. In the western part of the county, the topographic conditions give evidence of being the location of the terminal moraine of the glacier. There is no distinct indication of this moraine as far as the soil types are concerned, but the topography is distinctly morainic. It is in this part of the county that the Wisconsin drift deposit is of the greatest depth. Many of the hills are made up entirely of Wisconsin drift, the deposit extending for many feet below the base of these hills. The upland soils of the county are derived entirely from the Wisconsin drift and they are classed in the Clarion and Webster series.

PHYSIOGRAPHY AND DRAINAGE

In topography Palo Alto county is generally gently undulating to rolling, ft consists of a broad drift covered plain whose surface has been only slightly modified through erosion because of a rather indefinite drainage system.

In the four northeastern townships and in the southeastern townships lying to the east of the West Fork Des Moines river, the topography ranges from gently undulating to rolling and there are low hills rising from the broad flat plains of the Webster upland.

West of the river the topography becomes more rolling and in the extreme western part of the county the surface is more or less irregular and is made up of a succession of hills and depressions. In the northwestern part of the county,
along the Emmet county line, the topography becomes rough and broken and many of the hills rise to a height of 50 to 100 feet. Here, too, the slopes are steeper and the hills more sharply defined than in the remainder of the morainic area. Similar rather rough areas are found in the southeastern section of Highland township, in the northeastern sections of Silver Lake township, and in the southwestern sections of Walnut township. In these rougher areas, indicating what is known as the morainic topography, there are areas of a gravelly subsoil phase of the Clarion loam, a type which may be considered to indicate morainic conditions.

Narrow strips of rough broken land extend on both sides of the West Fork of the Des Moines river and Jack creek in the vicinity of Graettinger. In these areas also the soil type is the gravelly subsoil phase of the Clarion loam.

The more or less undulating to rolling topography which is characteristic of the county in general is broken by the broad first bottoms and narrower second bottoms developed along the West Fork Des Moines river and the larger creeks, and by the narrower bottoms which are found along the smaller streams and...
intermittent drainage-ways. There are also many undrained depressions in the level upland where peat has accumulated. Practically all of these were probably originally lakes and ponds. At the present time many of them have been drained and the land is slowly being brought into a condition suitable for cultivation. Many of the peat areas may still be considered ponds, particularly under abnormal seasonal conditions. In the western part of the county four lakes of considerable size remain, and extending north from Emmetsburg there is a large lake known as Medium lake. Lost Island lake is the largest lake in the county and Silver lake, Rush lake and Virgin lake are smaller than the two already mentioned.

The drainage of the county is carried mainly by the West Fork Des Moines river which flows in a southeasterly direction across the county. A small area in the northwest corner of the county is drained to the west into the Little Sioux river. The main tributaries of the West Fork Des Moines river are Jack creek, Cylinder creek, Prairie creek, Beaver creek, Pilot creek and Silver creek. The first three of these drain the area east of the river and the remaining three drain the southwestern portion of the county, Pilot creek and Beaver creek joining the river in Pocahontas county to the south.

The flood plain of the West Fork Des Moines river lies from 50 to 100 feet below the uplands. Near Graettinger there are sharp river bluffs, but throughout the remainder of its course across the county, the river has banks which are characterized by an even gentle slope. It varies in width from 30 to 80 feet and meanders back and forth through the bottoms, making new channels from year to year. The drainage system of the county is quite inadequate, as will be evidenced from an examination of the drainage map. Considerable areas are not connected by natural drainage channels with the river and there are many depressions and low pond areas which do not have any natural outlets.

Fig. 2. Clarion loam topography near Ruthven.
Drainage conditions have been considerably improved in recent years by straightening and deepening the channels of some of the creeks, by cutting ditches and by the installation of tile. Many farms have been thoroughly tiled and drained, but there are still considerable areas in which drainage is very necessary if satisfactory crops are to be grown. An examination of the soil map will indicate the spotted conditions of the uplands and in many cases these small areas scattered over the surface of the land indicate poor drainage. This is particularly true in the north central portion of the county where the Webster silty clay loam is found in small scattered areas throughout the Webster loam upland. The same condition is evidenced in the western part of the county where there are many small areas of peat, Webster silty clay loam, and Lamoure silty clay loam scattered throughout the Clarion loam upland. Drainage is undoubtedly one of the most important treatments necessary for the development of a higher state of fertility and greater crop production for the soils of this county.

SOILS OF PALO ALTO COUNTY

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

Drift soils are those deposited by glaciers upon their retreat and they contain material from various sources and usually pebbles and boulders.

Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams by which they were formed or by a deepening of the river channels.

Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The total acreage and percent of the area of the county included in each of these three groups of soils are shown in table II.

Almost three-fourths of the total area of the county, 70.6 percent, is covered by the drift soils. The terrace soils are found only in small areas and make up only 3.3 percent of the total area of the county. The remainder of the county, 26.1 percent, is covered by swamp and bottomland.

There are 12 individual soil types in the county and these together with the gravelly subsoil phase of the Clarion loam and the areas of peat and muck make up a total of 14 separate soil areas. There are seven drift soils, including the phase of the Clarion loam, two terrace types and five areas of swamp and bottomland, including peat and muck. These various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The names which are given to the various types indicate

<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>253,760</td>
<td>70.6</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>12,032</td>
<td>3.3</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>93,248</td>
<td>26.1</td>
</tr>
<tr>
<td></td>
<td>359,040</td>
<td></td>
</tr>
</tbody>
</table>

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN PALO ALTO COUNTY.
quite definitely certain group characteristics. The areas of the various soil types in the county are shown in table III.

The Clarion loam is the largest individual soil type in the county and together with the gravelly subsoil phase it covers 37.7 percent of the total area. The Webster loam is almost as extensive at the Clarion loam, covering 28.0 percent of the total area of the county. These two soil types compose about two-thirds of the area of the county and are therefore the most important.

The Webster silt loam is likewise small in extent, covering only 1.7 percent of the total area. The Clarion fine sand, the Rogers silt loam and the Clarion fine sandy loam are all very small in area, covering 0.2, 0.1, 0.1 percent of the county, respectively. The terrace soils are both minor in extent, the O’Neill fine sandy loam covering 1.7 percent of the total area and the O’Neill loam 1.6 percent of the county.

The Lamoure silt loam is the most extensive bottomland type and is the third largest soil type in the county, covering 14.4 percent of the total area. The Wabash silt loam, the second largest bottomland soil, is very much smaller in area, covering 3.8 percent of the county. The Cass loam is slightly smaller than the Wabash silt loam, covering 3.6 percent of the county.

There are numerous small areas of peat and muck and the total area of these materials in the county amounts to 2.8 per cent.

The Cass silt loam is the smallest bottomland type and it is of minor importance, covering only 1.5 percent of the total area of the county.

The upland soils of the county are generally somewhat undulating to rolling in topography. This is particularly true in the eastern and southern part of the county. West of the river, however, and particularly in the northwestern part of the county, the topography becomes more distinctly rolling and in some cases even somewhat rough and broken. The Webster soils are quite generally level to gently undulating in topography while the Clarion loam varies from an undulating to a strongly rolling topography. This is the upland type which is

<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>138</td>
<td>Clarion loam</td>
<td>132,992</td>
<td>37.7</td>
</tr>
<tr>
<td>147</td>
<td>Clarion loam (gravelly subsoil phase)</td>
<td>2,624</td>
<td>0.7</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>100,592</td>
<td>28.0</td>
</tr>
<tr>
<td>107</td>
<td>Webster silt loam</td>
<td>9,984</td>
<td>2.8</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>6,272</td>
<td>1.7</td>
</tr>
<tr>
<td>148</td>
<td>Clarion fine sand</td>
<td>570</td>
<td>0.2</td>
</tr>
<tr>
<td>149</td>
<td>Rogers silt loam</td>
<td>512</td>
<td>0.2</td>
</tr>
<tr>
<td>149</td>
<td>Clarion fine sandy loam</td>
<td>448</td>
<td>0.1</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>110</td>
<td>O’Neill fine sandy loam</td>
<td>6,144</td>
<td>1.7</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>5,888</td>
<td>1.6</td>
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</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>111</td>
<td>Lamoure silt loam</td>
<td>51,648</td>
<td>14.4</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silt loam</td>
<td>13,632</td>
<td>3.8</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>12,736</td>
<td>3.6</td>
</tr>
<tr>
<td>21</td>
<td>Peat and muck</td>
<td>9,920</td>
<td>2.8</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>5,312</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>359,040</td>
<td></td>
</tr>
</tbody>
</table>
found in the more hilly section in the northwestern part of the county. Particularly in areas where the gravelly subsoil phase of the Clarion loam occurs, the topographic condition becomes strongly rolling to rough and broken. The topography of the Clarion fine sand is gently rolling while the Clarion fine sandy loam occurs on low ridges and hills. The terrace and bottomland types are all level to flat in topography.

The terrace types of the O’Neill series are very adequately drained, due of course to the sandy character of the subsoil. The upland types of the Webster series, particularly the silty clay loam, are in need of drainage and some portions of the silt loam, the loam, and the Clarion loam are likewise in need of drainage. The lighter textured upland types are quite satisfactorily drained. The bottomland soils of the Wabash and Lamoure series are in need of drainage. The Cass loam and the Cass silt loam also are often in need of drainage, even tho the subsoil is sandy, owing to the mucky character of the surface soils. All the bottomland types are, of course, subject to overflow and hence the drainage problem with these soils is particularly important. Besides adequate drainage of the bottomland types they should also be protected from overflow if good crops are to be grown.

The topographic conditions in the county, both in connection with the upland types and with the bottomlands, give evidence of the need of artificial drainage over considerable areas. The installation of tile and in some cases the use of ditches is very necessary if the soils of the county are to be made properly productive.

THE FERTILITY IN PALO ALTO COUNTY SOILS

Samples were taken for analyses from each of the soil types in Palo Alto county, with the exception of the Clarion fine sandy loam and the gravelly subsoil phase of the Clarion loam. The areas of peat and muck likewise were not sampled. The more extensive types were sampled in triplicate, while in the case of the minor types only one sample was taken.

All the samples were drawn so that they should be thoroly representative of the particular soil types and that all variations due to local conditions or special treatments should be eliminated. The samples were drawn at three depths, 0” to 6 2/3”, 6 2/3” to 20”, and 20” to 40”, representing the surface soil, subsurface soil and subsoil, respectively.

Analyses were made on all samples for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were employed in the determinations of phosphorus, nitrogen and carbon, and the limestone requirement was determined by the Veitch method. The figures given in the tables are the average of the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated in pounds per acre on the basis of 2,000,000 pounds of surface soil per acre.
TABLE IV. PLANT FOOD IN PALO ALTO COUNTY, IOWA, SOILS.

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam ................</td>
<td>1,589</td>
<td>2,186</td>
<td>57,600</td>
<td>345</td>
<td>Basic</td>
</tr>
<tr>
<td>107</td>
<td>Webster loam ................</td>
<td>1,589</td>
<td>2,186</td>
<td>57,600</td>
<td>345</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam ..........</td>
<td>1,589</td>
<td>2,186</td>
<td>57,600</td>
<td>345</td>
<td>Basic</td>
</tr>
<tr>
<td>148</td>
<td>Clarion fine sand ..........</td>
<td>1,589</td>
<td>2,186</td>
<td>57,600</td>
<td>345</td>
<td>Basic</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam ..........</td>
<td>1,589</td>
<td>2,186</td>
<td>57,600</td>
<td>345</td>
<td>Basic</td>
</tr>
<tr>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam ..</td>
<td>1,690</td>
<td>5,506</td>
<td>66,800</td>
<td>0</td>
<td>3,091</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam ...............</td>
<td>1,784</td>
<td>4,876</td>
<td>63,000</td>
<td>0</td>
<td>4,250</td>
</tr>
<tr>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam ..</td>
<td>1,566</td>
<td>10,018</td>
<td>117,808</td>
<td>16,992</td>
<td>Basic</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay ..........</td>
<td>2,478</td>
<td>7,930</td>
<td>97,168</td>
<td>432</td>
<td>Basic</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam ..................</td>
<td>1,516</td>
<td>7,902</td>
<td>98,400</td>
<td>0</td>
<td>386</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam ............</td>
<td>1,737</td>
<td>12,132</td>
<td>142,756</td>
<td>844</td>
<td>Basic</td>
</tr>
</tbody>
</table>

The phosphorus supply in the various soil types in the county is remarkably uniform. There is a range in content from 1,589 to 2,478 pounds per acre. There is evidently no large occurrence of this element in any of the soils of the county but the supply is considerably larger than is the case in many of the lighter textured soils in other counties. Even in the Clarion fine sand, the type containing the least amount of any, the supply is only slightly less than in the Webster silty clay loam, which is ordinarily particularly well supplied with this element.

There is absolutely no relation between the phosphorus content of the soils and the various groups of soils. The terrace types are apparently about as well supplied as the bottomlands and the upland soils will average very much the same. Furthermore, there is very little opportunity to draw any conclusions regarding the relation of soil type to phosphorus supply. The Clarion and Webster soils of the upland are very similarly supplied with this constituent. The Clarion fine sand is somewhat lower than the loam. The Webster loam is somewhat lower than the silt loam. The O'Neill fine sandy loam shows less phosphorus than the loam and the Cass loam is lower in this constituent than the silt loam.

The differences in all these cases, however, are very small and, in fact, they hardly warrant conclusions except in so far as they verify evidence obtained in other counties to the effect that light textured types are usually lower in phosphorus than the heavier textured types of the same series.

In some cases there may be an exception to this general rule and such an exception appears in the results in table IV. The Webster silty clay loam shows a smaller amount of phosphorus than the Webster silt loam, which is contrary to what would usually be expected. However, the Webster silt loam in this county, according to these analyses, is a particularly rich type. It is extremely high in organic matter and nitrogen and this may explain, in part at least, the higher phosphorus content. Perhaps there is more organic phosphorus in this type. The Rogers silt loam shows the highest phosphorus content of any of the upland types. However, this is a rather unusual soil, having been formed in an old lake bed and being excessively high in organic matter and in carbonates. Again the
high phosphorus content may be due to the occurrence of organic phosphorus. Probably in this case, however, the higher content is due to the fact that the soil has been cropped to a less extent and hence there has been a smaller removal of this constituent.

The Wabash silty clay and the Lamoure silty clay loam of the bottoms are higher in phosphorus than the soils of the Cass series. These are generally rich soils, being high in organic matter and in plant food. The surface soils of the Cass types in this county, however, are very much the same in composition as the surface soils of the Lamoure and Wabash as far as organic matter and nitrogen is concerned. They do seem to be slightly lower in phosphorus. This may be a condition due to the origin or particular nature of the soil or of the subsoil conditions. It is quite customary to assume that soils with sandy or gravelly subsoils are poorer in fertility and of less value, therefore, than soils with heavier textured subsoils. Occasionally, however, the former types may actually be much more profitably productive depending very largely upon seasonal conditions.

In general it seems evident from these analyses, that while the phosphorus supply is not extremely low, phosphorus fertilizers will need to be used on these soils in the rather near future if the soils are to be kept at the highest state of productivity. Even if the total amount present could be made available as rapidly as needed by crops, there is sufficient for only a limited number of years but as the supply of total phosphorus in the soil decreases there is a disproportionate decrease in available phosphorus. In other words, available phosphorus production in soils decreases much more rapidly than does the total supply. There is no means of determining accurately the rate of availability of the phosphorus in these soils but ordinarily it is believed that if the soil is well drained and cultivated and abundantly supplied with organic matter, the production of available plant food will occur sufficiently rapidly to supply the needs of growing crops. It may be, therefore, that available phosphorus is being produced in the soils of this county as rapidly as is necessary at the present time. The only way to determine whether or not this is true is to apply acid phosphate to a small area and if increased crop yields result from the application then it is certain that there is not sufficient available phosphorus being produced in the soil.

It would seem very desirable, therefore, that phosphorus fertilizers be tested on the soils of the county at the present time, to determine whether or not they will bring about increases in crops. Farmers may carry on a test on a small area on their farms and thus determine for their local conditions whether or not phosphorus is of value. An application of acid phosphate, for example, at the rate of 200 pounds per acre in the spring can readily be made to a portion of a field and if beneficial effects are noted then it may be certain that phosphorus fertilizers may be used to advantage on the particular soil.

THE NITROGEN SUPPLY

The nitrogen supply in the soils of the county is extremely variable. There is a range in this constituent from 2,186 to 13,898 pounds per acre. Apparently in most cases the soils are fairly well supplied with nitrogen, but in other instances the content is not large and the need for building the soil up in nitrogen
content is evident. As in the case of phosphorus, there is apparently no relation between the nitrogen supply and the various soil groups except that the terrace types are lower in this constituent on the average than the other groups. This, however, is due mainly to the fact that the terrace soils are both of the O'Neil series and the low content of nitrogen may be attributed more to the characteristics of the particular soil series than to any characteristics of the soil group. The bottomland soils are somewhat richer in nitrogen than the average of the other groups of soils, as would be expected, inasmuch as the bottomland types have been very little used for cultivated crops and there has been very little washing away of the plant food and a smaller amount of decomposition of organic matter than commonly occurs in the upland types.

There is very little evidence of relationship between the soil texture and the nitrogen content. The Clarion fine sand is considerably lower than the Clarion loam, but the O'Neil fine sandy loam is higher than the O'Neil loam and the Webster silty clay loam is lower in nitrogen than the Webster loam. These latter figures indicate that there are other factors which are important in determining the nitrogen content of the soil than those which go to make up the texture or the series. The Cass loam is considerably lower in nitrogen than the silt loam, which would be expected, but the Lamoure silty clay loam and the Wabash silty clay are lower in nitrogen than the Cass silt loam, which might again be taken to indicate that the texture of the soil is only one of several factors controlling the nitrogen content. Ordinarily the Lamoure and Wabash series would be expected to show more nitrogen than the Cass series so that there is an exception here in the case of the Cass silt loam when a comparison is made on the series basis. The Clarion fine sand contains the smallest amount of nitrogen of any of the soils in the county, while the Rogers silt loam shows the highest content. This is the same relation as was evident in the case of phosphorus. The Webster silt loam is extremely high in nitrogen, unusually high in fact, for this particular type. In fact it contains almost as much nitrogen as the Rogers silt loam which is known to be rather an abnormal soil. The other upland types contain an average amount of nitrogen and very much the same content is shown by the terrace soils. The bottomland types are much better supplied with this constituent.

From the fact that the nitrogen content is not extremely low, it should not be concluded that nitrogen may be disregarded in considering systems of permanent fertility. It is very necessary on the upland soils of this county that the proper treatments be practiced to keep up the nitrogen supply and even to increase the amount of this constituent in some cases. Farm manures and crop residues return to the soil some of the nitrogen which has been removed by the growth of crops and these materials should be utilized in all cases in keeping up the nitrogen supply. In some instances it may be necessary to use leguminous crops as green manures in order to supplement the farm manure or to take the place of farm manure. It would be a comparatively simple matter to keep up the nitrogen content in those soils in which it is high at present and equally simple, by the use of farm manure, crop residues and leguminous green manures, to increase the nitrogen content in those soils which are not so abundantly supplied.
In all soils under cultivation the relation between the content of nitrogen and of organic carbon is an indication of the rate of decomposition of the organic matter in the soils, or in other words, an indication of the production of available plant food. If the amount of organic carbon in relation to the nitrogen is reduced below a certain point, there is a decrease in the production of available plant food. In all cases in Palo Alto county the relation between these two constituents is such that there should be no question of a rapid production of available plant food. However, there are other factors involved in the case of these particular soils and the lack of drainage or inadequate removal of excess moisture which occurs in some cases, will prevent the most desirable rate of decomposition and hence will decrease the production of available plant food. When adequate drainage is insured in these soils, the chemical composition indicates that decomposition processes will proceed sufficiently rapidly to keep plants supplied with necessary food constituents.

There is usually a distinct relation between the nitrogen and organic carbon in soils and there is also a relation to the color of the soil. If the soil is light in color, it is low in organic matter and usually low in nitrogen. If it is black in color there is a large content of organic carbon and nitrogen is usually abundant. This relation holds true in the case of the Palo Alto county soils. There is a range in organic carbon from 27,600 pounds in the Clarion fine sand, up to 252,844 pounds in the Rogers silt loam. As in the case of nitrogen, the former type is the lowest of any in the county in carbon and the Rogers silt loam is the highest. The Cass silt loam, which is the second highest in nitrogen, is also second in organic carbon. The Webster silt loam which is third in nitrogen and only slightly lower than the Cass silt loam, is third also in the case of organic carbon and only slightly less in this constituent than the Cass silt loam. Similarly with the other soil types, the relations discussed in the case of nitrogen hold true in the case of organic carbon. Hence, as was noted in the case of nitrogen, there are no instances where the soils are alarmingly deficient in organic matter with the exception of the Clarion fine sand. In several of the soil types, however, the amount of organic carbon is not sufficient but that applications of farm manure would be of value. Furthermore, in practically all these types care must be taken to keep up the supply of organic matter or the soils will become deficient and crops will suffer.

Farm manure is the most important source of organic matter in soils. This material should be used on the soils of this county as far as it is available. All crop residues should be returned to the soils and there may be instances where leguminous green manure crops would be needed, particularly if farm manure is produced to only a limited extent and the soils begin to run down in organic matter and nitrogen content. It should be noted here also that in spite of the comparatively high content of organic matter in these soils, additions of farm manure give increased crop yields in practically all instances. Its beneficial effect may possibly be the result of the bacteria contained in the manure and may be attributed to a stimulation in the production of available plant food, but whatever the reason, the application of farm manure to these soils is known to increase crop growth and it will build up and keep up the supply of organic matter.
Several of the soils in the county show a content of inorganic carbon, only three, however, showing any large supply of this constituent in the surface soil. The Webster silt loam, the Rogers silt loam and the Lamoure silty clay loam all seem to be very rich in inorganic carbon. Several other types show small amounts, but in no other case is the amount sufficient to prevent the surface soil from showing an acid reaction in the very near future. Three types in addition to the three showing a high content of inorganic carbon, give no limestone requirement. Two others show such a low lime requirement that they may almost be considered to be basic in reaction. Only in the case of two upland types and the O’Neill soils of the terrace group, is there any considerable lime requirement indicated by the tests.

The figures given in the table should be considered merely indicative of the needs of the particular soil types and tests should be made on these types in all cases before applications of lime are made. Even a much larger number of analyses than those reported here would not yield an accurate figure on the lime requirement of a soil type. Variations frequently occur even in the same soil type and no general average figures will serve to show how much lime should be added to any particular soil. If the proper amount of lime is to be applied, tests of the particular soils should be run and if the amount of lime, shown to be necessary according to the test, is used the best growth of all crops and particularly of legumes will be secured. Probably in the course of the next few years several of the types in this county which show a basic reaction at present will give a lime requirement when tested. This is owing to the rapid removal of lime from soils which occurs by utilization by plants and by leaching. Hence the soils of the county, even those which now show a basic reaction, should be tested for acidity at intervals during the coming years and when the test shows a lime requirement that material may be applied with the assurance of profit.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of sub-

### TABLE V. PLANT FOOD IN PALO ALTO COUNTY, IOWA, SOILS.

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>3,609</td>
<td>7,640</td>
<td>94,400</td>
<td>0</td>
<td>4,121</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>3,196</td>
<td>9,153</td>
<td>114,171</td>
<td>829</td>
<td>Basic</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>2,936</td>
<td>9,080</td>
<td>117,706</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>2,747</td>
<td>9,864</td>
<td>117,700</td>
<td>49,100</td>
<td>Basic</td>
</tr>
<tr>
<td>148</td>
<td>Clarion fine sand</td>
<td>1,885</td>
<td>3,308</td>
<td>34,400</td>
<td>0</td>
<td>3,864</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>3,367</td>
<td>47,268</td>
<td>518,272</td>
<td>130,528</td>
<td>Basic</td>
</tr>
</tbody>
</table>

DRIFT SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>3,644</td>
<td>6,780</td>
<td>78,400</td>
<td>0</td>
<td>3,864</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>3,098</td>
<td>5,716</td>
<td>70,400</td>
<td>0</td>
<td>4,636</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>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>2,774</td>
<td>5,940</td>
<td>83,648</td>
<td>26,752</td>
<td>Basic</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>2,478</td>
<td>9,024</td>
<td>105,456</td>
<td>944</td>
<td>Basic</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>2,505</td>
<td>5,156</td>
<td>68,532</td>
<td>668</td>
<td>Basic</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>2,090</td>
<td>18,996</td>
<td>66,372</td>
<td>828</td>
<td>Basic</td>
</tr>
</tbody>
</table>

SWAMP AND BOTTOMLAND SOILS
TABLE VI. PLANT FOOD IN PALO ALTO 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>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>4,243</td>
<td>4,988</td>
<td>85,099</td>
<td>22,500</td>
<td>Basic</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>4,464</td>
<td>6,390</td>
<td>85,796</td>
<td>9,005</td>
<td>Basic</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>4,323</td>
<td>4,458</td>
<td>55,914</td>
<td>2,286</td>
<td>Basic</td>
</tr>
<tr>
<td>113</td>
<td>Webster silt loam</td>
<td>2,869</td>
<td>4,542</td>
<td>75,254</td>
<td>14,766</td>
<td>Basic</td>
</tr>
<tr>
<td>148</td>
<td>Clarion fine sand</td>
<td>5,010</td>
<td>1,680</td>
<td>25,800</td>
<td>2,319</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>5,091</td>
<td>65,424</td>
<td>72,812</td>
<td>279,588</td>
<td>Basic</td>
</tr>
<tr>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>3,535</td>
<td>3,402</td>
<td>39,000</td>
<td>0</td>
<td>1,158</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>3,839</td>
<td>1,848</td>
<td>26,400</td>
<td>0</td>
<td>3,577</td>
</tr>
<tr>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>3,273</td>
<td>3,444</td>
<td>49,680</td>
<td>54,720</td>
<td>Basic</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>3,111</td>
<td>2,814</td>
<td>37,020</td>
<td>3,180</td>
<td>Basic</td>
</tr>
<tr>
<td>106</td>
<td>Cass silt loam</td>
<td>2,828</td>
<td>1,596</td>
<td>22,002</td>
<td>1,398</td>
<td>Basic</td>
</tr>
</tbody>
</table>

surface and 6,000,000 pounds of subsoil per acre. The plant food content of the lower soil layers generally has very little effect on the fertility of the soil unless there is a very large amount of some one constituent present. In the soils of Palo Alto county there is no excessively large amount of any of the plant food constituents in any of the lower layers with the exception of the Rogers silt loam which, as has been stated, is manifestly an abnormal soil. The exact chemical composition of the lower soil layers is therefore of very little significance from the standpoint of determining the fertilizer requirements of the surface soils and these analyses will not be considered in detail.

The needs of the soils of the county as indicated in the case of the surface soils are very largely confirmed by the analyses of the lower soil layers. The phosphorus supply in these soils is not extremely high, neither is it very low. It seems evident, therefore, that phosphorus fertilizers will be needed at some time in the near future and they may also prove of some value at the present time in individual cases. The supply of organic matter and nitrogen is rather considerable in most of the types but it is apparent that for the continued fertility of these soils farm manure, crop residues and leguminous green manures will need to be utilized to keep up the supply of these constituents. In the subsurface soils only four of the types show an acid reaction, the two terrace soils and the Clarion fine sand and the Clarion loam. There is no large supply of lime in the subsurface, however, except in the same three types that showed a high content in the surface soil. In the subsoil, however, there are only three types which are not basic, the O’Neill terrace soils and the Clarion fine sand, and there is a rather considerable amount of lime present in nine of the soil types. The presence of lime in the subsoil, however, is of very little significance in determining the basic reaction of the surface soil. Lime rarely moves up in the soil and if the surface soil is acid it makes very little difference whether or not the subsoil is high in lime. The conclusions drawn in the case of the surface soils are not modified to any extent, therefore, by the analyses of the subsurface and subsoil samples and the recommendation regarding the testing of the soils in the county at the present time and at regular intervals in the future, should
be emphasized again. Only in this way can the farmer be sure that his soil is in the best reaction for crop growth and that he can secure a most satisfactory growth of legumes.

**GREENHOUSE EXPERIMENTS**

Two greenhouse experiments were carried out on soils from Palo Alto county in order to determine something regarding the fertilizer needs of the soils, and to get an idea of the value of the various fertilizing materials. These experiments dealt with two of the main soil types, the Clarion loam and the Webster silt loam. In addition to these two experiments, the results of the tests on the Weber silt clay loam in Buena Vista county are included because this type occurs in Palo Alto county also, and the results are undoubtedly applicable to that county.

The plan of all the experiments consisted in the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts used were the same as those employed in the field experiments and hence the results of these greenhouse tests may be considered to indicate roughly what would occur in the field. Manure was supplied at the rate of 8 tons per acre. Lime was added in sufficient amounts to neutralize the acidity as shown by the Veitch test and supply two tons additional. Rock phosphate was added 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 all the experiments, clover being seeded about one month after the wheat was up.

The results of the experiment on the Clarion loam from Palo Alto county are given in table VII.
TABLE VII. GREENHOUSE EXPERIMENT, CLARION LOAM, PALO ALTO 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>9.5</td>
<td>56.69</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>14.5</td>
<td>68.04</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>14.0</td>
<td>68.04</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>16.0</td>
<td>74.84</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>16.0</td>
<td>86.18</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>16.3</td>
<td>70.25</td>
</tr>
</tbody>
</table>

The effect of the applications of manure is shown very definitely in this table. Both the wheat and clover were increased in yield by the normal addition of manure.

The application of lime along with manure exerted no effect either on the wheat or clover. This particular soil sample was only very slightly acid in reaction and apparently did not need any lime. Other samples of the Clarion loam showing more of a lime requirement in the surface soils would undoubtedly need applications of lime and when the acidity is well developed in this type as frequently occurs, farm experience shows very definitely that the application of lime is necessary if the most satisfactory growth of legumes is to be secured.

The application of phosphorus fertilizers to this type seemed to give rather distinct crop increases, both for wheat and clover. In the case of the wheat there was practically the same effect from the rock phosphate, the acid phosphate and the complete commercial fertilizer. With the clover, however, the acid phosphate had a considerably greater effect, the rock phosphate showing a smaller influence and the complete commercial fertilizer the least beneficial effect. These results are of particular interest in that they indicate the possibility of value from the use of phosphorus fertilizers on the Clarion loam, the main soil type in this county. Just which material should be used on the type must be determined by more complete tests and particularly by field tests. It would seem from indications here that the differences in the relative value of the various phosphorus carriers may depend to a large extent upon the crop which is being grown.

It does not seem from these results that complete commercial fertilizers could be recommended as of any particular use on this soil.

Apparently the Clarion loam will respond to applications of farm manure and the use of lime in addition to manure is very desirable, especially when legumes are to be grown. The results indicate also that phosphorus fertilizers may be used to advantage on this soil and tests of the relative value of rock phosphate and acid phosphate are very desirable. Complete commercial fertilizers may also be tested but they seem to have less effect than the phosphorus carriers.

The results of the second greenhouse experiment on the Webster silt loam from Palo Alto county are given in table VIII.

Again with the Webster silt loam used in this experiment, the effect of manure, both on wheat and clover is quite evident. Both these crops were increased by the application of this material. Lime in addition to the manure had no effect on the wheat and only a very slight influence on the clover. This soil is
TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER SILT LOAM, PALO ALTO 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>23.0</td>
<td>45.36</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>28.0</td>
<td>49.89</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>26.0</td>
<td>52.16</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock phosphate</td>
<td>31.5</td>
<td>56.69</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid phosphate</td>
<td>32.5</td>
<td>59.96</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Complete commercial fertilizer</td>
<td>29.0</td>
<td>52.16</td>
</tr>
</tbody>
</table>

usually not acid, but in the case of this particular sample the surface soil was slightly acid and lime was applied, but the acidity was so slight that the lime had no effect.

The addition of phosphate fertilizers seemed to give increases both in wheat and clover, the acid phosphate showing up somewhat better in the case of both crops. The complete commercial fertilizer had little effect on either crop and, as on the Clarion loam, it showed very much less influence than did the rock phosphate and the acid phosphate.

It seems evident that on the Webster silt loam small applications of manure may bring about very profitable returns. In any case where the soil is acid, lime may be applied with profit and the indications point very strongly to the desirability of testing the use of phosphorus fertilizers on this type. Either acid phosphate or rock phosphate may be used in these tests, or preferably both materials may be applied to small areas and the comparative value of the two materials may then be determined. There is no evidence from these results of any particular value attached to the use of complete commercial fertilizer.
Tests of phosphorus fertilizers, however, may include the use of these materials if the farmer is particularly interested, and in case field trials show profitable returns they may be employed.

The third greenhouse experiment was carried out on the Webster silty clay loam from Buena Vista county and the results are included here as they may be considered quite definitely indicative of the needs of this same soil type in Palo Alto county. The results of this experiment are given in table IX.

It is evident from the results in this table that the application of manure brought about a distinct increase in the yields, both of the wheat and the clover, the gains being more pronounced in the case of the latter crop. The addition of lime with manure increased the yield of wheat slightly and gave a very pronounced increase in the case of clover. Rock phosphate showed no effect on the wheat and very little on the clover. Acid phosphate brought about an increase in the wheat and a slight effect on the clover. The complete commercial fertilizer had practically no effect either on the wheat or clover.

Apparently manure is a most valuable fertilizing material for this particular soil type and this in spite of the fact that this soil is very well supplied with organic matter and nitrogen. The addition of lime along with manure is also apparently of value, particularly on the clover. There are indications that phosphorus fertilizers may be of value but no definite conclusions can be drawn from this particular experiment.

**TABLE IX. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY.**

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight wheat grain in grams</th>
<th>Weight clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>26.56</td>
<td>29.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>29.46</td>
<td>36.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>31.71</td>
<td>44.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>28.95</td>
<td>46.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>35.80</td>
<td>45.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>31.13</td>
<td>46.0</td>
</tr>
</tbody>
</table>
Several field experiments are just being started in Palo Alto county and these must be continued for several years before results from them will be available for use. However, experiments have been carried on for several years in Buena Vista, Clay and Webster counties on soil types which occur in Palo Alto county and the results from these field tests will undoubtedly indicate the results which will be secured in Palo Alto on the same soil types. The results of these field experiments are included in this report.

The field experiment at Lundgren in Webster county is on the Webster loam, an important type in Palo Alto county. The field at Everly in Clay county is on the O'Neill loam, a type of considerable interest in this county. Two series of experiments have been under way at Truesdale in Buena Vista county on the Carrington loam. The Clarion loam in Palo Alto county is very similar to the Carrington loam in Buena Vista, practically the only difference being somewhat more lime in the subsoil of the Clarion. Hence the results of the Carrington loam in Buena Vista may be considered to indicate the needs of the Clarion loam in Palo Alto county.

These field experiments are all laid out on land which is thoroughly representative of individual soil types in the county. They are permanently located by the installation of corner stakes and it is planned to carry the experiments over a long period of years. Every precaution is taken in the application of fertilizers and in the harvesting of the crops to be certain that the results secured are accurate. While these fields are on a cooperative basis, the experimental handling of the plots is carried on by the Iowa Agricultural Experiment Station.

The plan of these tests is such that there are one or more series of plots on which various methods of soil treatment are used. One series includes the use of manure and therefore represents the livestock system of farming. A second series makes use of the crop residues, representing the grain system of farming, and no manure is applied. The results on the livestock series of plots only are given here inasmuch as the crop residue plots have not yet been conducted for a long enough time to show any effect of the residues.

Other fertilizing materials tested in these experiments are rock phosphate, acid phosphate, a complete commercial fertilizer and lime as needed. The rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is added at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer is used at the rate of 300 pounds per acre annually. Limestone is applied in a sufficient amount to neutralize the acidity of the soil and supply two tons additional.

There are 13 plots in these experiments, three of which are untreated or check plots and are numbered 1, 7 and 13. Plots 1 to 7 inclusive are included therefore in the livestock system and the results on these plots are the ones which will be considered in this report. The plots in these fields are all 1/10 of an acre in size being 156' 6" in length by 28' in width.

THE EVERLY FIELD

The results obtained on the Everly field in Clay county are given in table X. This field is laid out on the O'Neill loam, a minor type in Palo Alto county but one which is of considerable interest because of its characteristics and the diffi-
TABLE X. FIELD EXPERIMENT, O'NEILL LOAM, CLAY COUNTY.

Everly Field.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Corn bu. per acre</th>
<th>Corn bu. per acre</th>
<th>Oats bu. per acre</th>
<th>Clover tons per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1918</td>
<td>1919</td>
<td>1920</td>
<td>1921</td>
</tr>
<tr>
<td>1</td>
<td>Check</td>
<td>47.7</td>
<td>37.1</td>
<td>23.3</td>
<td>1.80</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>56.3</td>
<td>34.1</td>
<td>27.5</td>
<td>2.35</td>
</tr>
<tr>
<td>3</td>
<td>Manure + Lime</td>
<td>56.4</td>
<td>38.0</td>
<td>28.9</td>
<td>2.60</td>
</tr>
<tr>
<td>4</td>
<td>Manure + Lime + Rock phosphate</td>
<td>56.0</td>
<td>40.3</td>
<td>33.6</td>
<td>2.94</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Lime + Acid phosphate</td>
<td>59.2</td>
<td>39.0</td>
<td>32.6</td>
<td>3.28</td>
</tr>
<tr>
<td>6</td>
<td>Manure + Lime + Complete commercial fertilizer</td>
<td>55.4</td>
<td>40.9</td>
<td>30.9</td>
<td>2.97</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>46.6</td>
<td>37.1</td>
<td>24.1</td>
<td>1.80</td>
</tr>
</tbody>
</table>

The results secured on this field for 1918, 1919, 1920 and 1921 are given in the table. They are of particular interest inasmuch as the results of a complete four years’ rotation are shown under the livestock system of farming and they indicate quite definitely the value of various fertilizing treatments on this particular soil.

The effect of the application of manure to this soil is quite definitely shown in these results. The yield on the check plot in 1919 is a little high and this prevents the effect of manure from showing that year. However, the yield of corn is very definitely increased in 1918, the oats in 1920, and the clover in 1921. The addition of lime along with manure showed a very slight effect on the corn and a somewhat larger influence on the oats and the effect on the clover was quite pronounced. This is what would be expected from the fact that lime exerts its beneficial effect particularly on the clover of the rotation and it is not expected that it will have any large influence on corn and oats. Applications of rock phosphate, acid phosphate and a complete commercial fertilizer quite generally increased the crops of the rotation. Acid phosphate showed up somewhat the best on the corn the first year and considerably better than the other materials on the clover in 1921. There is very little difference in the effect of the acid and rock on the oats in 1920, the rock giving a slightly larger effect. Similarly in 1919 the rock seemed somewhat superior to the acid.

The results of this test should not be considered, however, as definitely indicating the relative value of these materials. In most cases the differences are too small to be of great significance and further results are needed before definite conclusions can be drawn. It would seem evident, however, that phosphorus fertilizers will prove of value on this soil type and one material may be more valuable than another, depending upon the crop which is to be grown as well as upon the seasonal and soil conditions. Tests of the relative value of rock phosphate and acid phosphate are particularly desirable on individual farms in order that the material which will give the largest economic effects may be chosen. It is not a question merely of increased crop yields but one of cost of treatment in connection with increased crop growth. It is evident that this soil type should receive liberal applications of manure and that lime should be applied when needed for the best crop yields and the application of phosphorus fertilizers would probably be of value in most cases.

THE TRUESDALE FIELD

The results on the Truesdale field are given in table XI. This field is located in Buena Vista county on the Carrington loam which, as has been noted, is a
TABLE XI. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY.

Truesdale Field—Series I.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Corn bu. per acre 1918</th>
<th>Corn bu. per acre 1919</th>
<th>Oats bu. per acre 1920</th>
<th>Clover tons per acre 1921</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>38.9</td>
<td>56.5</td>
<td>57.2</td>
<td>1.40</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>44.3</td>
<td>57.1</td>
<td>57.9</td>
<td>1.20</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>46.4</td>
<td>58.1</td>
<td>59.2</td>
<td>1.60</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>54.4</td>
<td>58.7</td>
<td>64.7</td>
<td>2.45</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>49.6</td>
<td>58.7</td>
<td>64.9</td>
<td>3.30</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>49.6</td>
<td>58.7</td>
<td>64.7</td>
<td>3.10</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>38.4</td>
<td>58.1</td>
<td>56.4</td>
<td>2.20</td>
</tr>
</tbody>
</table>

The type very similar to the Clarion loam of Palo Alto county. The difference between these types involves chiefly the occurrence of lime in the subsoil and as this has little influence on the crop yields it may be concluded that the results on this field would apply directly to the Clarion loam in Palo Alto county.

In this experiment a complete four-year rotation has been carried out and the effects of treatment on two corn crops, one oats crop and one clover crop are shown.

Manure brought about a distinct influence on the corn in 1918 and a smaller effect on the same crop in 1919. A very little influence was noted on the oats in 1920 and none at all on the clover in 1921. In fact, the yield on the manure crop in 1921 was undoubtedly slightly abnormal in that a smaller yield was secured than on the check plot. The influence of lime along with manure is evident on all the crops of the rotation, showing up not only on the clover but on the corn and oats as well. It would seem that lime may exert a beneficial effect indirectly on the grain crops of the rotation and its value should therefore not be determined entirely by the effect on clover, although that is the crop which is usually influenced to the largest extent.

The influence of rock phosphate, acid phosphate and a complete commercial fertilizer shows up quite distinctly on all the crops, although the corn crop in 1919 is increased to only a small extent. The clover is increased to a much greater degree than the other crops in the rotation and with this crop the acid phosphate gives greater effects than the rock and the complete commercial fertilizer shows only a slightly smaller effect than the acid phosphate. On the oats the three materials give practically identical effects and similarly on the corn crop in 1919. On the 1918 corn crop, however, rock phosphate gave a larger yield than did the other materials. Apparently phosphorus may be of value on this particular soil type and the application of phosphorus fertilizers may lead to distinct crop increases. The results do not permit of conclusions regarding the relative merits of the various materials. Further experiments must be carried out before a definite choice can be made between acid phosphate and rock phosphate. The results seem to indicate, however, the superior value of acid phosphate on clover. The complete commercial fertilizer does not give any larger effects than the phosphorus carriers and in some instances the influence is less, hence it would seem that these materials would not prove as profitable as the phosphorus fertilizers owing to the fact that they are more expensive.

The results on Series II of the Truesdale field are given in table XII for the years 1920 and 1921. The yields of oats in 1918 were very irregular and the
TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY.
Truesdale Field—Series II.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Corn bu. per acre 1920</th>
<th>Corn bu. per acre 1921</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>47.5</td>
<td>32.8</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>57.0</td>
<td>39.7</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Lime</td>
<td>59.0</td>
<td>41.8</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Lime+Rock phosphate</td>
<td>61.2</td>
<td>38.1</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Lime+Acid phosphate</td>
<td>62.1</td>
<td>40.1</td>
</tr>
<tr>
<td>6</td>
<td>Manure+Lime+Complete commercial fertilizer</td>
<td>64.0</td>
<td>44.4</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>57.1</td>
<td>36.2</td>
</tr>
</tbody>
</table>

clover in 1919 winter killed. Results on corn for 1920 and 1921, however, very largely confirm the conclusions reached in the discussion of the results of Series I. Here again the beneficial effect of manure is shown in increasing the corn yields. Lime in addition to manure gave a further increase. Rock phosphate, acid phosphate and a complete commercial fertilizer all increased the corn yields to a considerable extent with the exception of the rock phosphate in 1921 and on that particular plot the yield was evidently abnormal. It would seem from these results that a phosphorus fertilizer might be used on this soil with profit.

It is apparent from the results of these two experiments on the Truesdale field that manure is a particularly valuable fertilizing material for this soil and will exert a beneficial effect on all the crops of the rotation. Lime should be used when the surface soil is acid and the beneficial effect of this material will show up particularly well on the clover of the rotation. There is evidence that phosphorus fertilizers will prove of value on this soil and the testing of rock phosphate and acid phosphate on small areas is recommended. Complete commercial fertilizers do not seem to have any greater effect than the phosphorus carriers and hence they would prove less profitable owing to their greater cost. They may be used, however, provided comparative tests show them to be of superior value to the phosphorus carriers under any particular conditions.

THE LUNDGREN FIELD

The results of the experiment on the Lundgren field in Webster county are given in table XIII. The plots on this field are located on the Webster loam and the results secured on this particular type may be considered to indicate quite definitely the needs of the same soil in Palo Alto county. When this experiment was started the soil was not acid in reaction and no lime was applied, hence plots 2 and 3 are duplicates and the results given in the table are the averages of the yields on these two plots.

TABLE XIII. FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY.
Lundgren Field.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Corn bu. per acre 1919</th>
<th>Corn bu. per acre 1920</th>
<th>Oats bu. per acre 1921</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>59.0</td>
<td>63.8</td>
<td>32.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>59.4</td>
<td>63.8</td>
<td>35.3</td>
</tr>
<tr>
<td>3</td>
<td>Manure+Rock phosphate</td>
<td>61.3</td>
<td>69.3</td>
<td>38.7</td>
</tr>
<tr>
<td>4</td>
<td>Manure+Acid phosphate</td>
<td>65.1</td>
<td>67.2</td>
<td>35.8</td>
</tr>
<tr>
<td>5</td>
<td>Manure+Complete commercial fertilizer</td>
<td>65.1</td>
<td>74.2</td>
<td>36.6</td>
</tr>
<tr>
<td>6</td>
<td>Check</td>
<td>54.0</td>
<td>59.7</td>
<td>32.6</td>
</tr>
</tbody>
</table>
The yield of oats in 1918 is not given in the table, inasmuch as the results are very irregular, as is apt to be the case during the first year of such an experiment. The effect of manure on this particular soil has not shown up very definitely altho the oats crop is increased to some extent.

Rock phosphate, acid phosphate and a complete commercial fertilizer all increased the crop yields to a considerable extent, the rock phosphate showing up better on the oats, the complete commercial fertilizer the best on the corn in 1920 and the acid phosphate and the complete commercial fertilizer both giving better effects than the rock on the corn in 1919. There is evidence here that phosphorus will be of value on this particular soil, but apparently many more results are needed before any definite conclusions can be drawn regarding the relative value of these two materials. The complete commercial fertilizers showed up better than the phosphorus carriers in one instance, but this should not be taken as conclusive, particularly in view of the fact that in 1921 it had less effect than the rock phosphate. Owing to its greater cost a complete commercial fertilizer must give very much larger yields if it is to prove economically profitable. It would not seem from these results that it would be as valuable a fertilizer for this soil as a phosphorus carrier. Small applications of manure are undoubtedly of use on this particular soil and for its continued fertility this material should be applied regularly in normal amounts. Phosphorus fertilizers should be tested and they will undoubtedly be needed in the near future if they are not of profit at the present time.

These field experiments as a whole very largely confirm the indications of the greenhouse tests and also the results of much farm experience. Apparently the soils of the county will very largely respond to applications of farm manure. Some of the types are in need of this material to a much greater extent than others, but in no case can the fertility be maintained without the proper application of farm manure, unless expensive commercial fertilizers are purchased as substitutes for it. Lime is of value on these soils when they are acid even tho the acidity is only slight and confined to the surface soil. Phosphorus fertilizers seem to be of value and either rock phosphate or acid phosphate may give profitable returns on general farm crops. Just which material should be used must be determined for individual soil conditions. Complete commercial fertilizers do not seem to prove any more valuable than phosphorus carriers and hence must be looked upon as less economically desirable.

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

The field experiments which have been begun in Palo Alto county have been planned to throw some light on the problem of the fertilizer needs of the more important soil types of the county. When results have been secured from these fields for a period of several years, it is hoped that economic conclusions may be drawn regarding the relative value of various fertilizers on these soils. At present field experimental results in this county are not available but from the results of the greenhouse tests given earlier in this report and from the results
of certain field experiments in other counties, on soil types which are common
to this county, certain suggestions may be given regarding the treatments needed
for the soils of the county. Later it may be possible to draw more definite con­
clusions with respect to the use of certain fertilizers but it should be understood
that the suggestions given here are based upon the laboratory, greenhouse and
field tests which are discussed earlier in the report. They are also based upon
the practical experience of many farmers and no recommendations are made
which have not proven of value practically. In regard to the use of certain fer­
tilizing materials, the suggestion is made that farmers test these materials on
their own soils. If this suggestion is carried out they may secure very valuable
and definite information pertaining to the use of fertilizers on their own soils
and only in this way can it be definitely determined whether certain materials
will prove of profit under the particular soil conditions. The suggestions which
are made regarding definite soil treatments in this report are of proven value
and may be put into operation under any farming conditions.

MANURING

The soils of Palo Alto county are very much better supplied with organic
matter than is the case with the soils in many other counties. Only in one in­
stance is the organic matter content extremely low and that is in the case of the
Clarion fine sand, a very minor type in the county. In most instances the soils
are fairly rich in organic matter. In the case of the more extensive upland
types, however, the amount of organic matter is not at all excessive and in fact
it is not so large but that care must be taken to keep up the supply.

The application of farm manure to many of these soils is of considerable value
and it is probably the most valuable fertilizing material for use in the county.
The experience of many farmers indicates that normal applications of manure
to most of the upland types bring about increases in crop yields. The green­
house and field experiments discussed earlier in this report show that manure
will prove of value on these soils. This is the most economic material for keep­
ing up the organic matter supply, and even where the content of organic matter
is sufficient at present normal applications of manure should be made once in
a rotation whenever the production of manure on the farm is sufficient. Even
where other fertilizing materials are used on these soils, the greatest effects are
secured when they are combined with applications of farm manure. There is no
artificial material which can take the place of this natural fertilizer.

The beneficial effects of manure on soils are due to its influence on the chem­
ical, physical and bacteriological conditions. The actual increase in plant food
which it brings about may be of fundamental importance from the standpoint of
crop yields and permanent fertility. Manure contains a large portion of the
plant food constituents removed from soils by the crops grown and hence it
returns considerable amounts of plant food which would otherwise be lost from
the soil. Manure lengthens the life of the soil or in other words, it delays the
time when one or more of the necessary plant food elements will become so low
that crops will fail. It improves the physical condition of soils whether heavy
or light. Heavy soils are opened up and made less retentive of moisture and
better aerated. On the other hand, it makes light open soils less open and por-
uous, more retentive of moisture and less subject to loss of valuable matter by leaching. The direct results of this improved physical condition in the soil is the greater development of roots and hence better growth of the plant, but the improved physical condition exerts a secondary effect on crops, in that bacterial activities are encouraged and there is a greater production of available plant food. Crops are, therefore, better supplied with necessary constituents.

Manure contains enormous numbers of bacteria and other microscopic organisms whose introduction into the soil may prove very beneficial from the standpoint of crop yields. This is due to the fact that bacteria are the agents bringing about the production of available plant food, and the introduction of larger numbers of these organisms may be responsible in a large part for the beneficial effect of manure on the yields of certain crops. The organic matter content of manure is very rich and this material plays a very important part in crop production and soil fertility. It also serves as a food material for bacteria and hence is one of the reasons for the greater production of available plant food. There are undoubtedly cases where the beneficial effects of manure are due chiefly to a stimulation of bacterial action either because of larger numbers of bacteria and other organisms or of better growing conditions. In newly drained reclaimed areas when manure brings about beneficial effects, as is so often the case, they are very apt to be due to improved bacterial conditions, especially if the area in question is as extremely high in organic matter as is usual in undrained soils. There are probably other cases where the beneficial effects of manure are due to the improved physical condition in the soil or to the actual addition of plant food constituents. In general, however, on the soils of this county it seems probable that manure is of value because of its chemical, physical and bacteriological effects, all combined.

The beneficial effects of manure when applied to soils are so important that every precaution should be taken to preserve the manure produced on the farm and see that it is applied to the soil without loss. On the average livestock farm a large part of the value of manure is lost by leaching and exposure to the weather. It has been estimated that 70 to 90 percent of the valuable matter in manure may disappear in this way. In cases where such large losses occur, manure will not exert its usual highly beneficial effects and crop yields will be lower. This means that the improper storage and utilization of manure will bring about actual money loss to the farmer. Every farmer, therefore, should take special care to preserve the manure produced on his farm without loss in order that he may obtain the best effects from its application. It may be stored in a covered yard or pit and protected from the weather or some particular method may be employed which is most desirable for the farm conditions. No one method can be recommended for all circumstances inasmuch as the conditions on farms are so variable. A very satisfactory method in one case might prove highly undesirable in another. Almost any method may be employed to prevent loss from manure, provided it is kept moist and compact and not exposed to the weather. Under some conditions the application of manure, as produced, to the soil may be very desirable. When this method of application is possible, of course no storage of the material is needed and hence it may be applied with the least possible loss of valuable portions, and with the largest
effect on crop yields. It is not always practicable to apply manure as produced and in fact on most farms it is necessary to store the manure and apply at a convenient season.

When manure is properly stored and applied to the soil it is estimated under average livestock farming conditions that 75 to 80 percent of the plant food removed from the soil by the crops grown may be returned to the land. This estimate is based on the assumption that sufficient manure will be produced on the farm to make an application of 8 to 10 tons per acre to the entire acreage of the farm once in a four year rotation. There are many cases on livestock farms where this is not possible and then some of the soils of the farm are well supplied with manure while others receive it only very infrequently. The usual application of manure is 8 to 10 tons per acre for general farm crops, although in some instances larger applications than this are made, particularly on light open soils or for the growth of garden or truck crops. It is not generally advisable, however, to apply more than 16 to 20 tons per acre under any soil conditions for general farm crops and larger applications should be made only in the case of special crops.

On many of the soils of this county it would be particularly undesirable to make unusually heavy applications of manure. In fact, where the soils are fairly well supplied with organic matter, care should be taken in applying the manure, as it may bring about undesirable effects, particularly on small grain crops. In the case of some of the soils of this county manure should be applied in the rotation as far away from the oats as possible in order that there may be no danger of lodging, which may occur when manure is applied immediately preceding the oats crop. The usual method is to make the application of manure to the first corn crop of the regular four year rotation and in this way no undesirable effects on the oats result.

On the grain farm where very little manure is available for use, some other source of organic matter and nitrogen must be utilized and on the average livestock farm it is quite generally impossible to keep up the nitrogen and organic matter by the use of manure alone. Under both systems of farming, therefore, there are instances where green manuring will prove a profitable practice as a supplement to or substitute for the use of farm manure.

Leguminous crops are by far the most desirable for use as green manures owing to the fact that when well inoculated they are able to utilize the free nitrogen of the atmosphere and hence when they are turned under in the soil they increase the amount of this constituent. They really act as a nitrogenous fertilizer, but they also supply large amounts of organic matter and hence may take the place, to a large extent, of farm manure. Non-legumes are sometimes used as green manures where the nitrogen content is not low and it is especially desirable to increase the organic supply. There are very few instances, however, under which non-legumes would be as satisfactory as legumes. There are so many legumes which may be grown and used as green manures that one may be chosen which will fit in with almost any rotation and with practically any soil condition.

Green manuring is not a practice which can be recommended for any extensive use in Palo Alto county, but there are undoubtedly conditions under which
the turning under of a leguminous crop or at least a portion of a leguminous crop will aid materially in keeping up the organic matter and nitrogen in the soil. Even the plowing under of a part of the clover crop of the regular rotation is somewhat of a green manuring practice and often proves of value under grain farming and some livestock farming conditions. Green manuring should never be practiced carelessly nor blindly, as it may bring about undesirable effects if not carried out properly. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The organic matter content of soils may also be kept up to a considerable extent by the proper utilization of crop residues. If such materials as straw and stover are burned or otherwise destroyed there is an actual loss of a valuable natural fertilizing material. Many farmers by following such practices actually waste a very important means of keeping their soils productive. Such materials should be used for feed or bedding on the livestock farm and returned to the soil along with the manure. On the grain farm they may be applied directly to the soil or they may be stored and allowed to decompose partially before application. Under the latter system of farming it is particularly important to utilize the residues, inasmuch as manure production is so small. Not only do crop residues supply organic matter to the soils, but they contain considerable amounts of plant food constituents and thus they may have an important effect in lengthening the life of the soil. The value of crop residues in increasing crop yields and keeping soils productive is such that they should be considered as valuable supplements to manure and green manures for maintaining the soil in the best condition for crop growth.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Palo Alto county are not extremely low in phosphorus supply, but neither is there any large amount present and it may safely be concluded that phosphorus fertilizers will be needed on these soils in the near future. Furthermore, it is quite possible that these materials may prove of value in some cases at the present time. The supply of available phosphorus may be insufficient to produce maximum crops, even although the total phosphorus content is apparently quite adequate. There is no way to determine the amount of available phosphorus in these soils with any degree of accuracy except by making applications of phosphorus fertilizer to a small area. The analyses of the soils merely indicate the total supply and it remains for actual tests to show how fast this supply is being made available for plant use. It may be calculated that there is sufficient phosphorus to supply crops for a good many years but in spite of this rather considerable total content applications of phosphorus fertilizers may give crop increases. The greenhouse and field experiments described earlier in this report indicate that this may actually be the condition in some of the soils of Palo Alto county. Phosphorus fertilizers may yield profitable increases in crops at the present time. Field tests with these materials are under way and will permit of definite conclusions after several years' results have been secured. For the present it can only be urged that farmers test the value of phosphorus on their own soils.

If phosphorus fertilizers prove profitable, the next question which arises is which particular fertilizer should be used. Acid phosphate and rock phosphate
are the two common sources of phosphorus and considerable interest has centered around the selection of one of these materials. Acid phosphate is a commercial manufactured fertilizer in which the phosphorus is available and ready for plant use. Rock phosphate is a natural product and the phosphorus contained in it must be acted upon by certain agencies before it is of use to crops. Acid phosphate costs considerably more than rock phosphate but the latter material must be applied in very much larger amounts. Acid phosphate is applied annually in the spring while rock phosphate should be applied in the fall and in the regular four year rotation is usually plowed under with clover. If manure is applied to the soil and the general conditions in the soil are satisfactory, the phosphorus in rock phosphate may be changed to an available form very rapidly.

The experiments which are now under way in Palo Alto county are testing the value of these two phosphorus carriers and when definite results are secured the choice of the material to be used will depend upon the cost of the application and the value of the crop increase, taking into account the use of rock phosphate only once in four years and the application of acid phosphate annually. Farmers may test the use of these two materials on a small scale on their own farms and determine quite readily which material should be used. Directions which may be followed in carrying out simple tests with the use of these fertilizers are given in circular 51 of the Iowa Agricultural Experiment Station and farmers who are interested in carrying out such tests may secure further advice and information if they will write to the Soils Section.

The nitrogen content of the soils of Palo Alto county is extremely variable but in most cases the soils are very well supplied. It should not be assumed, however, that the amount present is sufficient so that crops may be grown indefinitely and nitrogen removed continually without reducing the fertility of the soil. Nitrogen may disappear very rapidly from soils by the removal of crops and by the washing away of soluble nitrates in the drainage water. Hence it is very important that the nitrogen content of soils be kept up thru the use at regular intervals of some nitrogenous fertilizing material. Farm manure and crop residues reduce the loss of nitrogen from soils when they are properly utilized and very often some other nitrogenous fertilizer must be employed to increase the nitrogen in the soil. When this is true, leguminous green manures should be used. They are the cheapest and most satisfactory nitrogenous fertilizers. Commercial nitrogenous fertilizers cannot be recommended for general farm crops. They may be of value in some instances as top dressings or for the growth of special crops but there is probably no case in which they should be used in this county. Legumes when well inoculated take their nitrogen from the air and hence when a portion or all of a legume crop is turned under in the soil there may be an increase in its nitrogen content. If a legume is used in a rotation under any system of farming, and every satisfactory rotation should contain a legume, there should be some addition of nitrogen to the soil. If the legume is used for hay then the nitrogen in it which was obtained from the atmosphere will be returned in large part in the manure. If a portion of the crop is turned under in the soil there will be an increase in nitrogen corresponding to the size of the crop. If only the seed of the crop is removed, there may be a
very large gain in nitrogen through its growth. The proper selection and utilization of legumes is the solution of the nitrogen problem and permanent fertility and for the soils of this county the nitrogen content may be kept up through the proper growing and handling of the legume crops of the rotation.

Analyses of a large number of soils of the state have shown that potassium is present in large amounts in practically all cases and it is very unlikely therefore that potassium will be needed on the soils of Palo Alto county for many years to come. If desirable physical conditions are maintained in the soil, the production of available potassium will be entirely adequate to keep crops supplied almost indefinitely. The proper drainage of the soils is a very important factor in insuring the satisfactory production of available potassium. The proper aeration of the soil which is accomplished by drainage and the use of farm manure and lime is the second factor of significance. The addition of organic matter to the soils is a third factor which should be taken into account. When drainage, aeration and organic matter supply are adequate, bacterial activities are increased and the production of available potassium will proceed rapidly. There may be instances where a potassium fertilizer would bring about some crop increase but this is very unlikely to be the case anywhere in Palo Alto county. If such materials are tested on a small scale, however, and show economic value, they may be utilized on larger areas without injury to the soil.

Complete commercial fertilizers cannot be recommended at the present time for use in this county. Nitrogen may be supplied by legumes and potassium is present in such large amounts that it seems very unlikely that complete fertilizers containing these two elements along with phosphorus would prove as economically desirable as phosphorus carriers. However, the field tests in the county include the use of a complete fertilizer and definite results will be obtained later which will show how such materials compare with acid phosphate and rock phosphate. Farmers may test these materials on their own soils if they are interested, making an application to a small area and comparing the effects on crop yields with those secured from the use of acid phosphate. If the complete fertilizers show more profit than the phosphorus fertilizer then the former may be used without fear of injury to the soil. They are not recommended for general use but there is absolutely no objection to their use if profitable returns are secured.

**LIMING**

Many of the soils of Palo Alto county are basic in reaction and not in need of lime. The Clarion loam, however, the most extensive soil type in the county, is slightly acid in the surface soil and the same condition exists in the Clarion fine sand. The two O’Neill soils on the terraces are likewise acid in reaction and the Webster loam and the Cass loam show almost a neutral reaction. In practically all these cases with the exception of the two O’Neill soils, the lower soil layers are well supplied with lime. This, however, does not mean that lime should not be applied to these soils when they are acid at the surface. Lime rarely moves upward in the soil and the amount present in the lower soil layers has very little influence on the surface soil. It is very necessary that the surface soil of the main upland types in the county be tested for acidity or lime require-
ment and if the most satisfactory crops are to be secured, particularly of legumes, the amount of lime shown to be necessary according to the tests should be applied.

There is a continual removal of lime from the soil by utilization by crops and by leaching and even altho the soil may not show acidity at the present time, the need of lime may become evident in the future, hence tests for acidity should be made at regular intervals, at least once in the ordinary four year rotation.

The figures given in the tables should be considered to indicate merely that the soils which are acid in this county require only comparatively small amounts of lime. Applications of lime to these soils should be made only after tests have been made on the individual soils. The acidity in soils is so extremely variable that even average figures of many tests will not show the needs under any one particular soil condition.

These Palo Alto county soils which show an acidity according to the tables and including the Clarion loam, the Webster loam, the Clarion fine sand, the O'Neill fine sandy loam and the O'Neill loam, should all be tested at regular intervals for acidity and lime should be applied as needed if the best yields of crops are to be secured, particularly of legumes such as clover and alfalfa. Farmers may test their own soils and determine the lime requirement but it will be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they will be able to apply the proper amount of lime and avoid the use of an insufficient amount or an excessive application. One test for soil needs should not be considered sufficient but the soils should be tested at regular intervals and the supply of lime kept up thru regular applications.

The beneficial effects of lime on soils have been shown by many experiments and much field experience. Legumes are very largely benefited by this material but in many cases other crops are increased to a considerable extent also. The experiments which have been discussed earlier in this report show some beneficial effects from lime on the various crops of the rotation and while, therefore, this material is needed to a much less extent in Palo Alto county than in many other sections of the state, whenever the soils are acid, lime should be applied and must be applied if the best crop growth is to be secured and the soils of the county are to be kept in a high state of productivity.

DRAINAGE

Drainage is probably one of the most important treatments needed for many of the soils of Palo Alto county. The fact that there are large areas of inadequately drained land has been mentioned earlier. The drainage map given in this report shows very definitely that there are considerable areas of gently undulating to flat land from which the excess moisture is not removed sufficiently rapidly. Under such soil conditions crop growth is not satisfactory and in fact in some seasons crops may fail completely. The upland soils of the Webster series are characterized by a level topography and particularly in the case of the Webster silty clay loam the drainage is very poor. The Clarion loam is ordinarily fairly well drained but the Webster loam and the Webster silt loam
are quite generally in need of tiling especially where the areas are flat. The bottomland types of the Lamoure and Wabash series are in need of drainage as are also the areas of peat and muck. The Rogers silt loam is also in need of drainage. In fact the only types in the county which are really entirely adequately drained are the O'Neill types and the Clarion fine sand. In many instances tiling is very necessary to bring about satisfactory crop production on these soils. In some instances ditching may be needed in order to provide outlets for the tile.

Considerable drainage work has been done in the county and large areas of land have been rendered highly productive. There is considerable evidence, therefore, that the expense of drainage even tho considerable is well warranted when the value of the crops grown is taken into account. No other treatment will take the place of drainage and other treatments will not bring about satisfactory effects if drainage conditions are unsatisfactory. In general it should be emphasized that the first treatment needed by many of the soils of Palo Alto county is adequate drainage and when this is true, tiling out of these areas should be done if satisfactory crop yields are to be secured.

THE ROTATION OF CROPS

The natural fertility of all soils is very rapidly reduced by the continuous growing of any one crop. From year to year there is a gradual removal of fertility and this is accompanied by a gradual decrease in the value of the land. The result, therefore, is to decrease the income of the farm and to reduce its value. A proper rotation of crops will prevent this reduction in fertility to a very large extent. Occasionally a particularly profitable crop is grown continuously and it is believed that the practice is of monetary advantage to the farmer. Such, however, is not the case. Experiments have shown that the rotation of crops actually brings in more money to the farmer than the continuous growing of any one crop. This is due to the fact that the crop yields are reduced so rapidly under continuous cropping. No particular experiments were carried out with crop rotations in Palo Alto county, but the following rotations may be given, as they are common in the state and have generally given very satisfactory results. Various modifications of these rotations are practiced and almost any rotation may be employed provided it contains a legume and the most profitable crops.

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. (This crop may remain on the land five years, and the fields 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 PALO ALTO COUNTY*

There are thirteen individual soil types in Palo Alto county and these together with the gravelly subsoil phase of the Clarion loam and an area of peat and muck make a total of fifteen separate soil areas. They are divided into three large groups according to their origin and location and these groups are known as drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are seven drift soils in the county and one phase, making a total of eight drift soil areas. They are classified in the Clarion, Webster and Rogers series and together they cover a total of 70.6 percent of the area of the county.

CLARION LOAM (138)

The Clarion loam is the most extensive individual soil type in the county as well as the largest drift soil. Together with the gravelly subsoil phase, which is very minor in extent, it covers 37.7 percent of the total area of the county.

It occurs in typical areas in all parts of the county occupying about one-half of the total upland area in the southwest quarter of the county. In the area northeast of the West Fork Des Moines river it occurs in relatively small areas on the uplands which are typically covered with the Webster series.

The surface soil of the Clarion loam is a brown to dark brown mellow loam 16 to 20 inches in depth. The subsoil is a grayish-brown to grayish-yellow heavy fine sandy loam to clay loam. In the lower subsoil there are frequently faint gray mottings or a solid gray color. Near Fairville and Depew, as well as in the vicinity of Lost Island and Virgin Lakes, the surface soil has lighter color and may approach a very fine sandy loam in texture. In the western townships which are in the morainic area, the surface soil is a lighter brown to brown loam, 12 to 18 inches deep, underlaid by a friable clay loam to fine sandy clay loam. Boulders, stones and gravel frequently occur on the surface and throughout the three foot section. In the northwestern part of the county where the topography is more rolling, the surface soil is shallower and the gray glacial till appears within the three foot section. Nearly everywhere throughout the lower subsoil shows a sufficient lime content to effervesce with acid. There are included within this type very small areas of the Clarion fine sandy loam and the gravelly subsoil phase of the Clarion loam which are too small to separate on the map.

In topography this soil is generally undulating to rolling. In the northwestern part of the county along the Emmet county line, the topography is strongly

*The description of individual soil types given in this report very closely follow those given in the Bureau of Soils report.
rolling. Likewise near streams and lakes there are some strongly rolling areas. Practically all of the Clarion loam is well drained and is not in need of tiling.

This soil is typically a prairie soil and the forested areas are confined to a few narrow belts of maple, willow, ash, walnut, cottonwood and oak along the river and to areas which have been planted for windbreaks. Practically all of the type is in cultivation or pasture. Corn, oats and hay are the most important crops grown. Corn is grown most extensively and yields on the average 35 to 60 bushels per acre. Some of the crop grown is sold but the major portion is used for feeding hogs, cattle and work stock. Oats are grown to a considerable extent with average yields of 35 to 60 bushels and much of this crop is used for feeding purposes, only a comparatively small portion being sold out of the county. Barley, rye, wheat, millet, sorghum, apples and all kinds of garden truck are grown by most of the farmers chiefly for home use. A small amount of the barley and rye and all of the wheat is sold and shipped out of the county. Rape is frequently seeded in the corn and used for feeding in the hogging down process. Alfalfa is grown occasionally but the chief hay crop consists of clover and timothy. Average yields of hay amount to 1 1/2 tons per acre and the crop is practically all utilized for feeding purposes.

The Clarion loam is naturally a rather rich productive soil but increased crop yields may be secured and the soil kept more highly productive if proper methods of treatment are followed. The supply of organic matter is not extremely high and applications of farm manure would be of value in most cases. If farm manure is not available, then the leguminous crop in the rotation should be utilized, at least in part, as a green manure, and in some instances it would undoubtedly be desirable to make use of the entire crop in this way. The nitrogen content may be increased thru the use of a legume and it is very necessary that some means be taken to increase and maintain the nitrogen supply in the soil. The surface soil of the Clarion loam is usually acid in reaction and altho in most cases the lower soil layers are well supplied with lime, if the surface soil is acid the amount of lime shown to be necessary according to the test should be applied. It is very advisable that this soil be tested for lime requirement at regular intervals if it is to be kept in the best reaction for the growth of crops and particularly of legumes. The amount of phosphorus present in the soil is not very large and it would seem that applications of phosphorus fertilizers might be of value at the present time. They will undoubtedly be needed in the near future inasmuch as the total supply is decreasing and there is little possibility of the required available phosphorus being produced sufficiently rapidly in all cases. The field experiments which are located on this type have not yet yielded results and hence definite recommendations regarding the use of phosphorus and also regarding the particular phosphorus fertilizer which should be used, cannot be given. It is urged, however, that every farmer who is interested test the value of acid phosphate and rock phosphate on his own soil and thus determine for his own conditions the need and value of this material. Later the results of the field experiments will be available and more definite recommendations can undoubtedly be made. There is probably no need of applications of complete commercial fertilizers to this soil type and hence these materials are not recommended for use at the present time. If tests on a
small area show them to be of value, they may be used, however, without fear of injury to the soil. Nitrogen may be supplied in considerable amounts by the growth of inoculated legumes and potassium is present in practically all cases in very large amounts. It would seem quite certain that phosphorus fertilizers would prove quite as valuable as the more expensive complete brands.

CLARION LOAM (Gravelly Subsoil Phase) (147)

This is a very minor type in the county, covering less than one percent of the total area. It occurs in small disconnected areas on the crests of ridges mainly in the northwest part of the county where the more rolling to rough areas of the upland are found. Several areas are found in Highland township and in Lost Island township and there are areas south of Graettinger and west of the river in Walnut township. There are a few small areas east of the West Fork Des Moines river and a few in the southern part of the county, especially in the vicinity of Rush Lake.

The surface soil of this phase is a light brown to brown light textured loam 7 to 9 inches in depth. The subsoil is a pale yellow to brownish-yellow fine sandy loam to fine sandy clay loam, faintly mottled with gray. Gravel appears throughout the subsoil and on the tops of the hills in the rougher areas the glacial till often appears in the three foot section. In topography the soil varies from rolling to strongly rolling and the drainage is good to excessive.

The larger part of this soil is utilized for pasture and only the areas on the more even slopes and rounded hills can be cultivated. It makes a good pasture soil and in the rougher portions it is probably most satisfactory when used in this way. When farmed along with the typical Clarion loam lower yields are secured. This is the only type in the county which is subject to erosion but when cultivated in the rougher areas there may be considerable washing. This would indicate the desirability of keeping such areas in pasture or in uncultivated crops. Contour plowing should also be practiced in order to prevent washing and probably in most cases cover crops should be grown. Other treatments which are needed when this soil is cultivated to make it more productive are the application of manure, or the turning under of leguminous crops as green manures. The use of phosphorus might prove of value and when the surface soil is acid lime should be applied.

WEBSTER LOAM (55)

The Webster loam is the second largest soil area in the county covering 28.0 percent of the total area of the county. It is found mainly in the northeastern part of the county and is the chief upland type in the entire area east of the West Fork Des Moines river. There are, however, many other areas of the Webster loam south and west of the river, occurring on the uplands in connection with the Clarion loam. This type is of particular importance in Ellington, Rush Lake and Great Oak townships.

The surface soil of the Webster loam is a very dark brown to black heavy loam 15 to 18 inches in depth. The subsoil is a grayish-brown to drab silty clay mottled with gray, yellow and brown. In some areas there is a subsurface layer between 18 and 22 inches which consists of a dark brown to almost black heavy loam to silty clay loam. There are small bodies of Webster silt loam and silty
clay loam which are included with this type as they are too small to be shown separately on the map. In the more level portions the surface soil is somewhat higher in clay and more sticky when wet.

In topography the Webster loam is very gently undulating to gently rolling. The more level topography and heavy subsoil have brought about poor drainage conditions and this type is very frequently in need of tiling in order to permit of satisfactory crop growth. Usually when adequate drainage is accomplished crop yields are very satisfactory.

Practically all of this soil is devoted to the growth of crops. Corn, oats, and hay are the chief crops grown and of these corn is by far the most important. It yields 35 to 40 bushels per acre on the average while under favorable seasonal conditions, yields of 80 to 90 bushels are secured. Much of the corn produced is utilized on the farms for feeding. Some of it is used for ensilage. The surplus is sold to the local elevators. Oats yield 35 to 50 bushels per acre and are largely used for feeding stock on the farms. The hay crop consists principally of clover or clover and timothy mixed and yields of 1 to 1 1/2 tons per acre are secured. The entire crop of hay is utilized for feeding purposes. Small areas are utilized for growing wheat, rye, flax, barley, millet, sorghum, and rape. The wheat and flax grown are all sold out of the county. Rye is used principally for spring pasturage, while barley, millet, and rape are used entirely in this way. Some of the sorghum produced is used for making syrup.

The Webster loam is a rather productive soil but crop yields may be increased thru proper treatments. It will respond to small applications of farm manure and this material or leguminous green manures should be used to keep up its content of nitrogen and organic matter. If it is acid in the surface soil as occasionally happens, applications of lime should be made. Ordinarily, however, it is not in need of lime. Phosphorus fertilizers may prove of value in certain cases and tests of rock phosphate and acid phosphate on the type are very desirable. The chief need of this soil is for more adequate drainage. In the more level areas particularly, the installation of tile is a very important operation and very necessary if the yields of all crops are to be satisfactory. This is particularly true of course in seasons of high rainfall. After the tiling of these areas has been accomplished it is often very desirable to make a small application of farm manure to stimulate the production of available plant food and insure the satisfactory feeding of the future crop.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is a minor type in the county covering 2.8 percent of the total area. Like the Webster silt loam it occurs mainly in the north-eastern part of the county in the area just east of the West Fork Des Moines river. There are small scattered areas of the type, however, throughout the portion of the county east of the river and a few areas are found west of the river in the southern part of the county. It occurs in comparatively small disconnected borders on the flatter sections of the uplands or on the slopes to the drainage-ways. It is found chiefly in association with the Webster loam of the upland.

The surface soil of this type is a very dark brown to black silty clay loam 14 to 16 inches deep. The subsoil is a yellowish-brown, drab or yellow tenacious
silty clay loam to silty clay mottled with gray and yellow. Boulders appear throughout the type both in the surface soil and subsoil.

In topography it varies from undulating to gently sloping and natural drainage is deficient. Probably 85 percent of the Webster silty clay loam is in cultivation. The undrained areas are left in native grasses which are either pastured or cut for hay. The only trees growing on this type are a few willows. Corn is the most important crop grown on the cultivated portion of the type and yields from 35 to 60 bushels per acre on well drained areas. Oats is a second crop of importance yielding from 40 to 50 bushels per acre. Iowa 105 and Iowa 103 are most desirable for use on this type as they are less apt to lodge. A large part of the corn produced and practically all of the oats is used for feed on the farm. Flax, which is occasionally grown on sod ground, produces from 8 to 12 bushels per acre. Wheat, barley and rye are grown to some extent.

The Webster silty clay loam is chiefly in need of drainage in order to make it more productive. When this is accomplished yields of general farm crops are quite satisfactory. Small applications of farm manure would be of value on newly reclaimed land and this material should be utilized regularly to keep up the organic matter supply. Applications of phosphorus fertilizers might be of value in some cases and tests of rock phosphate and acid phosphate are very desirable. This soil is basic in reaction at the present time and probably will not be in need of lime for years to come. Drainage is a factor of chief importance here and large crop yields are frequently secured on otherwise unproductive areas by the mere installation of a line of tile.

WEBSTER SILT LOAM (113)

The Webster silt loam is a minor type in the county covering 1.7 percent of the total area. It occurs mainly in small disconnected areas scattered throughout the Webster upland in the eastern part of the county and in the southern part of the county south and west of the West Fork Des Moines river. The largest area is west of Cylinder along the county line. There are only a very few almost insignificant areas west of the river.

The surface soil is a black heavy silt loam 8 to 12 inches in depth. The subsoil is a black silty clay loam to silty clay which grades at 22 to 24 inches into a mottled yellow, grey and brown plastic silty clay. It is typically high in content of lime and numerous iron stains occur throughout the soil. In many cases the surface material for a depth of 1 to 2 inches consists of a black fibrous muck which indicates a relatively high content of organic matter and explains the analyses given earlier in this report which showed an unusually high content of organic carbon and nitrogen in this particular type. This mucky surface condition is peculiar to the Webster silt loam in this county and hence the analyses are not representative of the same type in other counties. Boulders occur throughout the soil and subsoil. In topography the Webster silt loam is flat to gently sloping and the natural drainage of the soil is poor.

Only the few small areas of the type where artificial drainage has been installed are in cultivation. In these areas corn and oats are the principal crops grown, corn yielding 30 to 40 bushels per acre and oats 35 to 45 bushels. There are small acreages also in barley, flax and rye. The larger part of the type is
uncultivated and grows chiefly wild grasses most of which are cut for hay which is used for feed on the farms.

The Webster silt loam is a particularly rich productive soil when drained but satisfactory cultivated crops cannot be grown until thorough drainage is established. It is high in organic matter and nitrogen and abundantly supplied with lime, hence additions of organic materials and lime are not necessary at the present time except that small applications of farm manure would be of value on newly drained areas in stimulating decomposition and the production of available plant food. The phosphorus content is not particularly high and phosphorus fertilizers might be of value on this type when cultivated crops are grown.

**CLARION FINE SAND (148)**

This is a very minor type in the county, covering 0.2 percent of the total area. It occurs in narrow strips along the West Fork Des Moines river separating the uplands from the river-bottoms. The largest area extends from near Osgood in a narrow strip south for almost three miles. There are other very much smaller areas of the type occurring in similar positions along the edge of the uplands bordering the West Fork Des Moines river.

The surface soil of the Clarion fine sand is a light brown to grayish-brown fine sand 18 to 20 inches in depth and underlaid by a yellow loose textured fine sand. The topography of the type is gently undulating to rolling and the areas are 20 to 30 feet above the level of the river flood plains. Drainage is very satisfactory.

All of the type is under cultivation, the principal crops grown being corn, oats, wheat and clover. The yields of these crops are slightly less on the average than those secured on the Clarion loam. This soil is chiefly in need of organic matter in order to make it more productive and should receive liberal applications of farm manure and in many cases leguminous green manures would undoubtedly prove of value. It is acid in reaction in the surface and applications of lime should be made as shown to be necessary by tests. The phosphorus supply is not high and applications would probably prove of value for general farm crops. It should be emphasized, however, that the use of farm manure and the turning under of leguminous green manures to supplement the former, are practices of particular significance on this type.

**ROGERS SILT LOAM (140)**

The Rogers silt loam is a very minor type in the county, covering only 0.1 percent of the total area. It occurs in the beds of former shallow lakes which have been drained and only two areas are mapped in this county, one just south of Ruthven and the other south of Mallard.

The surface soil of this type is a grayish-brown to gray silt loam 18 to 20 inches deep, smooth and velvety when wet and having a floury structure when thoroughly dry. The subsoil is a greenish-brown to brownish-gray silt loam. There is a very high content of lime throughout the soil both surface and subsoil. In topography it is practically level and drainage is inadequate. About one-half of the type has been brought under cultivation, the remainder supporting a growth of water-loving grasses which are used for hay.
The chief need of this type to make it more productive is thorough drainage and cultivation and with these treatments satisfactory yields of most crops should be secured. Probably a small application of farm manure would aid when the land is newly tilled out. Eventually phosphorus fertilizers will prove of value when cultivated crops are being grown but for the present the only recommendation for the soil is adequate drainage.

CLARION FINE SANDY LOAM (149)

The Clarion fine sandy loam is of very minor importance in the county covering only 0.1 percent of the total area. It occurs only in small areas in the western part of the county along the Clay county line. Toward the east the type changes in texture and merges into the Clarion loam. The soil is developed to a considerable extent in Clay county and the areas in Palo Alto county are continuations of those found in Clay. Several areas of this type are included with the loam because of their small extent.

The surface soil of this type is a dark brown sandy loam extending to a depth of 8 to 10 inches. This rests upon a grayish-brown rather compact fine sandy loam which below 24 inches grades into a light brown fine sand or a grayish-yellow silt loam very much like the subsoil of the Clarion loam. If the lower subsoil is very sandy it may not show a high lime content. In general, however, there is a large amount of this material in the lower layers of this type.

This soil occurs on low ridges and hills and the drainage is entirely adequate. About 80 percent is cultivated, the remainder being in pasture. The same crops are grown as in the case of the Clarion loam and the yields secured are very much the same. The soil is acid at the surface and in need of lime especially for the growth of legumes. It will respond to applications of farm manure and if this material is not available leguminous green manures should be used in order to build up the supply of organic matter and nitrogen. It would probably also respond to applications of phosphorus fertilizers. The general treatments recommended for the Clarion loam would apply to the Clarion fine sandy loam.

TERRACE SOILS

There are two terrace types in the county, both belonging in the O'Neill series. Together they cover only a small proportion of the total area, 3.3 percent.

O'NEILL FINE SANDY LOAM (110)

The O'Neil fine sandy loam is comparatively small in area in the county covering but 1.7 percent of the total area. It occurs in several areas along the West Fork Des Moines river, the largest being found near Graettinger, Osgood and Emmetsburg. In the southern part of the county the type occurs in numerous small areas. It is found on the terraces 15 or 20 feet above overflow.

The surface soil consists of 12 to 16 inches of brown to dark brown loamy fine sand or fine sandy loam. The subsoil is a light brown to a yellowish-brown loose textured fine sandy loam passing into layers of sand and gravel below 20 to 26 inches. In some areas the surface soil grades directly into a light brown to yellowish-brown loamy sand which in turn passes into the sand and gravel at about 24 inches. A few areas of the O'Neil loam too small to show on the
map are included within this type. In topography it is level to gently sloping, drainage is excessive and crops are apt to suffer from drought.
About 80 percent of the type is in cultivation, the remainder being used for pasture which is largely made up of wild grasses. Corn is the chief crop grown and oats is second in acreage. Some rye is produced. Corn yields 20 to 25 bushels per acre, oats 30 to 42, and rye 22 to 37 bushels. A small amount of popcorn is grown on this type also.
The chief need of this soil to make it more productive is the incorporation of organic matter. Liberal applications of farm manure are very desirable and where this material is not available in sufficient amounts leguminous green manure crops should be employed. Building up the soil in this material makes it less drouthy and hence insures better crop production. The nitrogen content may also be kept up in this way. Phosphorus fertilizers would probably prove of value in some cases now and certainly will be needed in the near future.

**O'NEILL LOAM (108)**

The O'Neill loam is very similar in size to the fine sandy loam, covering 1.6 percent of the total area of the county. It occurs in numerous areas on the terraces of the West Fork Des Moines river and along Cylinder, Pilot and Beaver creeks. The largest area is along Cylinder creek, extending north for four miles from Cylinder. The second largest area is directly west of Emmetsburg. The remaining areas of the type are rather small and of minor importance.
The surface soil of this type is a dark brown to chocolate brown light textured loam 8 to 10 inches in depth. The subsoil is a reddish-brown to yellowish-brown sandy loam grading at 18 to 24 inches into a layer of yellow sand or sand and gravel. There are a few areas of the fine sandy loam included in this type as they are too small to show separately on the map. The topography of this soil is slightly sloping and it occurs 2 to 5 feet above the adjacent bottomland. The drainage of the type is adequate to excessive and crops may suffer for moisture in dry seasons.
About 95 percent of this soil is under cultivation. The principal crops grown are corn and oats. In favorable seasons corn yields 20 to 40 bushels per acre, oats 30 to 42, and rye 22 to 37 bushels. A small amount of popcorn is grown on this type also.

The chief need of this soil to make it more productive is the incorporation of organic matter. Liberal applications of farm manure are very desirable and where this material is not available in sufficient amounts leguminous green manure crops should be employed. Building up the soil in this material makes it less drouthy and hence insures better crop production. The nitrogen content may also be kept up in this way. Phosphorus fertilizers would probably prove of value in some cases now and certainly will be needed in the near future.

**Fig. 6.** A typical Palo Alto county farmstead. Lamoure silty clay loam in foreground.
acre and oats 30 to 40 bushels. In dry seasons these crops may fail almost completely. Wheat, rye, millet, sorghum, popcorn and potatoes are produced on a small scale, chiefly for home use.

This soil is particularly in need of organic matter in order to make it more productive and to reduce the injurious action of dry seasons. Liberal applications of farm manure are very necessary or leguminous crops should be used as green manures in order to build the soil up in nitrogen and organic matter. It is acid in reaction and should be limed. The phosphorus supply is low and additions of phosphorus fertilizers might prove of value at the present time and will undoubtedly be needed in the near future.

**SWAMP AND BOTTOMLAND SOILS**

There are four swamp and bottomland types in the county and one area of peat and muck, making five soil areas. These are classed in the Lamoure, Wabash, and Cass series and the areas of peat and muck are not separated, but are mapped under the combined name. The combined area of swamp and bottomland soils in the county amounts to 26.1 percent of the total area.

**LAMOURE SILTY CLAY LOAM (111)**

The Lamoure silty clay loam is the most extensive bottomland type in the county and it is the third largest soil type, covering 14.4 percent of the total area. It is developed in many small areas in all parts of the county along the main streams, the tributaries and the intermittent drainageways. It is usually found in narrow areas following the course of the streams and drainageways, although in many instances it occurs in depressed areas in the upland where drainage is deficient or actually lacking. The largest single areas of this type are one mile east of Medium Lake and east of Cylinder. There is also a rather extensive continuous irregularly shaped area east of Curlew and extending north and south along Beaver creek and some of the intermittent drainageways which join this creek. The greater portion of the type, however, is found in very small strips or disconnected areas.

The surface soil of the Lamoure silty clay loam is a black silty clay loam to heavy silt loam extending 12 to 16 inches in depth. The subsoil is a yellowish-brown, drab or mottled gray, yellow and brown silty clay loam showing iron stains at the lower depths in many areas. The subsoil is usually high in lime content and occasionally the surface soil is also well supplied. In some areas the lime content is very low or lacking in the surface soil and even the subsoil may give only a faint indication of lime. Within this type there are many minute areas of the Lamoure silt loam which are so small that they could not be shown separately on the map. In the depressions or pond-like areas in the uplands where drainage is particularly poor, the surface soil is almost black in color and contains a particularly large amount of organic matter. In fact, there may be an inch or more of dark brown peat or black fibrous muck. The surface soil texture in these areas is a silt loam to a silty clay and the black color may extend to a depth of 3 feet or more. The topography of the Lamoure silty clay loam is generally flat with a slight slope toward the streams. The areas are subject to overflow and drainage is very poor.
Very little of the type has been reclaimed by drainage and brought under cultivation. The greater part of it is utilized for producing wild hay. Corn and oats are grown to a small extent, corn yielding 30 to 50 bushels per acre and oats 30 to 55 bushels. In favorable seasons corn may yield more than on the adjacent uplands. Many oat varieties are unsatisfactory owing to lodging but Iowa 103 and Iowa 105 may be grown successfully. Some buckwheat has been grown and flax is sometimes utilized on newly reclaimed land.

The Lamoure silty clay loam is naturally a very productive soil after it has been drained. At least in seasons of normal rainfall yields of cultivated crops may be entirely satisfactory. Such land, however, must be adequately drained before being utilized in any way for cultivated crops. It should also be protected from overflow and when these operations are followed yields of general farm crops should be entirely satisfactory without other special treatment. A small application of farm manure might be of value on newly drained areas to stimulate the production of available plant food. The soil is usually high in lime but if in any case this is not true and it shows an acid reaction, lime should be added. Phosphorus fertilizers will be needed in the future when the soil is brought under cultivation and crops are being removed annually.

WABASH SILTY CLAY (27)

The Wabash silty clay is the second largest bottomland type in the county and the fourth largest individual type, covering 3.8 percent of the total area. It occurs mainly along the West Fork Des Moines river with a few small areas along Prairie creek, Cylinder creek, Jack creek and near the head of Medium lake. There is one continuous area of this type along the West Fork Des Moines river extending from the northern boundary of the county near Graettinger to a point three miles west of Rodman and another area extending from a point south of Rodman and following the course of the river until it flows out of the county on the Pocahontas line. These areas are extremely irregular and variable in width, in some cases being very narrow and widening out to a width of almost two miles just south of Emmetsburg.

The surface soil of this type is a dark brown to almost black silty clay, 12 to 15 inches in depth. It is underlaid by a dark slate or black waxy clay in some places faintly mottled with yellow and gray below 24 inches. There are some variations of this type along Prairie creek, from West Bend south. The surface soil here is almost a silt loam and the subsoil is a gray to dark brown silty clay. In the area three miles west of Rodman there are small areas included in the type where the surface soil is lighter in texture than the typical and the subsoil passes into a sandy loam or loamy sand below 30 inches. The surface of the soil is uniformly flat with a slight slope toward the stream. It lies from 8 to 12 feet above the normal water level of the river. Natural drainage is poor and the soil is subject to overflow.

About 10 percent of the type is in cultivation, the larger part being utilized for pasture or for the production of wild hay. A few forested areas are found along the river, the tree growth consisting principally of elm, oak, willow, and ash. Hay is the most important crop and yields of 1 to 1 1/2 tons per acre are secured. Corn is grown to some extent on the cultivated portion and in favor-
able seasons very satisfactory yields are obtained. Flax is sometimes grown on newly broken sod land and yields 8 to 10 bushels per acre.

The Wabash silty clay is principally in need of drainage and protection from overflow to make it a satisfactory soil for the growth of general farm crops. Drainage is absolutely essential and satisfactory crop yields cannot be insured unless the type is protected from overflow. Care must be taken in plowing and cultivating this soil to do so when it is not too wet or too dry, as in either case the physical condition of the soil will be injured. Small applications of farm manure would probably be of value on newly drained areas of this type. It is quite generally acid and should be limed. Phosphorus fertilizers will certainly be needed in the future and might be of value in certain cases even now. This type is naturally rich and with proper drainage and handling, very large crop yields may be secured.

CASS LOAM (18)

The Cass loam is the third largest bottomland type in the county being slightly smaller than the Wabash silty clay and covering 3.6 percent of the total area. It occurs in many areas of varying size along the West Fork Des Moines river and along Cylinder, Prairie and Pilot creeks. The largest continuous area is found along the course of the river west of Rodman. The second area of considerable size is found to the west of the river two miles south of Emmetsburg.

The surface soil of this type is a dark brown to black loam extending to a depth of 10 to 15 inches. The subsoil is a yellowish-brown sandy loam to sandy clay loam which grades into a layer of sand or sand and gravel below 30 inches. In some cases the surface soil is a black heavy loam to silty clay loam while in others the texture approaches a fine sandy loam. These variations from the typical soil are too small to show separately on the map. In its native state the surface of the soil is covered with a layer of black muck, 1 to 2 inches in depth. The stratified sand and gravel layer, which is characteristic of the Cass series, always occurs within the 3 foot section. The soil is level to gently sloping in topography and drainage is not entirely adequate. It is subject to overflow and unless protected from flood water cannot be utilized for general farm crops with any assurance of securing a satisfactory crop yield.

Only a small portion of the Cass loam is farmed, the greater portion of it being utilized for pasture or the production of hay. There are a few wooded areas, the tree growth consisting mainly of elm, maple and willow. In the cultivated areas corn, oats and flax are the principal crops, the latter being grown on newly-broken sod ground. There are also small acreages of barley, rye and buckwheat. By far the largest acreage is taken up by the hay, the greater portion of which is fed on the farms, but there is some sale of this product out of the county. On well drained areas corn yields on the average 30 to 50 bushels per acre, oats 30 to 45 bushels, flax 8 to 10 bushels and hay from 1 to 1½ tons per acre.

When protected from overflow and well drained, this type is quite satisfactorily productive. Small applications of farm manure would be of value when the type is newly drained and additions of lime would be of value when the soil shows an acid reaction which it ordinarily does and phosphorus fertilizers may
prove of value in some cases now but will undoubtedly be needed in the near future. The chief need of the type, however, is for drainage and protection from overflow.

PEAT AND MUCK (21)

There are numerous areas of peat and muck in all parts of the county, together covering 2.8 percent of the total area. They occur in depressed areas in the uplands and along intermittent drainageways where the drainage has been very poor and where probably in the past small lakes occurred. The largest individual area is found north of Lost Island lake. Peat and muck are not differentiated in this county, many areas showing the occurrence of peat in the center with an area of muck surrounding it.

Peat is a brown fibrous mass of partially decomposed vegetation. The material in the county is extremely variable depending upon the amount of decomposition it has undergone. In most of the areas it is 18 to 24 inches deep although in a few instances it has been found to extend to a depth of 3 feet. The subsoil material is a black silty clay to brownish-gray fine sand or sand. Where the decomposition of peat has been so extensive that the material has become black in color and the structure of the plants going to make up the deposit has disappeared, the material is called muck. The areas of muck could not be mapped separately in this county owing to their small extent and hence they are all grouped under the combined head. The topography of peat and muck areas is flat and in many instances water remains on them for long periods. These areas are indicated on the map as ponds.

When these areas of peat and muck have been drained and cultivated for a few years they may be utilized for the production of general farm crops. Alsike clover and timothy are recommended as the most desirable crop on newly reclaimed areas. This crop may be utilized for hay or for pasture, the latter being preferable, as the trampling of the stock will compact the peat and bring it
more quickly into decomposition. Oats are apt to lodge and corn will not do well until the peat areas have been under cultivation for several years. Rye grows well on reclaimed peat and potatoes also produce satisfactory crops. Onions, celery, cabbage, lettuce and some other vegetable crops are grown successfully on cultivated peat areas.

The chief treatment needed for areas of peat and muck is adequate drainage. Proper cultivation is then necessary. Fall plowing and deep plowing are recommended. Farm manure should not be applied except in very small applications to stimulate decomposition processes and the production of available plant food. Lime is not needed, as the peat is usually extremely well supplied with this material. The phosphorus content of peat is low and the application of phosphorus fertilizers may be of value in some cases and the use of special fertilizer brands may be very desirable where truck crops are to be grown.

CASS SILT LOAM (106)

The Cass silt loam is a minor type in the county covering only 1.5 percent of the total area. It occurs in the first bottoms of the West Fork Des Moines river, Cylinder creek and Prairie creek. The largest area is along Prairie creek east of Cylinder and rather considerable areas of the type occur along the river both north of Emmetsburg and south of this city.

The surface soil of the Cass loam is a black heavy silt loam to silty clay loam 6 to 8 inches in depth. The subsoil is a dark brown to grayish-brown sandy loam to sandy clay loam which grades at 20 to 30 inches into a loose textured yellow sand or mixture of sand and gravel. In some uncultivated areas the surface of the soil is covered with a thin layer of black muck. A few areas of Cass loam and silty clay loam too small to be shown separately on the map, are included in this type.

In topography it is practically flat, lying 10 to 13 feet above the normal level of the river. Along the creeks it lies 2 to 5 feet above the water level. Drainage is inadequate and the soil is subject to overflow.

Very little of this type is in cultivation, corn and oats being grown to some extent with fair yields in good seasons. Most of the type is used for the growing of hay or pasture, the hay being made up chiefly of wild grasses and yielding 1 to 1½ tons per acre.

The first treatment which this type needs to make it more productive is adequate drainage and then protection from overflow. The addition of small amounts of manure to newly drained areas would be of value to stimulate the production of available plant food constituents. The soil may be acid, in which case lime should be applied. It is not particularly well supplied with phosphorus and phosphorus fertilizers might be of value at the present time and certainly will be needed in the near future if the type is to be brought under cultivation and utilized for general farm crops.
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 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 peti­
tions 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 com­
pleted. 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 prac­
tically no danger of their ever running out. Such, for example, is the case with iron
and aluminum, past experience showing that the amount of these elements in the soil
remains practically constant.

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

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

**THE "SOIL DERIVED" ELEMENTS**

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

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

**AVAILABLE AND UNAVAILABLE PLANT FOOD**

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

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

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. 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. Phosphorus 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 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 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
Calculating Nitrogen (N) at 16c (Sodium Nitrate (NaNO₃)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl)).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Plant Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen Phosphorus Potassium</td>
<td>Nit of Phosphorus Potassium</td>
<td></td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75 12.75 14</td>
<td>$12.00 $1.52 $0.84</td>
<td>$14.37</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36 4.5 39</td>
<td>5.76 0.54 2.34</td>
<td>8.64</td>
</tr>
<tr>
<td>Corn, crop</td>
<td>......</td>
<td>111 17.25 53</td>
<td>17.76 2.07 3.18</td>
<td>23.01</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6 7.2 7.8</td>
<td>6.51 0.86 0.46</td>
<td>8.13</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15 2.4 27</td>
<td>2.40 0.28 1.62</td>
<td>4.30</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>......</td>
<td>57.6 9.6 34.8</td>
<td>9.21 1.14 2.08</td>
<td>12.43</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33 5.5 8</td>
<td>5.28 0.66 0.48</td>
<td>6.42</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5 2.5 20</td>
<td>2.48 0.30 1.56</td>
<td>4.38</td>
</tr>
<tr>
<td>Oats, crop</td>
<td>......</td>
<td>18.5 8 34</td>
<td>7.76 0.96 2.04</td>
<td>14.70</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>50 bu.</td>
<td>23 5 5.5</td>
<td>3.68 0.60 0.33</td>
<td>4.61</td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5 1 13</td>
<td>1.52 0.12 0.78</td>
<td>2.42</td>
</tr>
<tr>
<td>Barley, crop</td>
<td>......</td>
<td>32.5 6 18.5</td>
<td>5.20 0.72 1.11</td>
<td>7.03</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4 6 7.8</td>
<td>4.70 0.72 0.46</td>
<td>5.88</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12 3 21.30</td>
<td>1.92 0.36 1.26</td>
<td>3.54</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>......</td>
<td>41.4 9 28.8</td>
<td>6.62 1.08 1.72</td>
<td>9.42</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63 12.7 90</td>
<td>10.08 1.25 5.40</td>
<td>17.00</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300 27 144</td>
<td>48.00 3.24 8.64</td>
<td>59.88</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72 9 67.5</td>
<td>11.52 1.08 3.05</td>
<td>16.55</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120 15 90</td>
<td>19.20 1.80 5.40</td>
<td>16.40</td>
</tr>
</tbody>
</table>

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

REMOVAL FROM IOWA SOILS

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

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

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

PERMANENT FERTILITY IN IOWA SOILS

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

*Bulletin 150, Iowa Agricultural Experiment Station.*
Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production. Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for 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 thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils. The loss of moisture by evaporation from soils during periods of drought may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

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

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between
two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly ac­cepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the 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. 9.

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

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift 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, that is, therefore, inorganic 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 eolian.
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:

<table>
<thead>
<tr>
<th>Organic matter</th>
<th>Inorganic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>All partially destroyed</td>
<td>Stones—over 32 mm.*</td>
</tr>
<tr>
<td>or undecomposed</td>
<td>Gravel—32—2.0 mm.</td>
</tr>
<tr>
<td>vegetable and animal material.</td>
<td>Very coarse sand—2.0—1.0 mm.</td>
</tr>
<tr>
<td></td>
<td>Coarse sand—1.0—0.5 mm.</td>
</tr>
<tr>
<td></td>
<td>Medium sand—0.5—0.25 mm.</td>
</tr>
<tr>
<td></td>
<td>Fine sand—0.25—0.10 mm.</td>
</tr>
<tr>
<td></td>
<td>Very fine sand—0.10—0.05 mm.</td>
</tr>
<tr>
<td></td>
<td>Silt—0.05—0.00 mm.</td>
</tr>
</tbody>
</table>

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 50 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.

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

**Gravels**—More than 50 percent very coarse sand.

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

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.
METHODS USED IN THE SOIL SURVEY

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

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

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