Soil Survey of Iowa, Report No. 40—Woodbury County

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

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Fig. 1. Typical Marshall silt loam topography.
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WOODBURY COUNTY SOILS


Woodbury County is located in western Iowa, being separated by the Missouri and Big Sioux Rivers from Nebraska and South Dakota on the west and it is in the fourth tier of counties south of the Minnesota state line. It lies entirely in the Missouri loess soil area and hence the soils of the county are mainly of loessial origin.

The total area of the county is 877 square miles or 561,280 acres. Of this area 507,921 acres or 90.4 percent is in farm land. The total number of farms is 2,985 and the average size of the farms is 170 acres. The farms are operated by 1,248 owners, 385 relative renters, 1,167 renters, 151 classified as both owners and renters and 34 unclassified. The following figures taken from the Iowa Yearbook of Agriculture for 1923, show the utilization of the farm land in the county.

<table>
<thead>
<tr>
<th>Description</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in general farm crops</td>
<td>345,883</td>
</tr>
<tr>
<td>Acreage in farm buildings, feed lots and public highways</td>
<td>23,855</td>
</tr>
<tr>
<td>Acreage in waste land</td>
<td>17,670</td>
</tr>
<tr>
<td>Acreage in pasture</td>
<td>117,031</td>
</tr>
<tr>
<td>Acreage in farm woodlots used for timber only</td>
<td>1,438</td>
</tr>
<tr>
<td>Acreage in orchard</td>
<td>717</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>1,376</td>
</tr>
</tbody>
</table>

THE TYPE OF AGRICULTURE IN WOODBURY COUNTY

The type of agriculture practiced in Woodbury County at present consists of a system of general farming which includes the growing of corn, and other grains and some hay crops, and the raising and feeding of livestock. On many farms a large part of the net income is derived from the livestock industry, particularly from the sale of hogs and cattle. The chief crops grown are corn, oats, timothy and clover hay, alfalfa and wheat. With the exception of wheat, these crops are largely used on the farm as feed for the hogs and beef cattle. There is always, however, some surplus of the various crops, depending upon the particular conditions, and in general a part of the farm income is derived from the sale of this surplus. Where wheat is grown it serves as a source of cash income. The same is true of red clover seed and potatoes and a part of the oat and corn crops. Barley and potatoes are the most important of the minor crops. There are also areas of sweet clover, millet, sorghum, rape and popcorn in various parts of the county.

While the system of farming is very much the same throughout the county some variations exist which seem to be directly related to the soil and to the topographic conditions. The farming methods followed and the crops grown are practically identical on all of the upland where the soil and topography conditions are similar. Wheat, alfalfa and red clover are grown to a considerable

extent on the clays and silt loams of the bottomland; more so, in fact, than on the silt loam of the upland. On many of the bottomland farms, corn and alfalfa are practically the only crops raised. Potatoes are found to be the most satisfactorily productive on the fine sandy soils, while scarcely any wheat is grown on such types. Orchards have been found to be most successful on the silt loam uplands. The rotation of crops is generally practiced altho on some of the bottomland farms, corn is grown year after year in succession on the same land without any noticeable reduction in yields. This is possible because of the depth and high fertility of the bottomland soil, and it is not a practice which can be recommended.

There is a considerable acreage in waste land in this county and much of this land might be reclaimed and made productive thru the adoption of proper methods of soil treatment. General recommendations along this line cannot be given owing to the fact that the causes of the infertility of the land are so variable. In a later section of this report, suggestions will be offered regarding the treatment which would be the most desirable for such waste land areas. Advice regarding the handling of soils in special cases where the conditions are more or less abnormal, will be given by the Soils Section of the Iowa Agricultural Experiment Station, upon request.

GENERAL FARM CROPS GROWN IN WOODBURY COUNTY

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

The most important crop grown in the county, both from the standpoint of acreage and value, is corn. In 1923, it was estimated that this crop occupied 41.48 percent of the total farm land of the county. The average yields are estimated at 43 bushels per acre. In some seasons, and on the better drained and more productive land, the yields are much higher than this, often going up to 60 or 70 bushels per acre. These larger yields are frequently obtained on the bottomland soils. The upland soils will average about the same as the average for the county. Reid's Yellow Dent and various strains of this dent corn are grown most extensively. Some white corn is also grown, particularly on the bottomland. The larger part of the corn crop is used as feed for the hogs and beef cattle. Hogging down the corn is practiced to some extent and considerable silage is produced. In 1923, there were 269 silos in the county and 22,939 tons of silage were put up. On the average, probably not more than 10 percent of the total corn crop is sold, the remainder being used for feeding purposes.

TABLE I AVERAGE YIELDS AND VALUE OF CROPS GROWN IN WOODBURY COUNTY, IOWA*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage</th>
<th>Percent of total farm land of county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>210,717</td>
<td>41.48</td>
<td>43.0</td>
<td>9,060,831</td>
<td>$0.62</td>
<td>$5,617,715</td>
</tr>
<tr>
<td>Oats</td>
<td>72,133</td>
<td>14.20</td>
<td>36.0</td>
<td>2,596,788</td>
<td>$0.37</td>
<td>960,811</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>11,744</td>
<td>2.31</td>
<td>15.0</td>
<td>176,160</td>
<td>$0.89</td>
<td>156,782</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>1,730</td>
<td>0.34</td>
<td>10.0</td>
<td>17,300</td>
<td>$0.87</td>
<td>15,051</td>
</tr>
<tr>
<td>Barley</td>
<td>1,930</td>
<td>0.38</td>
<td>24.0</td>
<td>46,320</td>
<td>$0.52</td>
<td>24,086</td>
</tr>
<tr>
<td>Rye</td>
<td>1,938</td>
<td>0.18</td>
<td>26.0</td>
<td>24,388</td>
<td>$0.66</td>
<td>16,096</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,561</td>
<td>0.27</td>
<td>87.0</td>
<td>135,807</td>
<td>$0.77</td>
<td>104,571</td>
</tr>
<tr>
<td>Tame hay</td>
<td>11,010</td>
<td>2.16</td>
<td>1.6</td>
<td>17,616</td>
<td>$12.50</td>
<td>320,200</td>
</tr>
<tr>
<td>Wild hay</td>
<td>7,746</td>
<td>1.52</td>
<td>1.3</td>
<td>10,069</td>
<td>$10.50</td>
<td>105,724</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>26,374</td>
<td>5.19</td>
<td>3.1</td>
<td>81,759</td>
<td>$16.25</td>
<td>1,328,583</td>
</tr>
<tr>
<td>Pasture</td>
<td>117,031</td>
<td>23.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1923.
The oats crop is second in acreage in the county and third in value. Oats are grown on over 14 percent of the total farm land of the county and average yields amount to 36 bushels per acre. In many cases much higher yields than this are secured, particularly in favorable seasons. Oats usually are utilized as a nurse crop for alfalfa where the latter is grown in the rotation. In the ordinary rotation, it is followed by clover and timothy. A considerable amount of the oats grown in the county is sold on the market, there being a surplus on most farms for disposal in this way. Oats provide, therefore, a part of the normal income of the farms of the county.

Alfalfa is the third crop in acreage in the county and the second in value. It is the chief hay crop. In 1923, alfalfa was grown on 26,374 acres in the county, or 5.19 percent of the total farm land. Average yields of this crop amounted to 3.1 tons per acre. Usually three cuttings are obtained each year, and the stand of alfalfa is commonly maintained for at least five years. Alfalfa grows very successfully in Woodbury County and when proper precautions are taken to insure thorough inoculation, a proper reaction in soil and the use of good seed, no difficulty should be experienced in securing a stand. It is not only a valuable crop on the uplands, but has proven very desirable for use on the bottomlands when they are well drained. Often alfalfa is grown instead of timothy and red clover. Most of the crop is utilized on the farms for feed for cattle, sheep and work stock. It also furnishes valuable pastureage for hogs. A small part of the crop serves as a source of cash income, particularly on some farms in seasons when prices are high. It is recognized as a valuable crop for feed, however, and usually only a small surplus is disposed of on the markets.

The second hay crop in acreage and value in the county consists of a mixture of timothy and red clover. This crop is grown on 2.16 percent of the total farm land of the county and average yields amount to 1.6 tons per acre. In recent years red clover has been grown alone to a considerable extent, and this crop usually proves very successful except on some of the poorly drained areas. Wild hay is still grown on 1.52 percent of the total farm land of the county, chiefly, however, on the poorly drained clay soil in the bottoms of the Missouri River. Average yields of wild hay amount to 1.3 tons per acre. The hay consists of a mixture of coarse grasses and sedges and is of very much less value for feeding purposes than the tame hay.

Winter wheat is grown on 11,744 acres or 2.31 percent of the total farm land of the county, according to estimates for the year 1923. Average yields of this crop amounted to 15 bushels per acre. There is only a very small acreage in spring wheat and average yields of only 10 bushels per acre are secured. Winter wheat does well both on the silt loam of the uplands and on the heavier types of soils in the bottomlands. Wheat is a cash crop in the county.

Barley is grown on a small acreage in the county and average yields amount to 24 bushels per acre. The value of the crop is small. Practically all of it is used on the farms for feeding purposes.

Potatoes are grown on practically all of the farms for home use. The surplus is sold on the local markets. Average yields amount to 87 bushels per acre, and the value of the potato crop is considerable. On the silt loam of the uplands and on the lighter textured types on the bottomlands, potatoes do particularly well. While the surplus of this crop is marketed, it does not add materially to the farm income.

Minor crops grown in the county include rye, sweet clover, millet, sorghum, rape and popcorn. The area in the latter crop in 1923, was 163 acres and the total production amounted to 304,305 pounds.

Orchards are maintained on practically all of the farms and the fruit grown consists mainly of apples. No large surplus of this crop is available for sale, however. In 1923, the total number of bushels of apples harvested was estimated at 16,586. Other fruit including plums and cherries are grown to some
SOIL SURVEY OF IOWA

 extent but not entirely successfully. There are a few commercial orchards in the county.

Vegetable crops are grown on farms for supplying the home demand but there has been no development of truck farming in the county. The surplus of vegetables is disposed of on the local market but this adds little to the farm income.

WOODBURY COUNTY’S LIVESTOCK INDUSTRY

The livestock industry of the county includes the raising and feeding of hogs and cattle, dairying, the feeding of sheep and the raising of some horses and mules.

The following figures from the Iowa Yearbook of Agriculture for 1923 show the extent of the livestock industry in the county.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses, all ages</td>
<td>17,577</td>
</tr>
<tr>
<td>Mules, all ages</td>
<td>1,708</td>
</tr>
<tr>
<td>Swine on the farms July 1, 1923</td>
<td>201,832</td>
</tr>
<tr>
<td>Swine on the farms Jan. 1, 1924</td>
<td>148,859</td>
</tr>
<tr>
<td>Cattle, cows and heifers kept for milk</td>
<td>13,689</td>
</tr>
<tr>
<td>Cattle, other cattle not kept for milk</td>
<td>54,012</td>
</tr>
<tr>
<td>Cattle, total all ages Jan. 1, 1924</td>
<td>67,101</td>
</tr>
<tr>
<td>Sheep all ages on farms Jan. 1, 1924</td>
<td>4,785</td>
</tr>
<tr>
<td>Sheep shipped in for feeding, 1923</td>
<td>6,026</td>
</tr>
<tr>
<td>Sheep, total pounds of wool clipped</td>
<td>26,434</td>
</tr>
<tr>
<td>Poultry, total number all varieties</td>
<td>330,694</td>
</tr>
</tbody>
</table>

The raising and feeding of hogs is by far the most important livestock industry. The number of hogs on the farms Jan. 1, 1924 amounted to 148,650. The leading breeds are Poland China, Duroc Jersey and Hampshire. Some hogs are shipped in for feeding. Corn is used for fattening while alfalfa and some rape and clover furnish pastureage. The sale of hogs provides the chief source of income on the majority of farms.

Cattle feeding is commonly practiced on the farms. A large proportion of the cattle fed are shipped in from the local yards at Sioux City and from the western ranges. Corn, corn silage and alfalfa hay make up the principal feed. In 1923, there were on the farms 54,012 cattle, not kept for milk. The farm income from the sale of cattle is large in many instances.

Dairying is practiced to some extent in the county but chiefly to supply the local demand. The number of dairy cattle in 1923 was 13,089. The industry is not extensively developed and practically all of the dairy products are sold locally.

Sheep raising is practiced to a very small extent. The total number of sheep on the farms Jan. 1, 1924 was 4,785. Some farmers ship in sheep for feeding and the number thus shipped in in 1923, was estimated at 6,026. Sheep raising and feeding is not extensively developed in the county.

Flocks of poultry are maintained on practically all farms in the county, and the total number of all kinds of poultry in 1923 was estimated at 330,694. The flocks consist mainly of chickens. Over one million dozen of eggs was estimated as being received in the year 1923. The poultry industry is apparently of considerable significance. A large part of the products is utilized for home consumption, the surplus being disposed of chiefly on local markets. More attention to this industry would certainly bring about greater profit to the farmers.

Farm land in Woodbury County is quite variable in price depending upon the location with reference to towns and to railroad facilities, as well as with reference to the improvements on the farms and general soil conditions. The better upland soils in the county will sell for $200 to $250 per acre. The range in price of farm land is from $100 to $250 per acre. The less desirable areas, which include the more hilly sections of the upland, the more sandy land along the Missouri River and some poorly drained clay areas, in the bottoms, will bring from $100 to $150 per acre. The major portion of the land in the county is of the higher priced type and farm land as a whole is extremely valuable.
THE FERTILITY SITUATION IN WOODBURY COUNTY

In general, ordinary farm crops grown in Woodbury County give quite satisfactory yields. Better methods of soil treatment, however, may often be put into effect with resulting large increases in crops. The particular treatment which should be practiced will vary with the soils and with the special conditions, but in general certain treatments may be recommended for use throughout the county in order to provide for a better growth of crops and also to permit of the continued maintenance of the fertility of the soils in a permanent way.

While the uplands of the county are entirely adequately drained, there is a very evident lack of drainage on the broad areas of bottomland which are nearly level to flat and cut by only a few sluggish, winding streams or sloughs. On that portion of the bottomland where the soil is heavy and where the subsoil conditions are very impervious, the need of drainage is particularly evident. Installation of drainage ditches is very necessary and the laying of tile should be practiced before satisfactory crop yields can be secured on this land.

Lime is needed on many of the soils in the county for the best growth of general farm crops and particularly of legumes. The upland soils with the exception of the Knox silt loam, are generally acid in reaction in the surface soil. The same is true of the terrace types. On the bottoms, practically all of the soils except the Wabash types, are basic in reaction and in many cases contain considerable amounts of lime. These types, therefore, are not in need of lime and their reaction is quite satisfactory for the best growth of crops. On the uplands, however, the soils should be tested for acidity or lime needs and applications of lime should be made at regular intervals.

Many of the soil types in the county are not very well supplied with organic matter. A few are rich in this constituent, black in color and not in need, therefore, of application of materials supplying organic matter. On the uplands, however, while the soils are not strikingly deficient, application of farm manure would be very desirable to build up the content of organic matter. On the bottoms, particularly on the sandy types, farm manure is of large value. Even on those types which are apparently better supplied, applications of this material have proven of considerable value. Large increases in crop growth are regularly secured from the application of farm manure to the soils of this county. It should be emphasized that the chief need of the upland types of Woodbury County, in addition to phosphorus is for an increase in the amount of organic matter in which the soils are not very well supplied. If farm manure is not available for use, then green manuring would be of value. The turning under of a legume crop as a green manure would be a very desirable practice, particularly on the light colored sandy soils. The practice may also be followed to advantage, however, on the upland types as a supplement to the use of farm manure.

The nitrogen supply of the soils of the county is not low but it must be maintained if the soils are to be kept productive. This may be done by the proper use of well inoculated legumes as green manures and by the utilization of farm manure and crop residues. It does not seem likely that commercial nitrogenous fertilizers will be necessary if there is a proper practice adopted in regard to the use of leguminous crops.

The content of phosphorus is rather low in most of the soils in Woodbury County and it is quite evident that phosphorus fertilizers must be applied to the soils in this county in the near future, if crop production is to continue to be satisfactory. It is quite probable, however, that desirable results might be secured in many cases, at the present time, from the use of phosphorus fertilizers. Evidence has been secured from greenhouse experiments and from field tests with phosphate fertilizers, which would indicate that crops may respond profitably to the use of some phosphorus carrier. It has not been definitely shown whether acid phosphate or rock phosphate would be most desirable
for use, hence it is recommended that tests of both of these phosphate fertilizers be carried out on small areas on individual farms. In this way the farmer may determine the need of his soil for phosphorus and also determine which phosphate fertilizer can be used most profitably under his particular conditions.

Complete commercial fertilizers are not recommended for general use in the county at the present time. Tests which are under way in cooperative field experiments include the use of a complete commercial fertilizer and it is quite desirable that further tests be carried out on individual farms. Farmers who are interested are urged to compare the value of certain complete commercial fertilizers with acid phosphate. The evidence thus far secured from field experiments does not indicate that complete fertilizers will be of any larger value on the soils of this county than acid phosphate. The latter, therefore, would be preferable because of the fact that it is not so expensive.

Erosion occurs to considerable extent in the county particularly on the rougher uplands. The steep phase of the Carrington loam is a result of the extensive erosion of this type. The Knox silt loam is very much eroded on the rougher upland and there is some washing of the Marshall silt loam. Serious washing of the surface soil occurs in many areas and gullies are often readily formed. In all such cases some method should be followed to prevent or control the erosion process. Suggestions are offered later in this report and from among the methods described, some one may be chosen which will be suitable for almost any conditions.

THE GEOLOGY OF WOODBURY COUNTY

None of the soils in Woodbury County are derived in any part from the native bedrock, but all are formed from the glacial or loessial deposits, which in previous geological ages buried the rock to great depths. There is no need, therefore, of considering the character of the bedrock material in the county. The geological history of the area is of significance agriculturally only insofar as it affects the glacial and loessial deposits.

During the glacial age, at least two great ice sheets swept over the county and when the ice retreated, vast deposits of debris or glacial drift or till were left over the surface of the land. The earlier glacier, known as the Kansan, probably covered the entire surface of the land burying the native bedrock material and covering the weathered portions of this rock. The deposit left by the Kansan glacier was undoubtedly extremely variable in depth, ranging from a few feet to many hundred feet. Leveling as it did the inequalities of the surface of the land, filling the valleys and covering the hill tops thinly, it would naturally vary widely in depth. The Kansan drift material is usually referred to as blue clay inasmuch as this indicates the characteristic color and texture of the unweathered material. It contains sand, pebbles and boulders of varying sizes. When weathered, the color of this drift material changes to a yellow or reddish-yellow. None of the soils in Woodbury County are derived from the Kansan till and hence this deposit has no significance agriculturally.

At a later date, a second glacier, known as the Wisconsin, advanced over the surface of the county and it too deposited over the land a vast mass of glacial drift when it retreated. The depth of the Wisconsin glacial deposit is also quite variable ranging from a few inches in some cases to many feet in other areas. It consists of a mixture of boulders, sand, silt and clay. Originally it was yellowish or buff colored. After deposition, there was a long period of weathering and accumulation of organic matter and the characteristic color of the drift material in the surface soil has been changed to dark brown or even black. The subsoil still shows the typical grayish or yellowish color of the original material. There are two soil types in the county which are derived from this Wisconsin drift material, the Carrington silt loam and the steep phase of the Carrington
loam. Both of these occur in areas where the loessial covering has been entirely or partly removed, allowing the appearance of the underlying drift deposit either at the surface or close to the surface.

At some later date in geological history when climatic conditions were very different than at present, there was laid down over the surface of the county, a vast deposit of grayish or pale buff colored calcareous silty material known as loess. Presumably this deposit was made by the wind. The depth of the loess covering is extremely variable, ranging from 4 or 5 feet in thickness in some parts of the county to more than 100 feet in depth in other areas. Many of the topographic features of the old drift covered lands were obliterated by the deposition of the loess. In other cases, the loess covering was spread rather uniformly over the higher uplands and the low-lying terraces and bottoms. Since it was deposited the loess has been modified considerably by weathering and the action of climatic agencies and the growth of plants. There has been an accumulation of organic matter to a considerable extent in some areas and the color of the surface soil has changed to a dark brown.

Loess is a complex coarse silty material quite retentive of moisture and possessing the characteristic of standing in vertical cuts. Erosion does occur to some extent in loess, however, and on many of the steeper slopes in Woodbury County there has been considerable washing away of the surface covering and the soil which is exposed is a lighter brown than that occurring on the more gently rolling uplands and usually the unweathered loessial material appears at shallow depths. These areas where the color of the soil is lighter and the original loess material appears close to the surface have been mapped as the Knox silt loam. On the more extensive uplands where the topography is gently rolling to undulating and there has been more of an accumulation of organic matter and very little erosion, the soil is mapped as the Marshall silt loam. Only in those areas where the Carrington silt loam and the steep phase of the Carrington loam are mapped, has there been a complete removal of the surface covering of loess.

The terrace and bottomland soils in the county are derived mainly from the loessial material which has been carried down from the uplands. There are frequently, however, admixtures of glacial or drift material with the loess, and in many cases the bottomland soils are a combination of loessial and glacial material. It may be considered, however, that these soils have come mainly from the loessial deposit. It is evident that by far the greater part of the area of Woodbury County, is now covered by the original loessial deposit or by accumulations of loessial material.

PHYSIOGRAPHY AND DRAINAGE

Originally the land was probably smooth or nearly level, following the loessial deposit but in the ages which have elapsed since this deposition was made, there has been considerable washing away of the loess and much of the material has been carried away by the Missouri River and its tributary streams. The surface of the land has been changed to a more rolling to rough or hilly topography.

Three distinct topographic divisions of the county may be mentioned. The first consists of the upland plains which occur at an elevation of about 300 feet above the Missouri River. The larger streams and their numerous tributaries have cut thru this upland plain, making deep valleys and the surface of the plain presents, therefore, a hilly or strongly rolling appearance. There are very few level areas of upland, so extensive has been the action of the water flowing into the various drainageways, streams and tributaries. The top of the ridges and the hill tops are rounded and the slopes are generally smooth, due to the character of the loessial covering.

The second topographic division of the county includes the bluffs along the
rivers. These bluffs separate the bottomlands from the upland areas and they are usually from 200 to 300 feet high. In the northern part of the county the bluffs occur about four miles from the river. Near Sioux City, they border the stream for a short distance. South of the city, the bluff line gradually recedes from the river until at the southern border of the county, it is 15 miles east of the present river channel. Deep ravines with sharp ridges have been cut thru the bluffs by the washing away of the soil by the flood waters of the larger streams. The abrupt rise of these bluffs, the sharp outline of the ridges and the steep slopes, make up the most striking topographic features.

The third topographic division of the county includes the bottomland plains adjacent to the Missouri River. The surface of this plain is about 300 feet below the uplands. It lies approximately 20 feet above the low water level of the river, and it is generally above overflow. The topography of the area is smooth to level. Occasionally there are irregularities in the surface caused by old channels of the river and in such areas there are low swells of sand and long narrow depressions. The river is constantly changing its course and there is a gradual modification of the bottomland plain adjacent to the river channel. Part of this area is only three to eight feet above the normal low water level and is usually flooded at high water. This land consists of flats of silty muck and hummocky areas of sand, covered with a growth of willows and scattered cottonwood. In some places, it is merely barren sand bars. The channel of the river is now from one mile to two and a half miles in width.

The drainage of the county is brought about entirely by the Missouri River and its tributaries. The upland slopes gradually to the south and the streams flow in that general direction. Branches of the various rivers and streams extend thru every part of the upland and the drainage of the upland of the county is excellent. The eastern part of the county is drained by the Little Sioux River with its tributaries the chief of which are Pierson Creek, Bacon Creek, Wright Creek, Miller Creek and Parnell Creek. The southeastern corner of the county is drained by Maple River and its tributary, Reynolds Creek. The west central part of the county is drained by the Little Sioux River with its tributaries, the chief of which are Wolfe Creek, Muddy Creek, Big Whiskey

Fig. 3. Map showing natural drainage system of Woodbury County.
Creek and Elliott Creek. The northwestern corner of the county is drained by the Big Sioux River and its tributaries and also by the Floyd River. The bottomland plain in the southwestern part of the county is cut by a few sluggish winding streams or sloughs and the natural drainage of this part of the county is very poor. Drainage ditches have been installed throughout this area and tilling has been practiced to some extent and hence there has been a considerable improvement in the drainage conditions in a large part of this area. In general, however, the drainage of the bottomland is frequently quite inadequate. The accompanying map indicates the extensive drainage system of the upland area and the inadequate natural drainage of the bottomland area.

THE SOILS OF WOODBURY COUNTY

The soils of Woodbury County are grouped into four classes according to their origin and location. These are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from the deposits left by retreating glaciers and they consist of mixtures of sand, gravel and clay and frequently contain pebbles and boulders. Loess soils are fine dustlike deposits laid down over the surface of the land by the wind, presumably in a time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a depression of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams. Many of them are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Woodbury County are shown in table II.

Only a small part of the area of the county, 7.2 percent, is covered by the drift soils. They are found chiefly along the streams and drainageways in the eastern part of the county, principally separating the more rolling loessial uplands from the stream channels and bottomlands. The largest occurrence of the drift soils is found along the Little Sioux River. The loess soils cover almost two-thirds of the area of the county, 61 percent. They occur over the major portion of the upland area. Terrace soils occur to only a limited extent in the county, covering a total of 4.1 percent of the total area. They are found in small individual areas along the various streams of the county. Swamp and bottomland soils are developed to a considerable extent in the county particularly in the southwestern townships. Considerable areas of bottomland are also found along some of the major streams of the county. The entire area of Lakeport, Sloan and Liberty Townships is covered by bottomland soils. A large part of Willow, Green and Woodbury Townships are similarly occupied by the bottomlands. The total area of bottomland in the county amounts to 27.7 percent.

There are 17 individual soil types in the county and these with the colluvial phase of the Wabash silt loam, and the alluvial soils (undifferentiated) make a total of 19 soil areas. The steep phase of the Carrington loam is considered a soil type inasmuch as the typical Carrington loam does not occur in the county. There are two drift soils, two loess types, two areas of terrace soils and 13 areas of swamp and bottomland soils including the colluvial phase of the Wabash silt loam and the undifferentiated alluvial soils. The various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix of this report, and the names indicate certain group characteristics. The areas covered by the various soil types in the county are shown in table III.

The Carrington silt loam is the most extensive drift soil, covering 5.1 percent of the total area of the county. It is the fifth largest soil type in the county. The steep phase of the Carrington loam the second drift type is much less extensive covering only 2.1 percent of the county. The Marshall silt loam is the
largest individual soil type in the county as well as the most extensive loess soil. It covers more than half of the total area, 58.4 percent. The Knox silt loam is the second loess type in the county. It is very much smaller in area, covering only 2.6 percent of the county. The terrace soils are both small in area, the most extensive being the Waukesha silt loam, which covers 3.8 percent of the county. The O’Neill loam, the second terrace type, is very minor in occurrence, covering only 0.3 percent of the county.

On the bottomlands, the Lamoure clay is the most extensive type, covering 9.4 percent of the county. It is the second largest individual soil type in the county. The Wabash silt loam is the second largest bottomland soil and, together with the colluvial phase, which is much smaller in area it covers 7.3 percent of the county. It is the third most extensive soil type in the area. The Lamoure clay loam, the third largest bottom type covers 5.8 percent of the county, and it is the fourth most extensive type of the county. The remainder of the bottomland soils are very minor in area. The undifferentiated alluvial soils cover 1.5 percent of the county and the Cass loam 1.1 percent of the total area. The other types all cover less than one percent of the county.
The upland soils of the county vary somewhat in topography, the Marshall silt loam on the loessial uplands being generally gently undulating to rolling in topography. The Carrington silt loam has a very similar topographic condition, being slightly more rolling to rough, however. The Knox silt loam occurs on the steep bluffs along the borders of the uplands where these join the bottomlands or occur adjacent to the rivers, and the topography of this soil is steep to rough and abrupt. Similarly the steep phase of the Carrington loam is rough to abrupt in topography. The terrace soils and the swamp and bottomland types are all level to flat in topography and except for old river channels or recent deposits of alluvial material, present no distinct topographic features.

THE FERTILITY IN WOODBURY COUNTY SOILS

Samples were taken for analysis from each of the soil areas in the county except the Alluvial soils (undifferentiated) and the Cass fine sandy loam. These soils were not sampled because of the small area of Cass fine sandy loam and because of the great variation in the character of the alluvial soil material.

The more extensive soil types were sampled in triplicate while only one sample was taken from each of the minor types. These samplings were all made with the greatest care that the samples be representative of the individual soil types and that all variations due to previous treatment of the soil be eliminated. The samples were taken at three depths, 0—6% inches, 6% to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were followed in the determination of the phosphorus, nitrogen and carbon and the Truog qualitative test was used in the determination of the limestone requirement. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type, and they represent, therefore, the averages of 4 or 12 determinations.

THE SURFACE SOILS

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

The phosphorus content in the various soil types in the county is somewhat variable, ranging from 976 pounds in the Sarpy fine sand on the bottoms up to 1,939 pounds in the Cass silty clay loam, likewise on the bottoms. No definite relations appear between the phosphorus content of the soils and the different soil groups. On the average, the bottomland types are a little better supplied than the upland soils which might be expected from the fact that there has been less plant growth on these types and hence a smaller removal of phosphorus. The relationships among the individual soil types are much more definitely shown, however.

It is possible to make comparisons among the various soil series in a few cases and it would seem that the Waukesha silt loam is a little better supplied than the O'Neill loam on the terraces. On the bottoms, the Wabash and Lamoure soils seem to be somewhat richer in this constituent than the Cass and Sarpy soils. On the loessial uplands the Knox silt loam is higher in phosphorus than the Marshall silt loam. This is contrary to what would be expected and the usual results indicate a higher content of phosphorus in the Marshall silt loam. Evidently the particular sample of Knox silt loam which was analyzed contained a larger amount of phosphorus than is usual in this soil. The Carrington soils on the drift upland average about the same as the Marshall soils.

It would seem that there is probably some relationship between the phosphorus content of the soils and the characteristics which are used as a basis to dis-
### TABLE IV. PLANT FOOD IN WOODBURY COUNTY, IOWA, SOILS

Pounds Per Acre of 2 Million Pounds of Surface Soil (0—6"")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>14,000 pounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,387</td>
<td>3,760</td>
<td>43,680</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,131</td>
<td>2,120</td>
<td>38,228</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>1,351</td>
<td>3,460</td>
<td>49,239</td>
<td>0</td>
<td>3,333</td>
</tr>
<tr>
<td>11</td>
<td>Knox silt loam</td>
<td>1,575</td>
<td>2,840</td>
<td>25,763</td>
<td>21,020</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,495</td>
<td>3,480</td>
<td>46,137</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>1,212</td>
<td>3,580</td>
<td>44,999</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>166</td>
<td>Lamoure clay</td>
<td>1,575</td>
<td>2,200</td>
<td>28,598</td>
<td>4,362</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,885</td>
<td>5,280</td>
<td>78,241</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>1,670</td>
<td>3,440</td>
<td>45,045</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>155</td>
<td>Lamoure clay loam</td>
<td>1,124</td>
<td>3,399</td>
<td>29,129</td>
<td>1,450</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Cass loam</td>
<td>1,418</td>
<td>3,120</td>
<td>34,153</td>
<td>3,794</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>1,333</td>
<td>1,460</td>
<td>19,388</td>
<td>6,820</td>
<td>0</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>1,393</td>
<td>2,500</td>
<td>31,933</td>
<td>7,207</td>
<td>0</td>
</tr>
<tr>
<td>144</td>
<td>Sarpy silty clay loam</td>
<td>1,508</td>
<td>3,150</td>
<td>36,467</td>
<td>4,728</td>
<td>0</td>
</tr>
<tr>
<td>51</td>
<td>Cass silty clay loam</td>
<td>1,939</td>
<td>4,080</td>
<td>50,105</td>
<td>1,320</td>
<td>0</td>
</tr>
<tr>
<td>133</td>
<td>Sarpy fine sand</td>
<td>976</td>
<td>710</td>
<td>11,297</td>
<td>5,900</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,838</td>
<td>3,920</td>
<td>49,562</td>
<td>0</td>
<td>1,000</td>
</tr>
</tbody>
</table>

The relationship between the phosphorus content of the soils and their texture is usually more definitely shown than the relationship to soil groups or soil series. In this county it is only possible to make a few comparisons inasmuch as there are not any large number of types of soils in the various individual series. The Carrington silt loam is better supplied than the steep phase of the Carrington loam, which would be expected. On the bottomlands the Wabash silt loam is higher in phosphorus than the colluvial phase of the type and about the same as the Wabash silty clay loam. The Lamoure clay is higher than the Lamoure clay loam. The Cass silty clay loam is much higher than the Cass loam. The Sarpy silty clay loam is higher than the Sarpy silt loam which in turn is higher than the Sarpy very fine sandy loam and the lowest in phosphorus of the Sarpy soils in the Sarpy fine sand.

Previous observations of relationships between texture and phosphorus content are thus confirmed by these analyses. It seems evident that fine textured types are generally better supplied with phosphorus than coarse textured types. Silty clay loams are usually richer in this constituent than silt loams, loams and sandy loams. Silt loams may generally be expected to show a higher content of phosphorus than sandy types, and loams are generally higher in phosphorus than the sandy or fine sandy types of the same series.

It is evident from a consideration of the analyses of all of the soils in the county that the phosphorus supply is not adequate to keep crops supplied on...
these soils for an indefinite period. Phosphorus fertilizers will certainly be
needed on all of the soils in the very near future, and it seems probable that
phosphate fertilizers might be used in some cases at the present time with profit.
The evidence from greenhouse experiments and from some field experiments
on some of the same soils in other counties points to the fact that a phosphate
fertilizer may be frequently used in Woodbury County with profit.

The nitrogen content in the soils of Woodbury County varies widely. It
ranges from 710 pounds in the Sarpy fine sand up to 5,280 pounds in the Wa­
bash silt loam. Most of the types in the county are fairly well supplied with
this constituent but in a few cases the more sandy soils are low. In general it
may be said, however, that the supply of nitrogen is not inadequate in the soils
at present, but it certainly will become a limiting factor in growth some time
in the near future if precautions are not taken to keep up the supply. Systems
of permanent fertility demand the return of some nitrogen to the soils of this
county if the supply is to be maintained. In a few instances the soils show a
need for nitrogen at the present time.

There is no relationship evidenced between the nitrogen content of the soils
and the various soil groups. The bottomland types are a little better supplied,
on the average than the upland soils, but there are wide variations on the bot­
toms as would be expected because of the wide difference in character of the
soils present. The differences among the drift soils, loess soils and terrace soils
are too small to be of any significance.

Some relation is evidenced, however, between the various soil series and the
nitrogen supply, at least as far as is possible to make comparisons of series.
Thus the Marshall silt loam on the loessial uplands is higher in nitrogen than
the Knox silt loam. On the bottoms, the Wabash types are, in general, higher
than the other bottomland soils. The Sarpy soils are lower than the Cass
types and both the Cass and Sarpy soils are generally lower than the Lamoure
and Wabash types. Again there is evidently some relationship between the
characteristics which determine the soil series and the content of nitrogen.

The relationship to texture is, however, shown most definitely among the va­
nous types in the county. The Carrington silt loam is higher in nitrogen than
the steep phase of the Carrington loam. The Wabash silt loam is higher than
the colluvial phase of the same type. The Cass silty clay loam is higher than
the loam. The Sarpy silt loam is higher than the other types of the
Sarpy series. The Sarpy silt loam is higher than the sandy types and the Sarpy
fine sand is the lowest of all. The only exception to the general trend of the
results is the case of the Lamoure clay loam which is somewhat higher than the
Lamoure clay. This may be due to a peculiarity of the particular sample
analyzed. In general, it seems that the nitrogen content of soil varies con­siderably with the texture of the particular type. Light textured soils are bet­
ter supplied with this constituent than the coarse textured types. Silty clay
loams are better supplied than silt loams, loams are richer in nitrogen than
sandy loams or sandy soils.

While the supply of nitrogen in the soils of the county is not strikingly de­
ficient in any case, it is evident that the element must be considered when sys­
tems of permanent fertility are planned for the county. Some nitrogenous fer­tilizing material must be employed on these soils at regular intervals. Farm
manure is the most important and valuable nitrogenous fertilizer which can be
utilized for building up and keeping up the nitrogen supply of the soil.
The proper utilization of all crop residues will also be of material aid in main­taining the nitrogen supply. The cheapest and best method of keeping up
nitrogen on farms where the manure supply is limited and on grain farms, is
by the use of well inoculated legumes as green manures. The practice of green
manuring may be of considerable value as a supplement to the use of farm
manure and crop residues or as a substitute for farm manuring in Woodbury County.

A definite relationship is usually evidenced between the nitrogen content of the soil and the organic matter or organic carbon content. It is usually noted that soils which are lacking in nitrogen are apt to be in need of organic matter. The reverse is also frequently true. Soils which are deficient in organic matter may generally be assumed to be lacking in nitrogen. The amount of nitrogen and carbon in soil is indicated quite definitely by their color. If they are dark in color then there is usually a considerable amount of organic matter and nitrogen; if they are light colored the supply of these constituents may be considered to be inadequate. The appearance of soils is very apt to indicate quite accurately their needs for these constituents.

The organic carbon content of the soils in Woodbury County varies considerably as is apparent from the analyses. The range is from 11,297 pounds in the Sarpy fine sand up to 78,241 pounds in the Wabash silt loam. These are the same types which showed the lowest and highest amounts of nitrogen, respectively. The relationships among the various soils on the basis of their total organic carbon content are very much the same as those noted in the case of nitrogen. There is little evidence of any relationship between the organic matter supply and the soil groups, although the bottomland types are a little better supplied than the upland soils. The relationships among the various soil series are similar to those noted in the case of nitrogen and the same may be said of the soil types.

The effect of texture on the organic carbon content is much the same as in the case of nitrogen. Thus it is apparent that in light colored, light textured soils, more rolling in topography and with coarse textured subsoils, the supply of organic matter and nitrogen is lower than in dark colored soils, heavy in texture, flat to level in topography and with heavy textured subsoils. The Carrington loam is higher in organic matter than the steep phase of the Carrington loam. The Marshall silt loam is better supplied than the Knox silt loam. The Wabash and Lamoure soils are richer than the Cass and Sarpy types and the Cass is higher in organic matter than the Sarpy soils. The silty clay loams are better supplied than the silt loams, the silt loams are richer than the loams and the latter have more organic matter than the fine sandy loams or sands. These relationships are quite definitely shown by the various analyses.

The relationship between the carbon and nitrogen in soils indicates something of the rapidity with which the plant food in the soils is being changed into an available form. In many of the soils in Woodbury County this relationship is such that it is evident that the decomposition processes are not proceeding as rapidly as they should and there is an inadequate production of available constituents. On such soils, the application of farm manure would be of especially large value inasmuch as it supplies the organisms which bring about the rapid decomposition of plant food constituents and the production of available food material.

The application of farm manure is of value, however, on practically all of the soils in the county and certainly on the upland types. Crop residues also serve to maintain the organic matter content of soils and in many cases the use of leguminous crops as green manures may be desirable to aid in this connection.

The upland soils in the county, except for the Knox silt loam, are acid in reaction and show no content of inorganic carbon. The Knox silt loam is basic in reaction and shows a high content of carbonates. The terrace soils are both acid in reaction. On the bottomlands, the soils are all basic and all show a content of inorganic carbon except the three types of the Wabash series which are acid. The tests for the limestone requirement of the soils corresponds to the presence or absence of inorganic carbon, and those types which contain no inorganic carbon show a limestone requirement. Thus the Carrington silt loam
and the Carrington loam on the uplands, the Marshall silt loam on the loessial uplands and the Waukesha and O'Neill loams on the terraces, and the Wabash types on the bottoms show a need for lime. If the most satisfactory crop yields are to be secured on these soils, and especially the best yields of legumes, then lime must be applied in accordance with the needs as shown by special tests of the soil.

The amount of lime needed by the various soil types is indicated by the figures given in the table. These should not be considered to show definitely the needs of all of the soils of the same type in the county. There is a wide variation in the lime requirement of soils, even within the same types and it is always desirable that every individual soil be tested for its lime needs before any application is made. From the results given, therefore, it may merely be concluded that all the upland types except the Knox and only the Wabash soils on the bottoms are acid and in need of limestone and tests should be made in all cases before legumes are to be grown.

**THE SUBSURFACE SOILS AND SUBSOILS**

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

Unless there is a very large amount of some constituent in the lower soil layers or a striking deficiency in an element, there is little effect on the fertility of the soil indicated by the analyses of the lower soil layers. In general the analyses of the surface soils show fairly accurately the plant food content, the crop producing power of the soils, and thus indicate the needs. The lower soil layers in Woodbury County are not particularly high in any constituent nor are they strikingly deficient. It is not necessary, therefore, to discuss these analyses in detail.

It may merely be emphasized that the analyses of the soils at lower depths in the county serve to confirm the conclusions reached in the discussion of the analyses of the surface soils. It is apparent that phosphorus fertilizers will be needed on these soils in the near future and they might prove profitable for use at the present time. It is very important that the supply of organic matter and nitrogen be maintained in all the soils of the county, and, in some instances, it needs to be increased. This may be accomplished thru the proper use of farm manure, crop residues and the turning under of leguminous crops as green manures. The soils which were found to be acid at the surface generally showed a continuation of that acid condition down thru the subsoil. This is true in the case of the upland and terrace soils and on the bottoms the soils of the Wabash series which were acid at the surface show a content of a small amount of lime in the subsoil. The particular samples were evidently abnormal in this respect inasmuch as typical Wabash soils do not contain lime in the three foot section. Ordinarily, therefore, the Wabash soils on the bottoms would need to be tested and have applications of lime for the best growth of leguminous crops. The Carrington and Marshall soils on the uplands are certainly in need of lime according to these analyses and tests should be made of these types, if the best crop growth is to be secured. The same is true of the Waukesha and O'Neill soils on the terraces.

**GREENHOUSE EXPERIMENTS**

One greenhouse experiment was carried out on the Marshall silt loam from Woodbury County in order to secure some information regarding the fertilizer needs of this soil and regarding the value of the application of certain fertilizing materials. Experiments are also included on the Marshall silt loam from Montgomery County in 1918 and on the same type from this county in 1919.
TABLE V. PLANT FOOD IN WOODBURY COUNTY, IOWA, SOILS
Pounds Per Acre of 4 Million Pounds of Subsurface Soil (6"-20")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>2,154</td>
<td>3,480</td>
<td>43,680</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>1,832</td>
<td>1,320</td>
<td>28,228</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>2,324</td>
<td>3,633</td>
<td>49,940</td>
<td>0</td>
<td>3,000</td>
</tr>
<tr>
<td>11</td>
<td>Knox silt loam</td>
<td>2,828</td>
<td>2,640</td>
<td>18,770</td>
<td>71,320</td>
<td>0</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,480</td>
<td>4,120</td>
<td>46,137</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>2,316</td>
<td>4,360</td>
<td>44,499</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>166</td>
<td>Lamoure clay</td>
<td>2,208</td>
<td>3,600</td>
<td>33,252</td>
<td>14,796</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,124</td>
<td>8,000</td>
<td>102,102</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>3,340</td>
<td>6,560</td>
<td>80,808</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>185</td>
<td>Lamoure clay loam</td>
<td>3,058</td>
<td>7,120</td>
<td>29,126</td>
<td>1,450</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>2,100</td>
<td>6,120</td>
<td>54,665</td>
<td>5,121</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>2,424</td>
<td>760</td>
<td>10,733</td>
<td>6,820</td>
<td>0</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>2,424</td>
<td>3,320</td>
<td>34,606</td>
<td>12,804</td>
<td>0</td>
</tr>
<tr>
<td>144</td>
<td>Sarpy silty clay loam</td>
<td>2,855</td>
<td>5,360</td>
<td>44,358</td>
<td>7,838</td>
<td>0</td>
</tr>
<tr>
<td>51</td>
<td>Cass silty clay loam</td>
<td>2,746</td>
<td>4,320</td>
<td>50,697</td>
<td>18,972</td>
<td>0</td>
</tr>
<tr>
<td>133</td>
<td>Sarpy fine sand</td>
<td>1,925</td>
<td>580</td>
<td>11,094</td>
<td>7,852</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,694</td>
<td>4,520</td>
<td>49,562</td>
<td>670</td>
<td>0</td>
</tr>
</tbody>
</table>

The fertilizer treatments employed were the same in all of the experiments and included the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These materials were applied in the

TABLE VI. PLANT FOOD IN WOODBURY COUNTY, IOWA, SOILS
Pounds Per Acre of 6 Million Pounds of Subsoil (20"—40")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>3,597</td>
<td>2,640</td>
<td>33,885</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>57</td>
<td>Carrington loam (steep phase)</td>
<td>3,072</td>
<td>960</td>
<td>29,320</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>3,222</td>
<td>5,000</td>
<td>38,052</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>11</td>
<td>Knox silt loam</td>
<td>4,041</td>
<td>1,920</td>
<td>24,801</td>
<td>90,680</td>
<td>0</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>3,960</td>
<td>2,820</td>
<td>40,950</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>3,435</td>
<td>3,560</td>
<td>40,950</td>
<td>0</td>
<td>3,000</td>
</tr>
<tr>
<td>166</td>
<td>Lamoure clay</td>
<td>3,756</td>
<td>3,960</td>
<td>34,734</td>
<td>45,528</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>4,080</td>
<td>4,560</td>
<td>52,951</td>
<td>16,500</td>
<td>0</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (colluvial phase)</td>
<td>4,524</td>
<td>8,520</td>
<td>99,099</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>185</td>
<td>Lamoure clay loam</td>
<td>4,444</td>
<td>12,070</td>
<td>145,327</td>
<td>4,140</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>2,100</td>
<td>6,120</td>
<td>54,665</td>
<td>5,121</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>3,435</td>
<td>660</td>
<td>17,992</td>
<td>50,040</td>
<td>0</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>3,837</td>
<td>5,040</td>
<td>45,760</td>
<td>28,605</td>
<td>0</td>
</tr>
<tr>
<td>144</td>
<td>Sarpy silty clay loam</td>
<td>3,871</td>
<td>5,320</td>
<td>41,417</td>
<td>48,603</td>
<td>0</td>
</tr>
<tr>
<td>51</td>
<td>Cass silty clay loam</td>
<td>4,041</td>
<td>5,320</td>
<td>35,457</td>
<td>34,183</td>
<td>0</td>
</tr>
<tr>
<td>133</td>
<td>Sarpy fine sand</td>
<td>2,989</td>
<td>810</td>
<td>21,126</td>
<td>28,833</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,546</td>
<td>6,120</td>
<td>126,265</td>
<td>8,460</td>
<td>0</td>
</tr>
</tbody>
</table>
WOODBURY COUNTY SOILS

amounts in which they are usually used in the field and the results are, there­
fore, indicative of the fertilizer effects which may be expected on the farm. Manure was added at the rate of 8 tons per acre; lime was supplied in amounts sufficient to neutralize the acidity 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 complete commercial fer­­tilizer, at the rate of 300 pounds per acre. Wheat and clover were grown, the clover being seeded about one month after the wheat was up. In the test on the Marshall silt loam from Montgomery County in 1918 only the yield of clover was secured, the wheat yields not being obtained.

THE RESULTS ON MARSHALL SILT LOAM

The results of the experiment on the Marshall silt loam from Woodbury County are given in table VII. The figures are the averages of the weights of the wheat grain and clover in grams on the duplicate pots. The application of manure brought about an increase in the yield of wheat and had a small ef­­f­ect on the clover. Lime, in addition to manure, increased the wheat crop con­­siderably, but showed no effect on the clover. This is contrary to the usual results. Ordinarily the application of lime will show up particularly well on the legume crop of the rotation and in many cases, the beneficial effects of lime are not apparent on the corn and small grain crops. In this case, the effect was very large on the wheat and not so definite on the clover. The rock phos­­ph­­ate had a very slight effect on the yields of wheat and little or no effect on the clover. Acid phosphate, however, brought about a very distinct effect on the wheat and a large increase in the yield of clover. The complete commercial fertilizer exerted a greater effect than the acid phosphate in the case of the wheat crop but had a slightly less effect on the clover.

Apparently this soil will respond profitably to applications of manure, lime and phosphorus. The addition of manure seems to be of considerable value and lime along with manure may have a considerable effect not only on the legume but on the grain crops of the rotation. Acid phosphate seems to have a greater effect than rock phosphate in this particular case and in general it would seem that the use of acid phosphate might be more desirable than rock phosphate. The complete commercial fertilizer was more effective than the acid phosphate in the case of the wheat but had less effect on the clover. It seems probable, how­­ever that acid phosphate would generally prove more profitable for use than the complete fertilizer because of the much greater cost of the latter.

The results of the test on the Marshall silt loam from Montgomery County in 1918 are given in table VIII. Manure brought about a distinct increase in the clover but the addition of lime had no further effect. The sample was not distinctly acid in reaction and lime apparently was not very necessary. In most cases, however, on the Marshall silt loam, lime does prove of value. When the type is acid, applications of lime should be made in order to insure the best growth of legumes. The rock phosphate with the manure and lime had no effect on the clover but the acid phosphate and the complete commercial fer­­tilizer both brought about decided increases, the acid phosphate showing the larger effect. Again from this experiment it appears that manure is a very valu­­able fertilizer for this soil and applications of a phosphate fertilizer might also frequently be made with profit.

Table IX gives the results secured from the greenhouse experiment on the Marshall silt loam from Montgomery County in 1919. The application of manure gave a small effect on the wheat but again showed a large influence on the clover. Lime increased the wheat yield but had little or no effect on the clover.

Rock phosphate and acid phosphate both gave increases in the wheat yield and particularly large effects on the clover. The yields from the complete com-
Commercial fertilizer are not given as the crops were injured in those pots. The relative effects of the two phosphates in this test indicate that the acid phosphate had a larger influence than the rock on the clover but the reverse was true on the wheat. Differences are not distinctive enough, however, so that definite conclusions can be drawn. It seems quite possible that the two materials may prove of different value on different crops.

From all of these greenhouse experiments it is quite apparent that the application of farm manure is a very desirable practice, for improving the producing power of the type. When the soil is acid, applications of lime should be made in order to insure the best growth of legumes. Apparently a phosphate fertilizer will prove of considerable value and tests of rock phosphate and acid phosphate are urged on individual farms, in order to determine whether or not the soils will respond to phosphorus and also to learn which material may be used with the largest profit. The use of a complete commercial fertilizer cannot be recommended at the present time as acid phosphate seems to be quite as profitable for use.

TABLE VII. GREENHOUSE EXPERIMENT—MARSHALL SILT LOAM, WOODBURY COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Wt. wheat in grams</th>
<th>Wt. clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>7.051</td>
<td>35.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>7.850</td>
<td>39.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>8.946</td>
<td>35.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>9.023</td>
<td>39.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>9.247</td>
<td>48.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>10.216</td>
<td>45.0</td>
</tr>
</tbody>
</table>
WOODBURY COUNTY SOILS

TABLE VIII. GREENHOUSE EXPERIMENT—MARSHALL SILT LOAM, MONTGOMERY COUNTY, 1918

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>59.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>62.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>62.0</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>62.0</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>70.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>66.5</td>
</tr>
</tbody>
</table>

TABLE IX. GREENHOUSE EXPERIMENT—MARSHALL SILT LOAM, MONTGOMERY COUNTY, 1919

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>15.25</td>
<td>83.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>15.75</td>
<td>90.7</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>16.00</td>
<td>88.4</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>18.50</td>
<td>97.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>17.00</td>
<td>104.3</td>
</tr>
</tbody>
</table>

FIELD EXPERIMENTS

A field experiment has been started in Woodbury County but it has been under way for only a few years and the results have not been secured for a long enough period to be conclusive. Experiments have been under way in other counties, however, for a number of years and as these experiments are located on soil types which are the same as those occurring in Woodbury County, the results of some of these other field tests may be given, in this report. They certainly indicate quite definitely the results which may be secured on the same soil types in this county. Experiment on the Marshall silt loam on the Avoca field in Pottawattamie County on the same type on the Red Oak field in Montgomery County, on the Rock Valley field, in Sioux County and on the Villisca field in Montgomery County, on the Carrington silt loam on the Osage field in Mitchell County and on the Waukesha silt loam on the Clarinda field in Page County, are all included. Average results secured on the Marshall silt loam on all the fields on this type in the state are also given.

These experiments are planned to determine the value of various soil treatments and they are laid out on land which is representative of the particular soil types. The fields include 13 plots, 155 feet 7 inches by 28 feet, or one-tenth of an acre, in size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of the fertilizers and in the harvesting of the crops to insure accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former, manure is applied while in the latter crop residues are employed. The other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four year rotation. The crop residues treatment consists of the plowing under of the cornstalks which have been cut with a disc or stalk-cutter, turning under the straw from the small grains and the plowing under of at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amount to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in a four year rotation. Acid phosphate is employed at the rate of 200 pounds per acre annually. Until 1923, the old standard 2-8-2 complete commercial fertilizer was used, being applied at the
rate 300 pounds per acre annually. The new standard 2-12-2 brand is now being used, application being made at the rate of 267 pounds per acre annually. In this way, the complete fertilizer supplies the same amount of phosphorus as that contained in the 200 pounds of acid phosphate.

THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca field in Pottawattamie County are given in table X. The beneficial effect of manure on this soil is shown in practically all cases. The influence on the oats is noted particularly and on the clover and sweet clover. Little effect was evidenced on the corn in 1919 and none at all in 1922. Lime was not applied to this field until 1920 and in the succeeding years there was little evidence of the effect of this material except on the sweet clover in 1924, where a very large increase in yield was secured. The soil was not very acid in reaction and the crops preceding the sweet clover apparently were not benefited materially by the application of the lime. In many cases, however, the Marshall silt loam is more acid in reaction and, in such cases, the addition of lime is particularly necessary. There may be considerable effect on the yields of various crops from the use of lime.

The application of rock phosphate and acid phosphate along with the manure and lime showed some beneficial effects in several instances. The corn in 1919 was increased and the corn in 1922 showed considerable gains. The oats in 1923 were increased considerably. No effects from these fertilizers were evidenced on the sweet clover or on the clover in 1921, and no effect on the oats in 1920. The complete commercial fertilizer had very much the same effect as the phosphates except that a gain was noted in the case of the sweet clover and a larger influence was secured on the oats in 1923. Clover in 1921 also showed a small increase from the use of the complete fertilizer.

The crop residues treatment showed a small effect in several cases, but in general the influence was not particularly noteworthy. Lime with the crop residues brought about increases in the clover, corn, oats and sweet clover in the years succeeding the application of the material. The effect of the lime was evidenced particularly on the sweet clover. The rock phosphate and acid phosphate showed increases in crop yields in several cases, the effect of the acid phosphate being particularly noted on the oats in 1923, and on the oats in 1920. The rock phosphate brought about a gain in the clover in 1921. Sweet clover was not influenced apparently by either of the phosphate carriers. The complete commercial fertilizer had less effect than the acid phosphate except in the case of the clover in 1921 when a considerable increase in crop yields was brought about.
TABLE X. FIELD EXPERIMENT—MARSHALL SILT LOAM—POTTAWATTAMIE COUNTY. AVOCA FIELD.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1919 Corn bu. per A</th>
<th>1920 Oats bu. per A</th>
<th>1921 Clover tons per A</th>
<th>1923 Corn bu. per A</th>
<th>1924 Oats bu. per A</th>
<th>Biennial sweet clover tons per A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>72.9</td>
<td>62.2</td>
<td>2.0</td>
<td>58.1</td>
<td>48.7</td>
<td>0.36</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>72.1</td>
<td>69.0</td>
<td>2.7</td>
<td>53.6</td>
<td>56.7</td>
<td>0.63</td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>74.0</td>
<td>72.3</td>
<td>2.6</td>
<td>53.9</td>
<td>53.2</td>
<td>1.82</td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock phosphate</td>
<td>77.8</td>
<td>58.8</td>
<td>2.7</td>
<td>55.5</td>
<td>60.0</td>
<td>1.32</td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + acid phosphate</td>
<td>79.3</td>
<td>69.0</td>
<td>2.5</td>
<td>66.5</td>
<td>60.0</td>
<td>1.68</td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + complete commercial fertilizer</td>
<td>77.5</td>
<td>61.2</td>
<td>2.8</td>
<td>57.5</td>
<td>66.8</td>
<td>1.92</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>71.5</td>
<td>58.8</td>
<td>2.0</td>
<td>44.8</td>
<td>47.6</td>
<td>0.85</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>78.9</td>
<td>63.9</td>
<td>2.0</td>
<td>44.8</td>
<td>49.8</td>
<td>0.90</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + lime</td>
<td>80.7</td>
<td>68.1</td>
<td>2.1</td>
<td>50.0</td>
<td>50.7</td>
<td>1.92</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + lime + rock phosphate</td>
<td>78.5</td>
<td>68.6</td>
<td>2.8</td>
<td>54.8</td>
<td>59.0</td>
<td>1.83</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + lime + acid phosphate</td>
<td>81.1</td>
<td>75.1</td>
<td>2.2</td>
<td>54.1</td>
<td>64.5</td>
<td>1.50</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + lime + complete commercial fertilizer</td>
<td>80.4</td>
<td>68.6</td>
<td>2.9</td>
<td>52.0</td>
<td>52.1</td>
<td>1.44</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>80.0</td>
<td>68.6</td>
<td>2.2</td>
<td>46.3</td>
<td>50.9</td>
<td>1.12</td>
</tr>
</tbody>
</table>

It would seem from these results that the Marshall silt loam will respond in a large way to applications of farm manure and this material should be applied in liberal amounts to this soil. Additions of lime may be necessary on the type in many cases where it is strongly acid in reaction. Where the reaction is only slightly acid, beneficial effects from the lime may not be noted in the case of general farm crops. Sweet clover is particularly sensitive to a lack of lime and when this crop is to be grown, special care should be exercised to insure an adequate content of lime in the soil. In general it is important to test the Marshall silt loam and to provide for an abundant presence of lime when any legume is to be grown.

Beneficial effects from the use of phosphate fertilizers are noted in several cases, both with the manure and lime and under the grain system of farming with the crop residues and lime. The influence of these phosphate fertilizers is evidenced, particularly on the oats grown in the rotation. In a few cases increases were secured on the clovers. The complete commercial fertilizer in general had less effect than the acid phosphate and altho it may bring about slightly larger increases in crop yields in some cases, the use of acid phosphate can be considered ordinarily to be of more profit because the complete commercial fertilizer is much more expensive. It is recommended that tests of acid phosphate and rock phosphate be carried out on this soil on individual farms in order to determine the need of phosphorus and to learn which phosphate fertilizer may be employed with the greater profit.

THE RED OAK FIELD

The results secured on the Red Oak field on the Marshall silt loam in Montgomery County are given in table XI.

The beneficial effect of applications of manure to this soil is shown very definitely by the data in this table. The increased yield of winter wheat in 1918 is particularly noteworthy. The corn crops were increased to a large extent

---

1 Field slopes toward Plot 13.
2 Not limed until October 1, 1920. Three tons per acre.
3 Field pastured until June 1.
4 Corn injured by hail in August and by rainy spring.
in every case and similar increases were noted with the oats and winter wheat in 1922. There was a slight gain in the soybeans in 1924. Lime was applied to this soil in 1919 and there was apparently some effect of the use of this material on the corn crop, on the oats and wheat and on the soybeans in 1924. It is evident that the application of lime to the Marshall silt loam when it is acid will frequently bring about large increases in yields of general farm crops.

The addition of rock phosphate and acid phosphate along with the manure and lime brought about increases in crop yields in many cases. The effect of these phosphates was noted particularly on the winter wheat in 1922, altho gains were secured in the case of some of the other crops in various seasons. In none of the other cases, however, were any pronounced increases secured. The complete commercial fertilizer had about the same effect as the acid phosphate in practically all cases, showing up a little better in one or two instances, particularly in the case of the soybeans in 1924, but in general the results were very similar to those secured with the phosphate.

The crop residues treatment had little effect on the crop yields, which would be expected. Lime with crop residues brought about increases in yields in practically all cases. The soybeans in 1924 were increased to a considerable extent, but the increases of special interest are those noted with corn, oats, and winter wheat. The two phosphate fertilizers when applied with the crop residues and lime showed increased crop yields in several cases, again the effect being particularly noticeable on the winter wheat in 1922. The oats in 1921 were increased considerably and the acid phosphate had an effect on the wheat in 1918, and on the corn in 1920. There was little effect from the phosphate fertilizers in several cases. The complete commercial fertilizer again showed very similar effects to those noted in the case of the phosphates. In one or two instances the complete commercial fertilizer gave larger effects. This was the case particularly with the soybeans in 1924 and the corn in 1923. In general, however, it would seem that the complete fertilizer had no larger effects than acid phosphate and hence it would not be considered to be valuable for use.

These results confirm those secured on the Avoca field on the same soil type, indicating the value from the applications of manure and lime in many cases and the possible profit which may result from the application of a phosphate fertilizer. It would seem that the addition of lime is of particular value on this type, when it is acid, if legumes are to be grown. The effects of phosphate fertilizers are of particular note on winter wheat, altho considerable influence may be exerted on other crops in the rotation, from the use of a phosphorus carrier. No choice is possible between acid phosphate and rock phosphate, altho there is some evidence that the acid phosphate is somewhat preferable. Tests on individual farms are very desirable with these two phosphorus carriers. The complete commercial fertilizer had in general about the same effect as acid phosphate and hence could not be considered as desirable for use.

THE VILLISCA FIELD

The results secured on the Marshall silt loam on the Villisca field in Montgomery County are given in table XII.

The application of manure increased the crop yields in each year as shown in the table. A large effect was noted on the clover in 1918 and a similar large increase was found on the corn in 1922. Lime was not applied to this field until the fall of 1920. In the succeeding years the effect of lime was evidenced on the clover and the corn crop. Evidently the soil was in need of the addition in order to secure larger yields of these crops.

The addition of rock phosphate or acid phosphate with the manure and lime increased the crop yields in practically all cases, the gains being definitely evidenced on the clover in 1918. Rock phosphate showed a little effect on the same crop in 1921, but the acid phosphate did not show up in that year. In
### Table XI. Field Experiment—Marshall Silt Loam—Montgomery County, Red Oak Field

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 W. Wheat bu. per A.</th>
<th>1919 Corn bu. per A.</th>
<th>1920 Corn bu. per A.</th>
<th>1921 Oats bu. per A.</th>
<th>1922 W. Wheat bu. per A.</th>
<th>1923 Corn bu. per A.</th>
<th>1924 Soybeans bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>13.6</td>
<td>52.0</td>
<td>56.0</td>
<td>28.2</td>
<td>13.2</td>
<td>54.5</td>
<td>11.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>34.1</td>
<td>57.2</td>
<td>61.6</td>
<td>36.9</td>
<td>15.5</td>
<td>57.8</td>
<td>12.4</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>31.8</td>
<td>59.2</td>
<td>66.0</td>
<td>37.8</td>
<td>18.9</td>
<td>64.7</td>
<td>14.2</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>27.7</td>
<td>60.0</td>
<td>63.0</td>
<td>35.6</td>
<td>28.6</td>
<td>64.6</td>
<td>13.7</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>31.8</td>
<td>58.5</td>
<td>62.7</td>
<td>39.4</td>
<td>30.7</td>
<td>62.9</td>
<td>13.1</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>29.5</td>
<td>56.2</td>
<td>64.2</td>
<td>36.4</td>
<td>25.4</td>
<td>61.3</td>
<td>14.6</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>29.5</td>
<td>54.2</td>
<td>56.6</td>
<td>31.8</td>
<td>17.4</td>
<td>50.6</td>
<td>10.5</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>25.0</td>
<td>53.7</td>
<td>60.2</td>
<td>31.2</td>
<td>19.5</td>
<td>55.0</td>
<td>12.2</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+lime+rock phosphate</td>
<td>18.1</td>
<td>57.7</td>
<td>59.2</td>
<td>35.0</td>
<td>23.8</td>
<td>55.7</td>
<td>12.3</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+lime+acid phosphate</td>
<td>27.2</td>
<td>53.7</td>
<td>61.6</td>
<td>38.9</td>
<td>22.3</td>
<td>52.7</td>
<td>12.1</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+lime+complete commercial fertilizer</td>
<td>26.1</td>
<td>57.0</td>
<td>57.3</td>
<td>37.8</td>
<td>22.2</td>
<td>56.8</td>
<td>14.0</td>
</tr>
<tr>
<td>12</td>
<td>Check</td>
<td>13.6</td>
<td>48.2</td>
<td>51.4</td>
<td>29.0</td>
<td>15.2</td>
<td>52.0</td>
<td>8.9</td>
</tr>
</tbody>
</table>

1920, the acid phosphate showed a particularly large effect on the oats. In 1922 and 1923, the effects of these two phosphates were very similar on the corn crops, increases being secured in both cases. The complete commercial fertilizer gave somewhat better effects than the phosphates in one or two cases, notably on the clover in 1918 and the corn in 1922. In some of the other seasons, it was a little better than the acid phosphate and in some cases showed less effect than the rock phosphate. In 1920, it had much less effect on the oats than the acid phosphate but was more effective than the rock phosphate.

Very little influence of the crop residues was evidenced on the yields of the various crops. Lime applied with the crop residues brought about increases in the crops in 1921, 1922 and 1923. The differences were not large in any case but were quite definite. The rock phosphate and acid phosphate gave some increases in crop yields in practically all cases with the exception of the clover in 1921. The differences were not very large except in one or two cases. Corn in 1919 and the oats in 1920 were increased considerably by the acid phosphate while the rock phosphate had little influence. In 1922 and 1923, the acid phosphate was a little better than the rock but the differences were not large in either case. The complete commercial fertilizer with the lime and crop residues had a somewhat greater effect than the acid phosphate in three or four cases but the differences were not large, except on the corn in 1922. It was more effective than the acid phosphate on the oats in 1920 but showed less effect than the phosphate on the clover in 1918 and corn in 1919.

It would seem from this experiment that the Marshall silt loam will respond to applications of manure, the addition of lime when the soil is acid and in many cases to the application of a phosphate fertilizer.

---

1 Clover killed and plowed up. Yield plot 7 error.
2 ½ tons lime applied May 15.
3 ½ tons lime applied in Sept.
4 Dry weather killed out clover.
TABLE XII. FIELD EXPERIMENT—MARSHALL SILT LOAM—MONTGOMERY COUNTY. VILLISCA FIELD.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918* Clover tons per A.</th>
<th>1919 Corn bu. per A.</th>
<th>1920* Oats bu. per A.</th>
<th>1921 Clover tons per A.</th>
<th>1922 Corn bu. per A.</th>
<th>1923* Corn bu. per A.</th>
<th>1924* Corn</th>
<th>1924* Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>1.00</td>
<td>49.3</td>
<td>46.2</td>
<td>0.73</td>
<td>64.1</td>
<td>37.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>1.20</td>
<td>51.0</td>
<td>52.1</td>
<td>0.88</td>
<td>73.9</td>
<td>38.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>1.30</td>
<td>50.3</td>
<td>52.7</td>
<td>0.99</td>
<td>76.6</td>
<td>43.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>1.50</td>
<td>52.0</td>
<td>54.7</td>
<td>1.12</td>
<td>81.1</td>
<td>44.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>1.40</td>
<td>49.0</td>
<td>72.7</td>
<td>0.80</td>
<td>80.3</td>
<td>45.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>1.60</td>
<td>48.7</td>
<td>58.1</td>
<td>1.04</td>
<td>82.4</td>
<td>45.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>1.65</td>
<td>52.0</td>
<td>49.3</td>
<td>0.93</td>
<td>63.3</td>
<td>38.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>1.60</td>
<td>49.3</td>
<td>47.9</td>
<td>0.91</td>
<td>63.3</td>
<td>37.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+lime+rock phosphate</td>
<td>1.50</td>
<td>48.3</td>
<td>52.4</td>
<td>0.60</td>
<td>66.8</td>
<td>41.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+lime+acid phosphate</td>
<td>1.55</td>
<td>53.0</td>
<td>59.7</td>
<td>0.83</td>
<td>67.3</td>
<td>42.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+lime+complete commercial fertilizer</td>
<td>1.45</td>
<td>51.7</td>
<td>62.8</td>
<td>0.91</td>
<td>73.1</td>
<td>43.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Check</td>
<td>1.55</td>
<td>55.7</td>
<td>51.4</td>
<td>0.70</td>
<td>64.9</td>
<td>36.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results are very similar to those secured in the two fields just discussed and apparently the needs of the Marshall silt loam are very much the same throughout the area in which it occurs. It is recommended that liberal applications of farm manure be made to this type, that lime be applied when the soil is acid, in order to provide the best growth of legumes, and it is urged that farmers test the effect of rock phosphate and acid phosphate on small areas on their own farms in order to determine whether or not their soils will respond to phosphorus and which phosphate fertilizer should be used. Complete commercial fertilizers are not recommended for general use at the present time because acid phosphate seems to be quite as effective and it is much less expensive.

THE OSAGE FIELD

The results secured on the Carrington silt loam on the Osage field in Mitchell County are given in table XIII. The application of manure increased the crop yields on this soil on each crop except the oats in 1924. Very large effects were noted in the case of the oats in 1920 and the clover in 1921. Large increases were also secured on the corn in 1918, in 1922 and in 1923. Lime applied with manure brought about a further increase in crop yields in most cases. The influence of the lime was particularly noted on the clover in 1921. Large effects were also secured on the corn in 1919 and in 1923 and on the oats in 1924. The addition of rock phosphate or acid phosphate with manure and lime proved of value to the crop yields in many cases. In fact increases were secured in the case of all the crops except the clover in 1921. The acid phosphate showed a slightly larger effect in practically all cases than the rock phosphate. On the oats in 1924, very much larger gains were secured from the acid phosphate. Except for this particular crop, however, the differences were not large enough to indicate any very great superiority for the acid phosphate over the rock phosphate.
phosphate. The complete commercial fertilizer had a greater effect than the acid phosphate in three cases but it showed a smaller effect than either of the phosphates on the corn in 1918, 1922 and 1923. In no case, however, was there very large difference in the effect of the complete commercial fertilizer and the phosphates.

The crop residues showed practically no effect on the yields of the various crops grown on this field. Lime applied with the residues exerted a very pronounced effect in some cases. Increases were noted in practically all of the crops, the greatest increases being secured on the corn in 1923 and on the oats in 1924. A large effect was also secured on the corn in 1919. Rock phosphate or acid phosphate with the crop residues and lime brought about crop increases in most cases, altho again the clover showed up slightly better than the rock phosphate in several cases but in other instances, the rock phosphate seemed quite superior. The differences were not very large in any of the crops. The yield on the acid phosphate plot in 1924 was low because of injury by gophers. The complete commercial fertilizer with the lime and crop residues increased the crop yields much more than the phosphate in most cases. The differences were quite pronounced in the case of the clover in 1921, the oats in 1920 and the corn in 1919 and 1923.

These results indicate quite definitely the value of manure when applied to the Carrington silt loam. Large increases in crop yields are secured from the use of this material. Lime is of large effect on the soil and should be applied according to the needs as indicated by tests of the soil. If the best growth of legumes and of all general farm crops is to be secured then lime must be applied to this type. The soil will respond to an application of a phosphate fertilizer. It is impossible at present to choose between rock phosphate and acid phosphate as the beneficial results from the materials vary with the conditions and the

TABLE XIII. FIELD EXPERIMENT—CARRINGTON SILT LOAM—MITCHELL COUNTY. OSAGE FIELD—SERIES 1.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918* Corn bu. per A.</th>
<th>1919 Corn bu. per A.</th>
<th>1920* Corn bu. per A.</th>
<th>1921* Oats bu.</th>
<th>1922* Clover bu. per A.</th>
<th>1923* Corn bu. per A.</th>
<th>1924* Oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>46.5</td>
<td>55.8</td>
<td>34.6</td>
<td>1.09</td>
<td>58.8</td>
<td>42.3</td>
<td>72.4</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>52.8</td>
<td>60.0</td>
<td>60.3</td>
<td>1.56</td>
<td>68.0</td>
<td>50.8</td>
<td>71.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>52.8</td>
<td>70.0</td>
<td>56.3</td>
<td>1.98</td>
<td>68.0</td>
<td>64.1</td>
<td>82.8</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>54.8</td>
<td>72.0</td>
<td>61.2</td>
<td>1.94</td>
<td>74.3</td>
<td>70.7</td>
<td>86.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>56.4</td>
<td>77.0</td>
<td>61.2</td>
<td>1.82</td>
<td>76.0</td>
<td>70.7</td>
<td>98.0</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>44.5</td>
<td>79.0</td>
<td>67.3</td>
<td>1.63</td>
<td>72.3</td>
<td>70.2</td>
<td>102.9</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>38.8</td>
<td>67.0</td>
<td>59.8</td>
<td>1.48</td>
<td>50.0</td>
<td>53.7</td>
<td>74.3</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>37.7</td>
<td>65.0</td>
<td>55.0</td>
<td>1.56</td>
<td>51.4</td>
<td>52.0</td>
<td>71.8</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+lime</td>
<td>39.4</td>
<td>74.0</td>
<td>50.3</td>
<td>1.56</td>
<td>58.3</td>
<td>65.2</td>
<td>81.6</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+lime+rock phosphate</td>
<td>47.4</td>
<td>75.0</td>
<td>61.8</td>
<td>1.56</td>
<td>57.7</td>
<td>64.4</td>
<td>90.3</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+lime+acid phosphate</td>
<td>44.2</td>
<td>73.0</td>
<td>59.8</td>
<td>1.44</td>
<td>62.3</td>
<td>64.9</td>
<td>73.4</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+lime+complete commercial fertilizer</td>
<td>48.8</td>
<td>78.0</td>
<td>67.3</td>
<td>1.79</td>
<td>65.5</td>
<td>69.9</td>
<td>87.1</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>38.7</td>
<td>67.0</td>
<td>53.1</td>
<td>1.69</td>
<td>52.3</td>
<td>53.2</td>
<td>75.6</td>
</tr>
</tbody>
</table>

*Four tons lime applied.
*Plot 1 low yield—oats down badly; four tons lime applied Sept.
*Clover pastured heavily in spring.
*Corn down badly on checks and crop residue plots.
*Dry weather reduced yield.
*Oats lodged. Gophers injured crop on plot 11.
crops grown. It is recommended that farmers test the relative effect of rock phosphate and acid phosphate on their own soils, and thus determine for their particular conditions which will prove the more profitable. The use of a complete commercial fertilizer can hardly be recommended from the data given, as it would seem that a phosphate fertilizer might be quite as valuable and it would prove much less expensive. The results are very much the same on the crop residues plots, representing the grain system of farming. Here again the effect of lime is evident and the beneficial influence of a phosphate fertilizer is shown quite definitely.

THE CLARINDA FIELD

The results secured on the Waukesha silt loam on the Clarinda field in Page County are given in table XIV. Manure brought about very definite increases in crop yields in most cases on this field. Lime applied with manure proved of benefit on practically all of the crops grown. The influence was noted not only on clover but also in a very large way on the corn and oats. The rock phosphate or acid phosphate applied with manure and lime proved of considerable value to the crops grown in most cases. The influence was particularly great on the clover in 1917, the acid phosphate showing up somewhat better than the rock phosphate, in that case. Very definite increases were also secured on the corn in 1919 and in 1923. The complete commercial fertilizer had a greater effect than the acid phosphate in one or two cases, particularly on the oats in 1920 and in 1924. In most instances, however, the acid phosphate was even more effective than the complete fertilizer.

The crop residues showed little effect on the various crops grown, except in the case of the oats in 1924, when a considerable increase was secured. Lime in addition to the residues proved of value on all the crops, the effect being particularly noticeable on the clover in 1917 and on the corn in 1922. Increases were quite definite in several other cases on corn and oats. The rock phosphate or acid phosphate, used with the lime and crop residues increased crop yields in many cases. The clover in 1917 was benefited to a particularly large extent and the corn in 1922 showed a considerable increase.

The oats in 1916 were increased by both phosphates, the acid phosphate giving very much larger effects. In 1919, the acid phosphate increased the corn to a considerable extent while the rock phosphate showed practically no influence. In 1920, the two phosphates had about the same effect and, in 1923, the acid phosphate was slightly superior to the rock phosphate. The complete commercial fertilizer had somewhat greater effects than the acid phosphate on the corn in 1922 and 1923. It also was somewhat better than acid phosphate in its effect on the oats in 1920 and in 1924. In the other seasons, however, the influence of the complete commercial fertilizer was less than that of the acid phosphate.

The results secured in this field experiment indicate the value of applications of farm manure to the Waukesha silt loam. Considerable increases in crop yields follow the application of this material. Lime should be applied with manure when the soil is acid and large increases in the yields of legumes will be secured from the proper use of lime. Definite increases in yields of other general farm crops will also be secured from the application of lime. The soils apparently will respond in many cases to applications of a phosphate fertilizer. Sometimes the acid phosphate seems superior while in other cases the rock phosphate gives quite as good results. It is recommended, therefore, that on this soil, farmers test the relative value of acid phosphate and rock phosphate under their own conditions so that they may determine which fertilizer can be used the more profitably. It is not recommended that a complete commercial fertilizer be used generally on this soil, as it would seem that acid phosphate would give quite as satisfactory results and prove less expensive.
## TABLE XIV. FIELD EXPERIMENT—WAUKESHA SILT LOAM—PAGE COUNTY.
### CLARINDA FIELD—SERIES 100.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1915 Corn, bu. per A.</th>
<th>1916 Oats, bu. per A.</th>
<th>1917 Clover, tons per A.</th>
<th>1918 Corn, bu. per A.</th>
<th>1919 Oats, bu. per A.</th>
<th>1920 Oats, bu. per A.</th>
<th>1921 Soybeans, bu. per A.</th>
<th>1922 Corn, bu. per A.</th>
<th>1923 Oats, bu. per A.</th>
<th>1924 Corn, bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>51.2</td>
<td>61.1</td>
<td>1.19</td>
<td>55.1</td>
<td>51.0</td>
<td>23.5</td>
<td>79.4</td>
<td>65.9</td>
<td>55.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>49.9</td>
<td>54.4</td>
<td>1.36</td>
<td>58.7</td>
<td>52.3</td>
<td>25.3</td>
<td>87.4</td>
<td>73.7</td>
<td>53.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>50.6</td>
<td>63.3</td>
<td>1.56</td>
<td>62.6</td>
<td>61.8</td>
<td>25.2</td>
<td>89.6</td>
<td>73.6</td>
<td>61.3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock phosphate</td>
<td>48.2</td>
<td>50.0</td>
<td>2.89</td>
<td>69.3</td>
<td>63.6</td>
<td>24.2</td>
<td>87.9</td>
<td>82.1</td>
<td>53.7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + acid phosphate</td>
<td>54.8</td>
<td>52.2</td>
<td>3.40</td>
<td>70.9</td>
<td>60.4</td>
<td>24.3</td>
<td>88.3</td>
<td>78.0</td>
<td>56.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + complete commercial fertilizer</td>
<td>49.7</td>
<td>50.0</td>
<td>2.55</td>
<td>59.7</td>
<td>73.5</td>
<td>23.3</td>
<td>90.8</td>
<td>76.7</td>
<td>66.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>48.0</td>
<td>47.7</td>
<td>1.36</td>
<td>56.3</td>
<td>41.8</td>
<td>24.0</td>
<td>82.4</td>
<td>64.6</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>45.2</td>
<td>41.1</td>
<td>1.53</td>
<td>56.5</td>
<td>55.7</td>
<td>23.0</td>
<td>71.8</td>
<td>53.8</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + lime</td>
<td>51.4</td>
<td>43.3</td>
<td>2.21</td>
<td>58.2</td>
<td>58.7</td>
<td>25.8</td>
<td>81.2</td>
<td>48.6</td>
<td>49.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + lime + rock phosphate</td>
<td>51.6</td>
<td>47.7</td>
<td>2.71</td>
<td>60.7</td>
<td>61.1</td>
<td>25.8</td>
<td>85.2</td>
<td>54.5</td>
<td>52.7</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + lime + acid phosphate</td>
<td>53.4</td>
<td>54.4</td>
<td>2.89</td>
<td>69.8</td>
<td>60.4</td>
<td>24.8</td>
<td>87.5</td>
<td>57.2</td>
<td>54.1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + lime + complete commercial fertilizer</td>
<td>50.3</td>
<td>47.7</td>
<td>2.72</td>
<td>65.3</td>
<td>62.4</td>
<td>24.8</td>
<td>90.6</td>
<td>70.1</td>
<td>58.8</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>50.5</td>
<td>47.7</td>
<td>1.36</td>
<td>57.2</td>
<td>42.5</td>
<td>22.5</td>
<td>88.7</td>
<td>71.8</td>
<td>43.9</td>
<td></td>
</tr>
</tbody>
</table>

### AVERAGE RESULTS ON THE MARSHALL SILT LOAM

The average crop yields and increases secured from the various fertilizer treatments applied to the Marshall silt loam on all the fields on that type in Iowa are given in table XV. The value of manure on the corn, oats, clover and wheat on this soil is clearly shown, the effect being the greatest on the corn and oats.

Lime increased the yields of all the crops, particularly the clover and wheat. The phosphates with manure and lime gave distinct increases in all cases, the acid phosphate proving superior to the rock phosphate in every instance. The difference was the greatest in the case of the clover. The complete commercial fertilizer had less effect than the phosphates on the corn, clover and wheat but gave somewhat greater effects on the oats, not enough, however, to make its use profitable.

The crop residues showed little effect on any of the crops. Lime with the residues brought about pronounced increases. The phosphates with the lime and crop residues both showed beneficial effects, the acid phosphate again proving more effective than the rock phosphate. The greatest difference was noted in the case of the oats. The complete commercial fertilizer showed less effect than the acid phosphate in most cases; only in the case of oats was it better than the rock phosphate.

It is evident from these average figures, which confirm the results given on the individual fields on this same type, that the Marshall silt loam may be profitably fertilized with manure, lime and phosphorus. It would seem that...
### TABLE XV. MARSHALL Silt Loam. AVERAGE CROP YIELDS AND INCREASES DUE TO FERTILIZER TREATMENT. IOWA EXPERIMENT FIELDS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Corn* Increase for treatment bu. per acre</th>
<th>Oats* Increase for treatment bu. per acre</th>
<th>Clover* Increase for treatment tons per acre</th>
<th>Winter Wheat* Increase for treatment bu. per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>68.4</td>
<td>35.8</td>
<td>1.33</td>
<td>15.3</td>
</tr>
<tr>
<td>Manure</td>
<td>63.4</td>
<td>42.3</td>
<td>1.40</td>
<td>15.5</td>
</tr>
<tr>
<td>Manure + lime</td>
<td>65.7</td>
<td>44.4</td>
<td>1.60</td>
<td>18.6</td>
</tr>
<tr>
<td>Manure + lime + rock phosphate</td>
<td>70.2</td>
<td>45.8</td>
<td>2.80</td>
<td>28.6</td>
</tr>
<tr>
<td>Manure + lime + acid phosphate</td>
<td>71.6</td>
<td>44.8</td>
<td>3.40</td>
<td>30.7</td>
</tr>
<tr>
<td>Manure + lime + complete commercial fertilizer</td>
<td>69.4</td>
<td>52.0</td>
<td>2.60</td>
<td>25.4</td>
</tr>
<tr>
<td>Crop residues</td>
<td>59.3</td>
<td>43.5</td>
<td>1.50</td>
<td>16.4</td>
</tr>
<tr>
<td>Crop residues + lime + rock phosphate</td>
<td>63.0</td>
<td>43.8</td>
<td>2.20</td>
<td>19.5</td>
</tr>
<tr>
<td>Crop residues + lime + acid phosphate</td>
<td>67.2</td>
<td>47.8</td>
<td>2.70</td>
<td>23.8</td>
</tr>
<tr>
<td>Crop residues + lime + complete commercial fertilizer</td>
<td>67.5</td>
<td>52.0</td>
<td>2.80</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Acid phosphate may be somewhat better than the rock phosphate under both systems of farming, but the results along this line are not entirely definite, and it is urged that tests of these two fertilizers be carried out on individual farms in order that the farmer may use that material which will give him the best results. The complete commercial fertilizer had less effect than the acid phosphate in practically all cases, and hence it cannot be considered desirable for use on this soil. Lime is evidently of value on the type when it is acid, and it is important therefore, that the soil be tested for acidity and lime be applied as needed.

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

The laboratory, greenhouse and field experiments which have been discussed in previous pages have indicated quite definitely the general needs of the soils of this county, hence, some recommendations may be given which will be applicable to the county as a whole. It is recognized that the field tests reported in these pages have been carried out in other counties, but the soil types are the same as those occurring in Woodbury County and hence the results may be considered to indicate quite definitely the effects of the same fertilizer treatments in this county. The recommendations which are given here are based upon these experiments but also upon the general experience of many farmers. No suggestions are made except those which have been shown to be of value by much practical experience. Any of the recommendation made here can be put into effect on any farm.

*Corn yields averaged from four years' results on four fields; oats from four years' results on four fields; clover from one year's results on one field and winter wheat from one year's results on one field.
In several cases it is suggested that tests be carried out on individual farms and it should be noted that many farmers are already carrying out simple tests of fertilizing materials and securing data of considerable value to themselves and to farmers who are located on the same soils. Such tests can be carried out quite readily. The Soils Section of the Iowa Agricultural Experiment Station, is ready to aid any farmers who may be interested in conducting tests on their own soils.

**LIMING**

The upland soils of Woodbury County, except for the Knox silt loam were all found to be acid in the surface soil. In general this acidity extended down thru the subsoil. Only in the case of the steep phase Carrington loam was there found a high content of lime in the subsoil. It would seem, therefore, that on the uplands and also on the terraces in Woodbury County, as these latter soils are also acid in reaction thruout the three foot section, additions of lime would be very necessary for the best crop growth. The Marshall silt loam, the most extensive upland type is generally acid in reaction and while the extent of acidity is not great, still this soil will respond in many cases to applications of lime as has been indicated by the field experiments reported earlier.

The figures given in the tables have shown the limestone requirements of the various upland soil types but these figures should be considered merely indicative of the needs of the soils inasmuch as soils vary widely in lime requirement and even different samples of soils of the same type may show a differing acidity. It is necessary, therefore, that the soil in any field be tested for lime needs, before there is any application, then a proper amount of lime may be applied and the best results secured from its use. It is recommended that the upland soils in Woodbury County be tested for their lime needs, especially before seeding to a legume, and the amount of lime shown to be necessary by this test should be applied. Farmers may test their own soils for lime requirement but it will usually be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

The greenhouse and field experiments discussed earlier in this report indicated quite definitely the value of applications of lime to the acid uplands and terrace soils. Experiences on many farms have also shown a beneficial effect on crop yields from the application of lime, when the soil is acid. It is evident therefore, that the soils in Woodbury County on the uplands and on the terraces should be tested for lime requirements at regular intervals. One application of lime will not suffice for all time. It is urged that the soil be tested at least once in a four year rotation, in order that the lime needs may be met before seeding to the legume in the rotation. It is particularly necessary to supply lime to these soils, if alfalfa or sweet clover are to be grown.

Further information regarding the use of lime on soils, losses by leaching and other points connected with liming are given in Extension Bulletin 105 of the Iowa Agricultural Experiment Station. A list of companies prepared to furnish lime for agricultural use is also given in this bulletin.

**MANURING**

As has been noted earlier in this report the soils of Woodbury County are not in general strikingly lacking in organic matter but in a few cases there is a deficiency. In most of the upland types the supply of organic matter is not large and it is very necessary that some fertilizing material be used on these soils to return organic matter to them and keep them in the best condition for crop growth. On those types which are low in organic matter, particularly the sandy soils on the bottoms, additions of organic matter are particularly necessary. On
soil survey of iowa

the heavy black types on the bottoms it is not important that organic matter be applied at present, insomuch as these soils are very rich in this constituent.

farm manure is the most valuable fertilizer which can be employed for increasing the fertility of soils, and it is of value largely because it supplies organic matter. it brings about large crop increases on soils which are light in color and sandy in texture and quite evidently deficient in organic matter. on the upland soils in this county it is of particularly large value. its effect has been noted on the marshall silt loam, on the carrington silt loam and on the terrace soils. its value is also large on the other upland types. on some of the bottomland soils, particularly those which are sandy in texture, the use of farm manure is very desirable. on the heavier black soils, it can be used only in smaller quantities but sometimes it is of value when the soils are newly drained because of the addition of microorganisms which increase the production of available plant food in these soils. when it is applied to these heavy, black types, only small applications should be made and it should not be applied preceding the small grain crop.

the ordinary application of manure amounts to about 8 to 10 tons per acre once in a four year rotation. it is not considered desirable to apply more than this amount of manure, except on soils which are very light in color or in cases where truck crops are to be grown. on average soils for general farm crops, the largest increases per ton of manure are secured with 8 tons.

green manuring, or the turning under of a leguminous crop in the soil, is an important farm practice which may be followed with profitable effects in some cases in woodbury county. on many livestock farms, green manuring is necessary in order to supplement the use of farm manure, as there is an insufficient production of the latter material to keep all the land on the farm supplied. the practice is of particular value, of course, on grain farms where little or no farm manure is produced. in such cases it serves as a substitute for farm manure. wherever it is not possible to keep up the supply of organic matter and nitrogen in woodbury county upland soils thru the use of farm manure, then the practice of green manuring should be followed. legumes should be used for green manure rather than non-legumes insomuch as it is possible thru the use of legumes, when they are well inoculated, to utilize nitrogen from the atmosphere. thus the supply of this constituent in the soil may be increased. green manuring is not a practice which can be followed carelessly, however, as undesirable results may occur if the conditions in the soil are not satisfactory for the best decomposition of the green material.

crop residues should always be thoroughly utilized on the farm insomuch as they contain considerable amounts of plant food removed from the soil by the crops grown and they also contain much valuable organic matter. if they are burned or otherwise destroyed as is so often the case, there is a considerable loss of valuable fertilizing constituents from the land. on the livestock farms the residues may be used for feed or bedding and returned to the land with the manure. on the grain farm they may be stored and allowed to decompose partially before they are applied or they may be applied directly to the land.

the use of commercial fertilizers

the total content of phosphorus in the soils of woodbury county is generally quite low and it is apparent that phosphorus fertilizers will be needed on the soils of this county in the very near future, if crop production is to continue to be satisfactory. there are indications, however, that profitable effects may be secured at the present time from the use of phosphate fertilizers on some of the soils in this county. the greenhouse and field experiments discussed earlier in this report have indicated that considerable increases in crop yields may often be secured from the use of a phosphate carrier.
There are two phosphate fertilizers which may be employed, rock phosphate and acid phosphate. The latter provides the element phosphorus in a form which is immediately available for plant food. Rock phosphate, however, contains the element in a form which is only slowly made available in the soil. Acid phosphate is more expensive but it is applied in smaller amounts, usually at the rate of 150 to 200 pounds per acre annually. Rock phosphate is applied only once in a four year rotation at the rate of about one ton per acre. It is impossible at the present time to determine which of these two phosphorus carriers will give the most desirable effect. In some cases, acid phosphate seemed to prove preferable on some of the crops grown and in other cases rock phosphate has shown up quite as well. It seems probable that acid phosphate might prove most satisfactory for general use on the soils of this county but, in view of the good results secured in some cases from the rock phosphate, it is urged that farmers test these two phosphorus carriers on their own soils and thus determine for their own condition which material will be the more valuable. Simple tests may be carried out quite readily on any farm. Directions which may be followed in carrying out such tests are given in circular 82 of the Iowa Agricultural Experiment Station.

The nitrogen content of the soils of Woodbury County is not particularly low in any case but in general the soils are fairly well supplied with this constituent. Applications of some material supplying nitrogen must be made regularly to all the soils, however, if the supply is to be kept up. In a few cases there is undoubtedly a need for nitrogen at the present time.

Farm manure is a very valuable nitrogenous fertilizer inasmuch as it returns to the land a large part of this constituent removed by the crops grown. On livestock farms, when the manure is properly preserved and returned to the soil, it will play a large part in keeping up the nitrogen supply. Obviously it cannot serve to increase the nitrogen content of the soil to any extent. Its use is very desirable, however, to aid in maintaining the supply already present in the soil.

Leguminous crops used as green manures provide the cheapest and best nitrogenous fertilizers which can be applied. When a legume is inoculated a large part of the nitrogen which it contains is taken from the atmosphere and hence when the crop is turned under in the soil as a green manure there is a corresponding increase in the nitrogen content. When it is desirable to increase the nitrogen supply in the soil the use of leguminous green manures is strongly recommended. They should also be used in all cases where farm manure is not available for application to the land or where the supply of this material is inadequate to make a reasonable application at regular intervals.

Crop residues, when properly applied to the land, also supply some nitrogen and hence these materials may be considered as supplements to farm manure and leguminous green manures. On most farms, it is necessary that all three of these materials be properly utilized if the supply of nitrogen in the soils is to be maintained. It is not believed that commercial nitrogenous fertilizers are needed on the soils of Woodbury County, inasmuch as the nitrogen supply may be increased and maintained thru the proper use of leguminous green manures, farm manure and crop residues.

Previous analyses have indicated that there is a large content of total potassium present in the soils of Woodbury County and it does not seem likely, therefore, that potassium fertilizers will be needed on these soils at the present time. If the potassium is changed into an available form as rapidly as it should be, crops should be well supplied with this constituent for many years to come. The soil conditions should be made satisfactory for the production of available potassium and this is accomplished thru proper cultivation and drainage, proper application of organic matter and lime, the general treatments which are recommended for all the soils in the county. Potassium fertilizers cannot be recommended for general use in this county. If it is desired, small amounts may be
tested on limited areas, using the fertilizer as a top dressing and if profitable results are secured there is no objection to the application of the material. Complete commercial fertilizers may be profitable for use in some cases but it is believed that in general acid phosphate will prove quite as profitable or even more profitable because of the smaller cost of the material. Complete commercial fertilizers supply nitrogen and potassium as well as phosphorus, and hence they cost considerably more. Nitrogen may be more cheaply supplied in the form of a leguminous green manure. Potassium is not likely to be deficient or needed and hence it would seem that acid phosphate supplying only the element phosphorus, would be quite as valuable for use and more profitable. The experimental data which have been reported indicate that in most cases practically as large returns can be secured from the use of a phosphate fertilizer as from a complete commercial fertilizer. Hence the latter are not recommended for general use in the county at present. They may be tested on small areas in comparison with acid phosphate by interested farmers and if profitable results are secured from their use then they may be used on larger areas with assurance of profit.

DRAINAGE

Attention was called earlier in this report to the fact that drainage is very poor on the extensive areas of bottomland in the county. On the uplands, the drainage is excellent and in fact there are very few if any cases where the natural drainage of the land is not sufficient. On the bottoms, however, the topography is level to flat and the subsoil conditions are such that the establishment of drainage ditches and the installation of tile are very necessary before successful crops can be grown. An examination of the map showing the drainage in the county will indicate the poor natural drainage of the bottomland area. Soils which are too wet will not produce good crops and the first treatment needed on many of these bottomland soils in Woodbury County is proper drainage. Many areas of the bottomland have been drained thru the drainage ditches and tile but there are still areas where drainage is inadequate. Further installation of tile is necessary in many cases in order that thorough removal of excess moisture may be accomplished. The farmers in Woodbury County should see to it that their land is well drained if they wish to secure the best returns. Tiling may be expensive but the results secured always warrant the outlay. No fertilizer treatments should be practiced on land until it is well drained. The practical experience of many farmers indicates quite definitely that the benefits from tiling are large and in many cases it may mean the difference between no crops and very satisfactory crop yields.

THE ROTATION OF CROPS

It is quite generally recognized now that the continual growing of any one crop is much less satisfactory than the use of a good rotation. Even if a crop is of particular value still it is more profitable in the long run to rotate crops, including in the rotation, crops which may be of less actual money value. This is due to the fact that under continuous cropping the yields of crops are very much more rapidly reduced than when a rotation is practiced. Farm experience confirms this conclusion and considerable experimental data support it.

No special tests have been carried out in Woodbury County to determine the most desirable rotation to be followed but there are a number of rotations which are in quite general use throughout the state and from among these some one may be chosen which will be suitable for conditions in this county. Modifications of the rotations as suggested may of course often be made with desirable results. In fact almost any rotation may be employed with satisfaction providing it in-
cludes a legume and a profitable crop. The following are some of the common rotations in use in Iowa.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

First year — Corn.
Second year — Oats.
Third year — Clover.
Fourth year — Wheat.
Fifth year — Alfalfa (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year rotation).

4. FOUR-YEAR ROTATIONS

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

5. THREE-YEAR ROTATIONS

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

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

THE PREVENTION OF EROSION

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes.

Erosion occurs to some extent in Woodbury County, its effects being particularly noted on the steep phase Carrington loam and on the Knox silt loam on the bluffs. In many areas, however, there is considerable washing also of the Marshall silt loam on the more rolling upland. Evidently there are many cases in the county where some means of prevention or control of the destructive action of erosion should be adopted.

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

**Erosion Due to Dead Furrows**

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

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

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

**Earth Dams.**—It is a simple method of preventing erosion in small gullies to fill them with straw. This may be done at threshing time with some saving
of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a ‘Christopher’ or ‘Dickey’ dam.

The ‘Christopher’ or ‘Dickey’ Dam.—This modification of the earth dam, consists merely in laying a line of tile down the gully and beneath the dam. An elbow or a ‘T,’ called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

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

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

The Rubbish Dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method.

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

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

The Concrete Dam.—One of the more effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

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

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as for small gullies. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

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

Straightening and Tiling.—The straightening of the larger streams in bot-
tomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed.

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

HILLSIDE EROSION

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

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

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

Contour Discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called “contour discing” and it has proven quite satisfactory in many cases in Iowa.

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

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

INDIVIDUAL SOIL TYPES IN WOODBURY COUNTY *

There are 16 individual soil types in Woodbury County and these with the steep phase Carrington loam, the colluvial phase Wabash silt loam and the undifferentiated alluvial soils make a total of 19 separate soil areas. They are divided into four groups, drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

CARRINGTON Silt Loam (83)

There are two drift soils in the county classified in the Carrington series. Together they cover 7.2 percent of the total area of the county.

The Carrington silt loam is the most extensive drift soil in the county and the fifth largest soil type. It covers 5.1 percent of the total area. It occurs on the slopes of the deeper stream valleys in the eastern and central parts of the county. The larger portion of the type is found along the slopes to the Little Sioux River and its larger tributaries. There are no large individual areas of the type, as it occurs in narrow, irregular strips along the streams. It is developed where the loess has been wholly or partially removed and glacial drift is found within the three foot section.

The surface soil of the Carrington silt loam is a dark brown silt loam extending to a depth of 6 to 10 inches, grading gradually into a brown heavy silt loam.

*The description of individual soil types given in the Bureau of Soils Report have been closely followed in this section of the Report.
At 14 to 16 inches it becomes a brown or yellowish-brown silty clay loam containing some gravel and occasionally glacial boulders. In some areas typical glacial drift consisting of a yellow mixture of gravel, sand and clay is encountered at depths below two feet. There are variations in the depth of the surface soil. In many cases, it is quite shallow, while in other instances it extends for a distance of 10 inches. In some areas, the surface soil is almost absent, there is no typical dark brown surface covering and the underlying drift material is exposed.

In topography the Carrington silt loam is generally moderately rolling to rolling. The slopes are mostly smooth and not as steep as those of the steep phase Carrington loam. Drainage is good and in the rougher areas may be excessive. The subsoil is not gravelly enough to make the soil at all drouthy. A larger part of the type is utilized for cultivated crops and corn, oats, wheat, timothy, clover and alfalfa are the principal crops grown. Corn yields from 25 to 35 bushels per acre, oats 27 to 35 bushels, wheat 12 to 15 bushels and hay 1 to 1½ tons per acre. On the area which is not cultivated, there is some tree growth consisting of a few groves of oak, maple, elm and ash. Occasionally the type is occupied by windbreaks of maple, cottonwood, elm and evergreens.

The Carrington silt loam is naturally a rather productive soil. It will respond, however, to applications of farm manure and liberal amounts of this material should be applied. Occasionally leguminous green manures may be profitably employed on this type especially where farm manure is not available in sufficient amounts to keep the soil well supplied. It is acid in reaction and lime should be used for the best growth of general farm crops and particularly of legumes. Tests of the soil should be made at regular intervals to insure the maintenance of the supply of lime. The use of phosphorus fertilizers would undoubtedly be very profitable on this soil. Tests on the type in other counties have indicated large returns from the use of the phosphorus carriers, and farmers are urged to test the relative effect of acid phosphate and rock phosphate on this soil on their own farms, and thus determine for their own particular conditions whether phosphorus is needed and, if so, which phosphorus carrier will prove the more profitable.

The use of complete commercial fertilizers on the type cannot be recommended at the present time but they may be tested in comparison with phosphates. Commercial nitrogenous or potassium fertilizers are not recommended for use until tests have been carried out which have shown definitely their value. In some areas the soil is subject to erosion and protection from this destructive action is necessary.

### CARRINGTON LOAM STEEP PHASE (57)

The steep phase Carrington loam is the second drift soil in the county, being much smaller in extent than the silt loam. It covers 2.1 percent of the total area. It occurs mainly along the Little Sioux River, in the eastern part of the county. The areas are all small, narrow and irregular in shape.

The surface soil of the steep phase Carrington loam is a dark brown mellow loam, changing at a depth of 7 to 10 inches into a lighter brown loam. The subsoil is a yellowish mixture of sand, gravel and clay and is encountered at depths between 2 and 4 feet. The underlying material consists of glacial drift, a mixture of sand, gravel, boulders and stiff sandy clay. Gravel and boulders are occasionally found scattered over the surface soil. In many places the lower subsoil contains some lime and tests occasionally show effervescence. This characteristic, however, did not occur generally enough to warrant changing the type name to Clarion loam or separating the areas. They were too small to show on the map. The surface soil is usually dark brown in color and fairly well supplied with organic matter. But in the gullied areas along the steepest slopes, there is very little surface soil present and the color of the material at the surface is more like that of the underlying yellowish glacial till.
The type is found along the lower parts of the slopes bordering the steeper stream valleys and the topography is strongly rolling to rough and broken. The slopes are usually rough and steep and the streams have cut deeply thru the soil material, reaching the glacial drift beneath the loess covering. The soil is well drained and in places drainage is excessive. Destructive erosion occurs constantly.

The larger part of this type is too steep and rough for cultivation and it is devoted to pasture, generally affording excellent grazing for a large part of the year. Bluegrass grows well and the steeper slopes should certainly always be left in sod in order to prevent erosion. When the land is not too steep or badly cut up by gully ing, there has been a considerable utilization of it for general farm crops, notably corn, oats, timothy and clover. A few of the areas are in forest consisting mainly of oak, elm, ash, basswood and maple. In some of the smoother areas small fruits and apples are grown.

The chief need of the steep phase Carrington loam is for protection from erosion. On the steeper slopes, sod should be maintained at all times in order to prevent the washing away of the soil. On the smoother areas, yields of general farm crops are fairly satisfactory, but considerable increases will be secured thru the proper application of farm manure, the addition of lime when the soil shows distinctive acidity and the application of a phosphate fertilizer.

**LOESS SOILS**

There are two loess soils in the county classified in the Marshall and Knox series. Together they cover 61 percent of the total area.

**MARSHALL SILT LOAM (9)**

The Marshall silt loam is the largest individual soil type in the county as well as the most extensive loess soil. It covers over half of the total area, 58.4 percent of the county, occupying nearly 90 percent of the upland area. It occurs in all parts of the county, on the uplands, and it is found in numerous extensive individual areas, extending for miles over the uplands cut only by the intermittent drainageways and the smaller tributaries. Where the larger streams cut thru the upland the Marshall silt loam frequently joins the Carrington silt loam on the slopes and on the steeper slopes the Carrington loam steep phase which is adjacent to the bottoms.

The surface soil of the Marshall silt loam is a brown to dark brown mellow silt loam 7 to 12 inches in depth. Below this point the soil becomes a brown, slightly more compact silt loam, changing at 16 to 20 inches into a yellowish-brown, pale yellowish heavy, compact silt loam. The depth of the brown to dark brown surface soil varies considerably in different locations. At the base of the slopes the soil is a dark brown to almost black mellow loam, extending to a depth of as much as 20 to 30 inches. On the steeper slopes and ridge tops, where erosion has occurred to a considerable extent, the dark colored surface soil is very thin and in some cases nearly absent. Frequently this condition is evidenced by the appearance of light brownish or yellow spots in elevated areas. Throuth much of Union, Rutland, Arlington and Banner Townships, the surface soil is deeper and darker in color, varying from dark brown to very dark brown. In the areas between the streams in the eastern part of the county the dark colored surface soil predominates. In many places lime is found in the lower part of the three foot section, usually occurring in concretions. In many cases, however, this is not true and the calcareous material is found much deeper than three feet from the surface. Frequently the surface soil is acid in reaction and the acidity extends down to a considerable depth.

In topography, the Marshall silt loam is strongly rolling or hilly. In the eastern part of the county, except for narrow areas along the Little Sioux River,
the topography is more undulating to gently rolling. Here the streams have cut less sharply into the uplands. In the western part of the county, the streams have excavated deep broad valleys and the slopes are frequently considerably cut by deep drainage channels. The natural drainage of the type is everywhere quite adequate. Erosion occurs to a considerable extent and gullies form on the steeper slopes.

Practically all of the type is under cultivation. Corn, oats, timothy and red clover hay, alfalfa and wheat are the principal crops grown. Average yields of corn amount to 35 to 40 bushels per acre. Oats yield 30 to 40 bushels, timothy and clover hay, 1 to 1½ tons, alfalfa 3 tons and wheat 16 to 18 bushels per acre. The yields vary somewhat depending upon the location of the soil. At the base of the slopes, where the soil is deeper and darker in color, the yields are the best; while on the tops of ridges and on the steeper slopes, the yields are lower. Crops of minor importance grown on the type include rye, barley, sweet clover, sorghum and potatoes. Gardens are maintained on every farm and serve to supply the home demand. Orchard fruits are grown to some extent but not in any commercial way.

The Marshall silt loam is normally a fairly satisfactorily productive soil, but crops may be increased in yields thru proper treatment. Applications of farm manure are very desirable and large amounts of this material should be used on this soil wherever possible in order to insure better crops. The manure would be of particular value on those areas where the surface soil is thinner and lighter in color, but it would show profit in all cases on the soil. In general, the surface soil of the Marshall silt loam is acid in reaction and it would respond to applications of lime, particularly when legumes are seeded. In some cases lime occurs in the lower depths under the Marshall silt loam but as lime rarely moves upward in the soil, the occurrence of this lime in the subsoil has little effect on the needs of the surface soil. The soil should be tested regularly and if acidity is shown, applications of lime are recommended.

The content of phosphorus in the soil is not high and applications of phos-
Phosphorus fertilizers will certainly prove of value. Tests which have been carried out on this soil in other counties have indicated large returns from the use of a phosphorus fertilizer in many cases. Either acid phosphate or rock phosphate should be used. Results thus far secured do not indicate which will be the more profitable. Farmers are urged to test both of these materials on small areas on their own farms and thus they may determine whether their soil will respond to an application of phosphorus and if so which phosphorus fertilizer should be employed. Complete commercial fertilizers may likewise be tested in comparison with phosphates on this soil. It is not believed that they will prove as profitable for general use at the present time as acid phosphate, however, inasmuch as the results thus far secured, have indicated quite as large returns from the phosphates and the cost of the commercial fertilizer is much greater.

The soil should be protected from erosion as it is subject to serious washing and gullying very frequently occurs to a considerable extent. It is very necessary, therefore, that precautions be taken to prevent or control the washing away of the surface soil and the formation of gullies. From among the methods suggested earlier in this report some one may be chosen which will be suitable for use under practically all conditions. It should be emphasized that on the steeper areas of this soil it is particularly necessary that it be protected from erosion.

**Knox Silt Loam (11)**

The Knox silt loam is the second largest loess soil in the county and it is of very much smaller occurrence, covering only 0.6 percent of the total area. It is developed mainly on the bluffs, bordering the bottoms of the Missouri river and it occurs in numerous areas quite irregular in shape. Most of the areas of the type are narrow but in several places they cover several square miles. One of the largest areas is in the extreme northwest corner of the county. Another area of considerable size lies northeast of Sergeant Bluffs and a third is found on the southern boundary of the county between Hornick and Smithland. Several small areas are mapped in the northeast corner of the county in Rock Township.
The surface soil of the Knox silt loam is a light brown to brown mellow friable silt loam extending to a depth of 8 to 12 inches. The subsoil is a yellowish-brown or pale buff loose friable silt loam, very much like the original loessial material. The color of the surface soil is quite variable depending upon the content of organic matter. On the steep eroded slopes it is very light in color, while on the more nearly level areas and at the lower parts of the slopes the color is darker and the soil is very much deeper. The subsoil is always high in lime and effervesces when tested with acid. In many places the surface soil is also highly calcareous.

In topography, the Knox silt loam is steep, rough and broken and erosion occurs to a very considerable extent. Drainage is good to excessive.

Most of the land is too steep for cultivation, and is utilized only for pasture. Some areas of smooth land are available, however, and these are in cultivated crops. Such areas occur where the slopes to the lowland are more gradual. Corn, oats and wheat are the principal crops grown. Yields are much lower than those secured on the Marshall silt loam. Minor crops are potatoes, alfalfa, vegetables and small fruits. The type is well suited for truck and fruit crops and might be used successfully for vineyards and orchards.

In the cultivated areas, the chief need of the soil is for organic matter and liberal applications of farm manure should be made. Leguminous crops should be turned under as green manures in many cases in order to build up the supply of organic matter. Both of these treatments by supplying organic matter aid in preventing the washing away of the surface soil and the formation of gullies. The prevention of erosion and of gully formation is one of the most important treatments that the soil needs. When the land is cultivated contour plowing should be practiced and terracing might also be of great help. The steeper slopes should, of course, be left in pasture and should never be cultivated. On the cultivated areas additions of phosphate fertilizers might also be of value inasmuch as the phosphorus content of the soil is low. It is recommended that tests of acid phosphate and rock phosphate be carried out on areas where general farm crops are to be grown. Where vegetables and root crops are grown, complete fertilizers might often be used with profit. There are many areas where fruit growing might be successfully practiced.

**TERRACE SOILS**

There are two terrace soils in the county, classified in the Waukesha and O’Neill series. Together they cover 4.1 percent of the total area.

**WAUKESHA SILT LOAM (75)**

The Waukesha silt loam is the more extensive of the terrace soils, covering 3.8 percent of the total area of the county. It occurs in a number of rather extensive areas along the Little Sioux River and along the West Fork of the Little Sioux River. The largest individual occurrences of the type are found in the vicinity of Moville and south along the West Fork of the Little Sioux River on the east side of the river, and along the Little Sioux River west of Smithland. Numerous other areas of the type occur along these rivers and along some of the tributary streams. In general the areas are narrow, however, and irregular in shape, covering the old bottomlands or present terraces, separating the upland from the bottomland.

The Waukesha silt loam is a dark brown moderately compact silt loam, extending to a depth of 12 to 24 inches. The subsoil is a lighter brown heavy silt loam to clay loam, changing into a yellowish compact stiff or plastic silty clay loam, usually at depths of 24 to 36 inches.

Along the Little Sioux River the type occurs on the level to gently sloping terraces, 20 to 50 feet above the river. In other areas the type is very similar
Fig. 8. Knox silt loam on bluff bordering bottomland.

...to the Wabash silt loam, lying, however, somewhat higher and having a better natural drainage system. In some areas, particularly in those near Moville and Climbing Hill, the soil is very much the same as the Marshall silt loam. In a few instances, lime concretions were found in the lower part of the three foot section, but these were not sufficiently common to warrant a changing of the type or a separation out of the areas where lime occurred.

Practically all of the Waukesha silt loam is under cultivation and general farm crops are grown. Corn is the most important followed by oats, wheat and hay. The latter consists mostly of clover and timothy, grown separately or together, and of some alfalfa. Barley and rye are minor crops. Yields of all these crops are very much the same as those secured on the Marshall silt loam.

The needs of the Waukesha silt loam for fertilizer treatments which will increase crop yields are very much the same as those noted in the case of the Marshall silt loam. Applications of organic matter are very desirable and liberal amounts of farm manure should be applied. Leguminous crops may be turned under as green manures with considerable profit in some cases. The soil is acid in reaction and applications of lime are very desirable, especially if legumes are to be grown. It will respond to applications of phosphorus fertilizers and it is urged that tests of acid phosphate and rock phosphate be made on small areas on this type in order to determine the profit from the use of phosphorus and also to determine which phosphorus carrier should be employed.

O’NEILL LOAM (108)

The O’Neill loam is a minor type in the county covering 0.3 percent of the total area. It occurs only along the Little Sioux River, in a number of small irregular shaped areas on the terraces. The only area of the type of any size is south and west of Correctionville. The remaining areas are small and relatively unimportant.

The O’Neill loam is brown to dark brown fine silty loam extending to a depth of 10 to 15 inches. The subsoil is a yellowish clay loam or friable sandy loam, which at depths of 2 to 2½ feet changes into a layer of unconsolidated sand and
gravel. In some areas, the surface soil is more sandy than typical and approaches a fine sandy loam. These areas are included with the typical soil as they are too small to separate on the map. In one or two areas some calcareous material was found in the lower part of the three foot section but in general the soil is acid in reaction throughout the entire three foot section. The small areas where calcareous material occurs were too small to show on the map and are included with the typical soil.

The O’Neill loam occurs on high terraces along the Little Sioux River and the surface topography is level to gently sloping. The soil is adequately drained. In dry seasons, the type is inclined to be drouthy and crops frequently suffer for lack of moisture. This is due mainly to the sand and gravel subsoil.

A large portion of the type is under cultivation and the principal crops grown are corn, alfalfa and red clover. Small grains are grown to some extent but yields are frequently poor. Millet, sorghum, popcorn and potatoes are also grown on a small scale. Corn yields average 35 to 40 bushels per acre and oats about 30 to 35 bushels. The yields of all crops grown on the type are extremely variable depending upon the seasonal conditions.

The need of the O’Neill loam to make it more productive is chiefly for the incorporation of organic matter in order to permit of the better retention of moisture and to reduce the danger of crop injury from drouth. Liberal amounts of farm manure should be applied to the type and it would also be of value in many cases to turn under a leguminous crop as a green manure. The soil is acid in reaction and lime should be applied before legumes are grown. It will undoubtedly respond to applications of phosphorus fertilizers and it is recommended that tests of acid phosphate and rock phosphate be carried out on the type in order to determine the profit from the use of phosphorus and which material should be applied.

SWAMP AND BOTTOMLAND SOILS

There are 11 swamp and bottomland soils in the county, classified in the Wabash, Lamoure, Cass and Sarpy series. These together with the colluvial phase Wabash silt loam and undifferentiated alluvial soils make up a total of 13 areas of swamp and bottomlands.

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Fig. 9. Waukesha silt loam on the terrace.
The Lamoure clay is the most extensive bottomland soil in the county and the second largest type. It covers 9.4 percent of the total area. It occurs in numerous areas on the bottomlands of the county, the largest area occupying a large part of Sloan and Grange Townships, extending over into Willow, Liberty and Woodbury Townships.

The surface soil of the Lamoure clay is a dark stiff clay averaging 6 to 10 inches in depth. Below that point it becomes a dark grey or drab plastic, impervious clay. The dark slaty gray color extends to depths of 18 to 24 inches, while below the color is grayish with spots of brown. In many places the surface soil is highly calcareous but in other spots no effervescence is obtained at the surface. At shallow depths, however, there is always a large amount of lime usually in the form of white nodules, and the soil effervesces freely with acid. The type is strongly cohesive or gummy when wet and is locally called "gumbo."

The layer of clay is usually more than 3 feet in thickness and, in many areas, extends to at least 15 feet. In some places, there are thin layers from 12 to 15 inches in thickness of a grayish or yellowish friable silt. This variation from a typical soil occurs in some areas near Luton but they were too small to separate on the map. In two areas, one, 2½ miles south of Bronson and the other, 2½ miles east of Hornick, there is a mucky variation of the typical Lamoure clay. In these areas the soil contains a very high content of organic matter mixed with clay and in some places a layer or two to three inches of black muck appears on the surface. These areas occur in marshy depressions or where it was formerly marshy. Shells of fresh water animals appear on the surface of the soil and through the soil section. When these areas are cultivated, they quickly change so that they resemble the Lamoure clay closely. In the areas of recently drained lakes or sloughs and recently abandoned channels of the Missouri River there is a further variation from the typical soil. In these spots, the soil is lighter in color. It has the same structure and is high in calcareous material, but apparently there has not been as large an accumulation of organic matter.

The Lamoure clay occurs on the broad flats and low-lying depressions on the bottomlands, but it is 20 to 30 feet above the present channel of the river and is free from overflow. Drainage is naturally poor, however, owing to the flat-
ness of the topography and the impervious character of the clay subsoil. Drainage ditches have been established and tile has been laid so that much of this area has been made cultivable. In many cases, however, the drainage is still inadequate for the production of the most satisfactory growth of crops.

Corn, winter wheat and alfalfa are the principal crops grown. Corn yields about 30 bushels per acre, winter wheat 15 to 20 bushels and alfalfa 2 to 3 tons. Crops are grown on about 85 to 95 percent of the type. The remainder which is the more poorly drained areas still is in virgin condition and yields of wild hay and coarse grasses are secured.

The type is chiefly in need of drainage to make it satisfactorily productive. Good crop yields can be secured when it is well drained and if drainage is not thorough the yields will be poor. When adequate drainage has been accomplished small applications of farm manure might be of value in stimulating the decomposition processes and increasing the production of available plant food in the soil. An application of a phosphate fertilizer might also be of value and tests of acid phosphate are recommended on this soil.

**WABASH SILT LOAM (26)**

The Wabash silt loam is the second largest bottomland soil in the county. Together with the colluvial phase, which is very much smaller in extent, it covers 7.3 percent of the total area. It occurs in numerous areas along the streams which traverse the uplands of the county. The largest development of the type is along the Little Sioux River from Smithland north. Along the other streams thru the uplands, both the main streams and the tributaries and small drainageways, narrow areas of the type occur.

The Wabash silt loam is a dark brown to nearly black mellow silt loam, grading at 10 to 16 inches into a more clayey material, generally a slightly plastic silty clay loam. The silt loam texture extends from depths of 10 inches to as much as 3 feet and the dark color persists frequently for more than 3 feet. At depths of from 2 to 4 feet, the subsoil is a dark slaty gray to a mottled gray and the texture approaches a silty clay loam. In topography, the Wabash silt loam is nearly flat to very gently sloping from the outer edges toward the stream occupying the valley. Some of the land is subject to overflow but the greater part of it is 10 to 15 feet above the flood plains. The streams have cut narrow channels, 10 to 20 feet in depth, thru this deposit of alluvial soil.

Practically all of the type is under cultivation with the exception of a few of the very poorly drained spots. There are a few wooded areas where the tree growth consists mostly of willow, cottonwood, box elder and ash. The principal crops grown are corn, alfalfa and pasture grasses. Corn yields from 40 to 60 bushels per acre, alfalfa from 3 to 3 1/2 tons per acre.

The Wabash silt loam will be benefited in many cases thru the proper installation of tile or ditching, since much of the area is still rather inadequately drained. When thoroughly drained, crops yields are very satisfactory. The type when recently drained will respond, however, to small applications of manure. It is acid in reaction and applications of lime would be of value when legumes are to be grown. It seems probable that a phosphate fertilizer will also prove of profit and tests of acid phosphate on a small area are suggested. Small grains are grown to a limited extent on the type inasmuch as they are apt to lodge. When these crops are grown manure should not be applied just preceding their growth, inasmuch as it would have a tendency to increase the lodging. In small amounts, however, for corn and other crops, manure would prove of value on this type.

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

The colluvial phase of the Wabash silt loam is very much smaller in extent than the typical soil, covering only about one percent of the total area of the
Fig. 11. View of Lamoure clay on the Missouri River bottoms.

county. It occurs in numerous narrow areas along the various streams of the county, usually extending from a few hundred feet to one-fourth of a mile in width. Its largest occurrence is along the bluffs in Granger and Willow Townships, separating the uplands from the broad, level bottomland area. Narrow strips occur along many of the drainageways in the county, being found adjacent to the streams and tributaries and occupying many of the intermittent drainageways. In many places the areas are too small to show on the map.

The surface soil of the colluvial phase of the Wabash silt loam is a dark brown silt loam ranging in color from brown to very dark brown and extending to a depth of one to three feet. It is underlaid by a heavier silty clay loam which in some places is black or at least darker than the surface soil. It consists mainly of surface soil washed down from the adjacent upland areas and the depth of this surface wash varies considerably in different locations. Along the bluffs, there is the thickest deposit while a thin covering extends out over the older alluvial deposit next to the river. In some areas the surface covering of loess from the upland is so recent that the color is much lighter, approaching a buff color. Drainage of the type is usually quite adequate.

This phase of the Wabash silt loam is utilized for cropping purposes and the same crops are grown as on the Wabash silt loam, the yields being very similar. The soil is naturally productive and excellent crops of corn and alfalfa are ordinarily secured. It will respond to the same treatments as have been recommended for the Wabash silt loam, namely the application of small amounts of farm manure, the addition of lime when the soil is acid which is usually the case, and possibly also the addition of a phosphate fertilizer. Tests of acid phosphate are recommended on the type.

LAMOURE CLAY LOAM (185)

The Lamoure clay loam is the third largest bottomland soil in the county, covering 5.8 percent of the total area. It occurs in extensive areas in the southwestern part of the county on the bottomlands of the Missouri River, the largest occurrences being found in the vicinity of Hornick, north of Salix and extending as far as Sergeant Bluffs and on north to Sioux City, and in a third area which
is rather extensive in the vicinity of Sloan. Numerous small areas of the type are also found in the southwestern townships.

The surface soil of the Lamoure clay loam is a black to very dark brown clay loam, extending to a depth of 12 or 18 inches. The subsoil is a drab to slate-gray, plastic, impervious clay. In some areas the soil consists of alternating layers of clay loam or clay and a grayish or yellowish friable silt. A silt layer is sometimes encountered at a depth of 10 to 20 inches and may vary from a few inches to a foot in thickness. These areas are of small occurrence and cannot be shown separately on the map. There are areas of the Lamoure clay included with this soil which it is impossible to separate, as they are so small. The type grades gradually into the Sarpy silty clay loam and the Cass silty clay loam and in some cases the boundary lines between these types are rather arbitrarily placed. The soil is basic in reaction and contains considerable amounts of lime in the form of concretions. The subsoil will effervesce freely with acid and in general the surface soil will also give an effervescence when tested, showing a high content of lime.

The Lamoure clay loam occurs on the high bottoms of the Missouri River, occupying a position about 30 to 35 feet above the normal water level of the river. In topography it is nearly level. Natural drainage of the type is inadequate except along the ditches and streams. The heavy texture of the soil and subsoil make the drainage a very important consideration.

Practically all of the type is under cultivation, the principal crops grown being corn, winter wheat, alfalfa and oats. Corn yields from 35 to 40 bushels per acre, wheat 18 to 22 bushels, alfalfa 3 to 4 tons and oats 20 to 40 bushels per acre.

The chief need of this type for increased crop yields is thorough drainage. Ditches have been located in a number of places but more are needed and the laying of tile is necessary. The thorough drainage of the type is essential if crop yields are to be satisfactory. When this is accomplished, large crops may be grown. Small amounts of manure may be applied with profit, when the type is newly drained, in order to stimulate the production of available plant food. Large amounts should not be used and manure should not be used preceding the small grain crop, owing to the danger of causing the grain to lodge. Small amounts of a phosphate fertilizer might be used profitably on the type for
general farm crops and tests of the value of acid phosphate on this soil are recommended.

**ALLUVIAL SOILS (UNDIFFERENTIATED) (186)**

There is a rather considerable area of undifferentiated alluvial soils mapped in the county, amounting to 1.5 percent of the total area. This designation has been applied to the rather considerable area of waste land which is found along the river and occurs as a result of the constant shifting of the channel of the river. The material could not be mapped as a soil type inasmuch as it consists of varying mixtures of deposits made by the river. The area represents barren wind-swept sand bars which are covered with water during flood stages of the river and areas of flood plain bottoms recently occupied by the channel.

The material on the surface of these areas consists of a gray silt and clay over which sand has been blown or deposited by the water current. Some areas are silty, some consist of fine sand and there are small bodies of silty clay. Much of the type is from 3 to 8 feet above the low water stage of the river and where accessible small bodies could be cultivated. But it is cut up by sloughs and likely to be overflowed by the river with every flood. Detailed separation of the various materials occurring on these areas would be difficult and of very little value as the river is constantly cutting away its banks and changing its course, depositing fine sand and silt at every flood. Much of the area mapped as these alluvial soils is covered with a dense growth of willows and practically none of it is cultivated.

**CASS LOAM (18)**

The Cass loam is a minor type in the county, covering 1.1 percent of the total area. It occurs in several areas in the southwestern part of the county, the largest development being in the vicinity of Salix. Another rather extensive area of the type is found in Liberty Township south of Sergeant Bluffs. A number of other smaller areas of the type occur in some of the western townships.

The surface soil of the Cass loam is a dark brown mellow loam, 12 to 16 inches in depth. The subsoil is a lighter brown to yellowish-brown loam to silt loam grading at from 20 to 24 inches thru a grayish to pale yellowish loose loam into a layer of loose, pervious fine sand and silt. In some areas the lower part of the three foot section consists of layers of fine sand and silt. The surface soil is not generally calcareous but the subsoil is highly calcareous and effervesces strongly when acid. There are included within this type small areas of the Cass fine sandy loam and silt loam which are too small to separate on the map.

In topography, the Cass loam is smooth or nearly level. The type occupies low swells or ridges slightly higher than the adjacent clay loams and clays. It is well drained due to the coarse textured character of its subsoil.

Practically all of the Cass loam is under cultivation. Corn and alfalfa are the principal crops grown. Some areas, however, are used for oats and wheat. The yields of these crops are very much the same as the average for the county.

The Cass loam would respond to applications of manure and undoubtedly small amounts of a phosphate fertilizer would prove of value. It is recommended that tests of acid phosphate and rock phosphate be made on this type.

**SARPY VERY FINE SANDY LOAM (28)**

The Sarpy very fine sandy loam is a minor type in the county, covering 0.8 percent of the total area. It occurs in numerous small areas in the northwestern part of the county along the river, the largest occurrences being found in Lakeport Township, south of Salix and in Liberty Township west of Salix adjacent
to the river. Smaller occurrences of the type are found throughout these townships and extending up to Woodbury Township.

The surface soil of the Sarpy very fine sandy loam is a buff or grayish very fine sand and silt, extending usually to depths of three feet or more. In some areas the soil is a little lighter in texture and contains more of the coarser particles. Occasionally it is light brown in color. There is very little change in the physical character of the soil within three or four feet of the surface. In the vicinity of Brown's Lake the surface soil is a gray, very fine sandy loam, 20 to 24 inches in depth underlaid by a gray to yellowish-gray fine silt. The type is highly calcareous and will effervesce freely with acid. The calcareous material usually occurs throughout the entire soil section but in a few places is not found at the surface. It is always present, however, at shallow depths.

The type occurs on low ridges and hummocks adjacent to the present or old channels of the Missouri River. In topography the surface is billowy or hummocky. The natural drainage is good because of the sandy character of the soil material.

In the larger areas where the land is accessible the soil has been brought under cultivation and corn and alfalfa are the principal crops grown. In the lower-lying bottoms, the fields are irregular and much cut by sloughs and the action of the rivers, and in places the uneven hummocky surface makes cultivation very difficult.

When the Sarpy very fine sandy loam is capable of cultivation it will respond profitably to liberal applications of farm manure and it would undoubtedly also respond to applications of a phosphate fertilizer.

SARPY SILT LOAM (89)

The Sarpy silt loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in several small areas in the western townships along the Missouri River, the largest occurrences being west and south of Sergeant Bluffs. There is also a small area of the type along the river north of Sioux City. It is found in long narrow areas along the river channels.

The surface soil of the Sarpy silt loam is a buff or grayish silt loam, 6 to 8
inches in depth. It is underlaid by layers of fine sand and silty clay, varying considerably in thickness. Generally the sandy layer occurs at shallow depths. The soil is highly calcareous and effervesces with acid at the surface and throughout the three foot section. In topography the type is ridgy and hummocky.

The greater part of the Sarpy silt loam is under cultivation, corn and alfalfa being the chief crops grown. Corn yields 30 to 35 bushels per acre and alfalfa 3 to $3\frac{1}{2}$ tons.

This type is chiefly in need of organic matter and applications of farm manure would be of large value. The turning under of green manure crops would also be of profit. The type would undoubtedly respond to applications of phosphorus fertilizers when general farm crops are to be grown and tests of acid phosphate are recommended. The type is well drained. Owing to its low position it is not drouthv, altho this might be expected because of the sandy character of the subsoil.

**SARPY SILTY CLAY LOAM (144)**

The Sarpy silty clay loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in several areas in the southwestern townships along the Missouri River, the principal occurrence of the type being in Liberty Township west of Sergeant Bluffs. Areas are also found in Lakeport Township west of Sloan.

The Sarpy silty clay loam is a grayish or very light brown silty clay loam, 4 to 10 inches in depth. The subsoil is a grayish to light brown sand or loosely coherent silt, extending to a depth of three feet or more. The type is high in calcareous material and effervesces freely with acid. In some places, the surface soil does not contain the calcareous material but it is always present at shallow depths.

The type occurs mainly in low depressions and represents the location of beds of former lakes or sloughs or abandoned channels of rivers. Depressions are usually bordered with narrow ridges or low hummocks of fine sand. There are, therefore, many areas where there are successions of hummocks of fine sand and areas of silt and clay. It is frequently impossible to make an exact separation between different textures. Small areas of the varying textures cannot be shown on the map and boundary lines are difficult to locate. In places the land is poorly drained and subject to flooding during the high water. Thruout the major portion, however, drainage is adequate.

On the cultivated areas corn and alfalfa are the chief crops grown. Wheat is grown to some extent also. Yields of these crops are good in favorable seasons. Some areas of the type are in need of drainage but in general drainage is fairly adequate. Small applications of farm manure would be of value and the type would probably respond to the application of a phosphate fertilizer.

**CASS SILTY CLAY LOAM (51)**

The Cass silty clay loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in several areas in the southwestern townships, the largest development being in Liberty Township north and west of Salix.

The surface soil of the Cass silty clay loam is a dark brown compact silty clay loam extending to a depth of 6 to 10 inches. The subsoil is a silt loam at 10 to 20 inches, grading into a looser and more pervious silt or very fine sand, extending to a depth of 30 to 40 inches. The color of the subsoil is a pale buff or gray, there being a gradual change from the dark colored surface material to the lighter colored subsoil. The layer of silt or fine sand is characteristic of this type, occurring at depths of three feet or less. Small areas of the Cass silt loam and fine sandy loam too small to show on the map are included.

In topography the soil is level to very gently sloping. Drainage is generally sufficient, but in wet seasons, artificial drainage is necessary.
All of the Cass silty clay loam is under cultivation. Corn, alfalfa, wheat and oats are the principal crops grown. The yields are very much the same as on the Lamoure clay loam with which the type is closely associated. Applications of farm manure in small amounts would be of value on this soil particularly after it is newly drained. It might also respond profitably to applications of a phosphorus fertilizer and tests of acid phosphate are recommended. The soil is high in calcareous material and the subsoil effervesces freely with acid. The surface soil is also frequently well supplied with lime and shows effervescence.

SARPY FINE SAND (133)

The Sarpy fine sand is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas in the southwestern townships. The largest areas lie at Brewers Lake and at Browns Lake. Small areas are mapped near the river in the western parts of Liberty and Woodbury Townships.

The Sarpy fine sand consists of hummocks and low narrow ridges of incoherent, fine and medium sand. Most of it has been recently deposited by the river and there is very little accumulation of organic matter. The loose sand extends to a depth of 2 to 10 feet or more.

Small areas of the type have been planted to corn and alfalfa, but yields of crops are very much less on this soil than on the finer textured types. It is droughty, as would be expected because of the loose texture of the soil and subsoil material. When it is to be cultivated its chief need is for the application of organic matter. Liberal amounts of farm manure should be employed and leguminous crops should be turned as green manures. The type is well supplied with calcareous material and will usually effervesce when tested with acid, hence applications of lime are unnecessary. The use of a phosphate fertilizer would undoubtedly prove of value and tests of acid phosphate are recommended.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas along the Little Sioux River, its chief occurrence being south of Anthon.

The surface soil of the Wabash silty clay loam is a dark brown to black silty clay loam, extending to a depth of 16 to 20 inches. The subsoil is a black heavy silty clay loam to silty clay, changing at 24 to 30 inches into a heavy dark gray to drab slightly mottled with rusty brown. In some areas, the black color of the surface soil extends to a depth of three or four feet without change and the texture of the soil and subsoil is very similar, the subsoil being a little heavier but more plastic in the lower part of the three foot section. In topography, the type is flat or slopes gently toward the streams and drainage is quite inadequate. It is subject to frequent overflow.

The greater part of the Wabash silty clay loam is devoted to pasture and supports an excellent growth of wild grasses. The only cultivated areas are those which are better drained and which are farmed with the adjoining types. Corn is the principal crop grown and, in favorable seasons, the yields are quite satisfactory.

The chief need of this soil is for thorough drain. When this is accomplished, it will respond to small applications of farm manure to stimulate the production of available plant food. The type is acid in reaction and additions of lime should be made. It would also undoubtedly respond to a phosphate fertilizer and tests of acid phosphate are recommended.
The Cass fine sandy loam is a minor type in the county, covering 0.1 percent of the total area. It occurs in the bottoms on the Missouri River, only two small areas having been mapped. The larger area is found three miles northwest of Salix.

The surface soil of the Cass fine sandy loam is a dark brown to very dark brown, fine to very fine sandy loam 12 to 15 inches in depth. The upper subsoil is a lighter brown to yellowish-brown and the lower subsoil between 22 to 28 inches in a loose pervious layer of fine sand or silt, grayish brown to pale yellowish in color. In topography, the type is nearly level. It is adequately drained and is never subject to overflow.

The type is practically all cultivated, corn, alfalfa and wheat being the main crops grown. It is chiefly in need of organic matter to make it more productive and liberal applications of farm manure should be made. The turning under of leguminous crops for green manures would also be of value on the type. It is well supplied with calcareous material, usually effervescing in the subsoil and frequently also in the surface soil and hence additions of lime are unnecessary. The use of a phosphate fertilizer would undoubtedly be of value for general farm crops grown on this soil and tests of acid phosphate are recommended. The type would be well adapted also to the growth of vegetables and truck crops. If the latter were grown, the use of some commercial fertilizer might be very desirable.
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 tests, but fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various 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 to insure the best crop production.

PLANT FOOD IN SOILS

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

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

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizers 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 method 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 is frequently lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth.

The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

Sulfur, like nitrogen, is present in the 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 to 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 ni-
### TABLE I. PLANT FOOD IN CROPS AND VALUE

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Plant Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Oats, crop</td>
<td>111</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats, crop</td>
<td>48.5</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley, crop</td>
<td>32.5</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>41.4</td>
<td>41.4</td>
<td>9</td>
<td>23.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>600</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>6.75</td>
<td>11.52</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

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

REMOVAL FROM IOWA SOIL

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.

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

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

CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thorough cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily effected 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 laying of drains to insure the removal of excessive moisture in heavy soils.

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

THE ROTATION OF CROPS

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

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 of 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 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 manure, crop residues and green manure, the first two being much more common.

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

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of 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 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. 14.

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

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

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a
period of geological time when climatic conditions were very different than at present.

These loess soils are very porous in spite of the fine texture and they rarely contain
large pebbles or stones. They present a strong contrast to the drift soils, which are
somewhat heavy in texture and filled with pebbles and stone. The three loess areas in
the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by
differences in texture and appearance, and they vary considerably in value for farming
purposes. In some sections the loess is very deep, while in other places the underlying
leached till or drift is very close to the surface. The fertility of these soils and
their needs are greatly influenced, therefore, by their depth.

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

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very gen­eral idea of soil conditions. Soils vary so widely in character and composition, depend­ing on many other factors than their source, that definite knowledge concerning their
needs can be secured only by thorou 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
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 of the soil type.

GENERAL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

Organic matter

| All partially destroyed or undecomposed vegetable and animal material. |
| Stones—over 32 mm.* |
| Gravel—32—2.0 mm. |
| Very coarse sand—2.0—1.0 mm. |
| Coarse sand—1.0—0.5 mm. |
| Medium sand—0.5—0.25 mm. |
| Fine sand—0.25—0.10 mm. |
| Very fine sand—0.10—0.05 mm. |
| Silt—0.05—0.00 mm. |

Inorganic matter

*25 mm. equals 1 in.  †Bureau of Soils Field Book.  †Loc. cit.
SOIL SURVEY OF IOWA

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—35 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.

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

Silty 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.

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man. The determination of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

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