Soil Survey of Iowa, Report No. 62—Warren County Soils

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SOIL SURVEY OF IOWA
WARREN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 62
October, 1930
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

Soil Survey Reports*

1 Bremer County.  
2 Pottawattamie County.  
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9 Scott County.  
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*For list of additional publications on soils see inside back cover.
SOIL SURVEY OF IOWA

Report No. 62—WARREN COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of A. M. O’Neal, L. W. Forman, H. R. Meldrum, A. J. Englehorn and R. E. Bennett

A waterhole in Warren County.
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WARREN COUNTY SOILS*

By W. H. STEVENSON and P. E. BROWN with the assistance of A. M. O'NEAL, L. W. FORMAN, H. R. MELDRUM, A. J. ENGLEHORN and R. E. BENNETT

Warren County is located in south central Iowa in the third tier of counties north of the Missouri line and is in the fifth tier of counties east of the Missouri River. It is partly in the Mississippi loess and partly in the Southern Iowa loess soil areas, and the soils of the county are mainly of loessial origin. There is, however, a considerable acreage of drift soils such as are found throughout the Southern Iowa loess soil area. These drift soils are derived from the Kansan till underlying the loessial deposits in southern Iowa.

The total area of Warren County is 575 square miles or 364,800 acres. Of this area 344,891 acres or 94.5 percent are in farm land. The total number of farms is 2,381 and the average size of the farms is 145 acres. Owners operate 51.1 percent of the farm land and renters 48.9 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1928 show the utilization of the farm land of the county.

<table>
<thead>
<tr>
<th>Description</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in general farm crops</td>
<td>189,110</td>
</tr>
<tr>
<td>Acreage in farm buildings, feed lots and public highways</td>
<td>15,834</td>
</tr>
<tr>
<td>Acreage in pasture</td>
<td>133,581</td>
</tr>
<tr>
<td>Acreage in waste land not utilized for any purpose</td>
<td>4,876</td>
</tr>
<tr>
<td>Acreage in farm woodlots used for timber only</td>
<td>1,960</td>
</tr>
<tr>
<td>Acreage in crop land lying idle</td>
<td>692</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>214</td>
</tr>
</tbody>
</table>

THE TYPE OF AGRICULTURE IN WARREN COUNTY

The type of agriculture most commonly followed in Warren County at the present time consists of a system of general farming including the production of corn, wheat, oats, hay and other general farm crops and the raising and feeding of cattle and hogs. Dairying and sheep raising are minor livestock industries. Practically all of the grain and hay crops with the exception of wheat are used as feed on the farms; hence it may be considered that the farming operations are chiefly on a livestock basis. In general the farm income of the county is derived from the sale of beef cattle, hogs, dairy products and surplus farm crops. In individual cases some income is provided from sheep raising, poultry products and the sale of special crops such as truck crops.

The acreage of waste land is rather large and much of this land might be reclaimed and made productive thru the adoption of proper methods of soil treatment. General recommendations for the handling of such land cannot be given as the causes of unproductiveness are variable, and different systems of management...
### TABLE I. ACREAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN WARREN COUNTY, IOWA*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage</th>
<th>Percent of total farm land of county</th>
<th>Bushels per tons or acres</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>94,924</td>
<td>27.5</td>
<td>45.2</td>
<td>4,290,565</td>
<td>$0.67</td>
<td>$2,874,679</td>
</tr>
<tr>
<td>Oats</td>
<td>38,825</td>
<td>11.2</td>
<td>42.4</td>
<td>1,647,212</td>
<td>$0.37</td>
<td>609,468</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>20,864</td>
<td>6.1</td>
<td>17.8</td>
<td>371,871</td>
<td>$1.00</td>
<td>371,871</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>306</td>
<td>0.1</td>
<td>19.1</td>
<td>5,854</td>
<td>$1.01</td>
<td>5,913</td>
</tr>
<tr>
<td>Barley</td>
<td>4,769</td>
<td>1.4</td>
<td>34.4</td>
<td>163,844</td>
<td>$0.54</td>
<td>88,476</td>
</tr>
<tr>
<td>Rye</td>
<td>544</td>
<td>0.2</td>
<td>14.9</td>
<td>8,130</td>
<td>$0.86</td>
<td>6,992</td>
</tr>
<tr>
<td>Clover hay†</td>
<td>4,172</td>
<td>1.2</td>
<td>1.85</td>
<td>7,718</td>
<td>$13.00</td>
<td>100,334</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>6,174</td>
<td>1.8</td>
<td>1.25</td>
<td>7,718</td>
<td>$10.50</td>
<td>81,039</td>
</tr>
<tr>
<td>Clover and timothy hay</td>
<td>11,992</td>
<td>3.5</td>
<td>1.69</td>
<td>20,266</td>
<td>$13.00</td>
<td>263,458</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>3,428</td>
<td>1.0</td>
<td>3.17</td>
<td>10,867</td>
<td>$16.50</td>
<td>179,306</td>
</tr>
<tr>
<td>All other tame hay</td>
<td>593</td>
<td>0.2</td>
<td>2.30</td>
<td>1,364</td>
<td>$13.00</td>
<td>17,732</td>
</tr>
<tr>
<td>Wild hay</td>
<td>290</td>
<td>0.1</td>
<td>1.27</td>
<td>368</td>
<td>$10.00</td>
<td>3,680</td>
</tr>
<tr>
<td>Soybeans grown with other crops</td>
<td>526</td>
<td>0.2</td>
<td>1.63</td>
<td>897</td>
<td>1.78</td>
<td>1,597</td>
</tr>
<tr>
<td>Soybeans grown alone</td>
<td>140</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans grown for seed</td>
<td>55</td>
<td>0.02</td>
<td>16.3</td>
<td>897</td>
<td>1.78</td>
<td>1,597</td>
</tr>
<tr>
<td>Potatoes</td>
<td>286</td>
<td>0.1</td>
<td>121.0</td>
<td>34,606</td>
<td>0.51</td>
<td>17,649</td>
</tr>
<tr>
<td>Timothy seed</td>
<td>512</td>
<td>0.2</td>
<td>4.3</td>
<td>2,218</td>
<td>2.15</td>
<td>4,769</td>
</tr>
<tr>
<td>Clover seed†</td>
<td>728</td>
<td>0.2</td>
<td>0.86</td>
<td>629</td>
<td>18.00</td>
<td>11,322</td>
</tr>
<tr>
<td>Sweet clover‡</td>
<td>563</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1928.
†Sweet clover not included.
‡All varieties for all purposes.

must be practiced in different cases. Later in this report suggestions will be offered for the management of land in the different soil types where crop yields at present are not entirely satisfactory.

### THE CROPS GROWN IN WARREN COUNTY

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

Corn is the most important crop grown, both in acreage and value. In 1928 it occupied 27.5 percent of the total farm land, and average yields amounted to 45.2 bushels per acre. In favorable seasons, on the better soils and under good systems of management, yields are much greater. The most popular varieties are Reid Yellow Dent, Boone County White, Johnson County White, Iowa Silvermine and Silver King. The yellow varieties are grown most extensively. Some Learning, a flint corn, is grown in certain localities. The corn produced is practically all used in the county as feed for hogs, beef cattle and work stock. In some years a surplus from the better farms is shipped to outside markets, but the supply rarely equals the demand, especially in the eastern half of the county where more cattle are fattened. Some corn is used for silage, and occasionally soybeans are planted in the rows with the corn to increase the value of the silage.

The second crop in acreage and value is oats. This crop was grown on 11.2 percent of the total farm land, and the yields averaged 42.4 bushels per acre in 1928. On the better soils larger yields are obtained. The varieties grown are chiefly Kherson, Iowa 103, Iowa 105, and Early Champion. Practically the entire
crop is utilized locally as feed, but occasionally a small surplus is sold thru co-operative elevators on outside markets.

Hay is the third crop in acreage and value. In 1928 clover hay was grown on 1.2 percent of the farm land, timothy hay on 1.8 percent and clover and timothy mixed on 3.5 percent of the farm land. In addition there was a small acreage in other tame hay and in wild hay. Average yields of clover and timothy mixed amounted to 1.69 tons per acre, of clover alone to 1.85 tons per acre and of timothy alone to 1.25 tons per acre. The value of all the hay crops produced is considerable. Some alsike clover is grown, especially on the bottomlands where it gives excellent results. Sweet clover is grown on limited areas in the county and is utilized as a pasture and forage crop or is turned under for green manuring purposes. Some sweet clover, some timothy and some clover seed are produced. All of the hay is used on the farms as feed for beef cattle, dairy cows and work animals, and in some sections the supply is not equal to the demand.

Wheat is the fourth crop in acreage and value, the winter varieties being grown almost exclusively. In 1928 winter wheat was grown on 6.1 percent of the total farm land and yields averaged 17.8 bushels per acre. Yields of spring wheat averaged 19.1 bushels per acre the same year. The most popular varieties of winter wheat are Kanred and Turkey. When spring wheat is grown, the variety seeded is usually Marquis. Practically the entire crop is sold thru elevators and cooperative associations on Chicago, Kansas City and Omaha markets.

Alfalfa is grown to a limited extent and is a very profitable crop. Average yields amounted to 3.17 tons per acre in 1928 and the total value of the crop is considerable. Dakota No. 12 and Grimm are the favorite varieties. When the soil is limed and the crop is inoculated, very satisfactory results may be secured. It is an excellent forage crop and is also of value as a soil builder.

Barley is grown on a limited area and yields in 1928 averaged 34.4 bushels per acre. The entire crop is utilized locally. Rye is of minor importance, yielding 14.9

Fig. 1. A Grundy silt loam topography in Warren County.
SOIL SURVEY OF IOWA

bushels per acre in the same year. This crop is used as hog feed on the farms. Sudan grass, kafir and vetch are grown to some extent for forage. Buckwheat is utilized occasionally as a cash crop. A few farmers grow rape for hog pasture. Some sorghum is grown for syrup.

Potatoes are grown on most farms and average yields amounted to 121 bushels per acre in 1928. The crop is entirely utilized on the farms. Truck crops and small fruits are produced in a limited way to supply the local demand. Cantaloupes and watermelons are grown on many of the sandy areas through the county. Most of the melons produced are sold on the local markets. Some are trucked to Des Moines.

Small apple orchards are found on most farms and the supply of fruit produced is all utilized locally. Jonathan, Winesap, Wealthy and Snow are the most common varieties. In some instances the trees are sprayed and the orchards are well cared for, excellent fruit being produced. In many cases, however, the orchards are neglected and the fruit is faulty.

THE LIVESTOCK INDUSTRY IN WARREN COUNTY

The livestock industries of the county include the raising and feeding of hogs and cattle, dairying, the raising and feeding of sheep and the raising of horses. The following figures taken from the Iowa Monthly Crop Report for July, 1928, giving Jan. 1, 1928, estimates made by the Bureau of Agricultural Economics in cooperation with the Iowa State Department of Agriculture, show the extent of the livestock industries:

<table>
<thead>
<tr>
<th>Animal</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horses</td>
<td>11,300</td>
</tr>
<tr>
<td>Mules</td>
<td>1,210</td>
</tr>
<tr>
<td>Cattle, all</td>
<td>34,500</td>
</tr>
<tr>
<td>Hogs</td>
<td>137,600</td>
</tr>
<tr>
<td>Sheep</td>
<td>16,600</td>
</tr>
</tbody>
</table>

The principal livestock industry is hog raising. On Jan. 1, 1928, there were 137,600 hogs on the farms of the county. Most of the hogs are of mixed breeding but on many farms an attempt is made to keep only purebred animals. The Duroc Jersey is the most popular breed, and the Poland China, Spotted Poland China and Chester White follow in numbers in the order named. There are also some Tamworth hogs. The hogs are sold either through cooperative selling associations or in car lots by individual farmers. The principal markets are Chicago and Kansas City.

The raising and feeding of beef cattle ranks second to hog raising in importance. On Jan. 1, 1928, there were 34,500 cattle on the farms, the major portion of which were beef cattle. Some cattle are raised on the farms in the county, but the common practice is to ship in feeders in the fall or early winter. The number of beef animals averages 17 head per farm, but in some parts of the county herds varying from 60 to 100 head are kept. The Shorthorn, Hereford and Aberdeen Angus are the most popular beef breeds. The finished cattle are usually shipped in car lots by the individual farmers to Kansas City and Omaha, but a few farmers sell to buyers for outside markets.

Dairying is the third livestock industry in importance. It is carried on as a sideline on most farms. Eight or ten cows are usually kept. In the vicinity of Indianola several farms are devoted to dairying. The most popular dairy breeds are the Holstein, Guernsey and Jersey, named in the order of their importance. In the
northern part of the county whole milk is collected and hauled to Des Moines, and in the southern and central parts the surplus milk is sold at the creamery in Indianola.

The raising and feeding of sheep is of minor importance and, for the most part, is carried on only in the rougher parts of the county. On Jan. 1, 1928, there were 16,600 head of sheep on the farms. The Shropshire and Oxford are the most popular breeds. Most of the sheep are shipped in for feeding. The native flocks are kept mainly for wool, and on some farms considerable income is derived from the sale of this product.

The raising of horses and mules is practiced in a very limited way in the county. Many farmers raise several colts each year to help keep up the supply of work stock. Animals of the draft type predominate.

Chickens and eggs are produced entirely as a side line, but the value of the poultry products is considerable. On many farms the sale of poultry adds considerably to the income. Poultry and eggs are sold largely at the produce house in Indianola or to buyers who resell in Des Moines.

THE FERTILITY IN WARREN COUNTY SOILS

In general the yields of farm crops secured in Warren County are satisfactory, but in many instances much larger crop yields might be secured by the adoption of better methods of soil management. Optimum crop yields will not be secured on land which is too wet. Altho tiling may prove somewhat expensive the value of the increases in crop yields secured will more than pay for the outlay.

The soils of the county are all acid in reaction and therefore in need of lime. The best yields of general farm crops cannot be secured on acid soils, and legumes frequently refuse to grow under acid soil conditions. It is very desirable, there-
fore, that the soils in the county be tested for lime needs and that the proper application of lime be made if the most satisfactory crop growth is to be secured.

Some of the soil types are rather poorly supplied with organic matter and nitrogen, and additions of some fertilizing materials supplying these constituents are essential. Even on the soils which are best supplied, such fertilizing materials should be applied regularly if the content of organic matter and nitrogen is to be kept up. The application of farm manure in liberal amounts is strongly recommended for the soils of this county. Large increases in the yields of general farm crops may be secured by its use. All crop residues should be utilized on the farms to aid in maintaining the supply of organic matter and nitrogen.

In many cases insufficient farm manure is produced to permit of regular applications to all the land on the farm. In such cases the turning under of leguminous crops as green manures is necessary to supplement the use of farm manure. On grain farms, where little or no farm manure is produced, the practice of green manuring is particularly important.

The soils of Warren County are rather low in content of phosphorus. It seems evident, therefore, that phosphate fertilizers will be needed on these soils in the very near future. There are indications from certain experiments which have been carried out and from experiences of some farmers that phosphate fertilizers might be of value at the present time. Economic returns may be secured in many cases in this county from the use of rock phosphate or superphosphate when applied in addition to the basic treatments of manure and lime. Definite recommendations cannot be made regarding the use of these fertilizers as the results secured are variable under different farm conditions. Farmers are urged, however, to test both phosphate fertilizers under their particular conditions.

Complete commercial fertilizers are not recommended for general use in the county at the present time, as the experiments thus far have not indicated any great superiority of these materials over superphosphate. They should be tested on small areas in comparison with the phosphates before they are used extensively. The use of commercial potash and nitrogen fertilizers cannot be recommended at present. They may prove of value in some cases as top dressings on limited areas or for special crops, but they should never be used until field tests have demonstrated their value.

Erosion occurs to some extent in Warren County, and a number of the soil types have been rather seriously injured by this destructive process. In many cases gullies have been formed and naturally fertile land has been made unproductive. Sheet washing is common on some of the soils and has resulted in the removal of much or all of the more fertile surface soil. The shallow phase of the Tama silt loam has been formed thru the washing away of a portion of the surface soil. The Clinton silt loam, the Shelby silt loam and the Lindley silt loam are particularly injured by erosion, and some of the other upland types occasionally give evidence of injury. Wherever the injurious effects of erosion are evident, some method should be employed to prevent or control the action. From among the methods suggested later in this report, some one may be chosen which will be satisfactory under almost any soil conditions.
THE GEOLOGY OF WARREN COUNTY

The bedrock material underlying the soils of Warren County is so deeply buried by subsequent deposits of drift and loess that it has no effect on the soils of the county. It is unnecessary, therefore, to consider the geological history of the county, as the earlier geological formations have no effect whatever upon present day soil conditions.

At least once during the glacial age a great glacier swept across the county and upon its retreat left behind a vast deposit of glacial drift or till. This material which is known as the Kansan drift is extremely variable in depth, ranging from a few feet to many feet in different areas. The topographic features of the county preceding the invasion by the glacier were modified to some extent, and the glacial material covered the older topographic features, completely filling the depressions and valleys and covering the higher lands. The drift material is a bluish-gray mixture of clay, silt, sand and gravel, containing numerous boulders. When weathered, the drift has been oxidized to a yellowish or reddish-brown and this weathered layer may vary from a few inches to three or four feet in depth. The subsoil usually consists of a tenacious, plastic silty clay to clay. Considerable amounts of coarse sand, gravel and boulders occur throughout the surface soil and subsoil. Lime has been leached away from the soil quite completely. Calcareous material is found only in the lower sections at depths of from 5 to 7 feet. The surface soil has been modified in many cases thru additions of organic matter and has become darker in color. The soils of the Shelby, Lindley and Carrington series have been derived from the Kansan till thru the washing away of the surface covering of loess.

At some previous geological period when climatic conditions were very different than at present, a layer of wind-blown material called loess was laid down over the entire surface of the county. In its unweathered condition loess is an even-grained material composed mainly of silt. It ranges in color from a light grayish-brown to a yellowish-brown. Under prairie conditions there was much plant growth, organic matter accumulated and dark colored soils were formed. Under forested conditions, however, there was less accumulation of organic matter and lighter colored loess types developed. The soils of the Tama, Grundy, Muscatine and Clinton series are derived from loess, the Tama, Muscatine and Grundy soils being formed on the prairies and the Clinton soils on the more rolling timbered areas. The latter soils are lighter in color. There has been considerable washing of the loess soils in many cases, and the shallow phase of the Tama silt loam indicates a beginning stage of such a washing action. The Lindley silt loam is mapped where the erosion has been more extensive and the loess covering has been more completely removed. Where the Shelby and Carrington soils have been mapped, the loess covering has been entirely carried away.

Extensive areas of first and second bottomlands which occur in the county are made up mainly of the loessial material washed down from the uplands and mixed with some of the underlying drift. Second bottomlands have been developed above overflow, and on the first bottoms the soil types are still subject to more or less frequent overflow.
Physiographically the county consists of a loess covered drift plain which varies from undulating to strongly rolling. The major portion of the northern half is slightly undulating to gently rolling. In this section the hills are smoothly rounded, the slopes are gentle and the destructive action of erosion is less in evidence than in other parts of the county. The valleys of the rivers and creeks are generally wider, and the bottomlands slope more gradually to the uplands than is common in the southern section of the county. South and east of a line drawn thru Lida, Spring Hill, Indianola, Ackworth and Hartford, the topographic features are more pronounced. The areas between the streams are less extensive than in the northern part of the county. They have a smoother surface and change abruptly into the rough eroded areas which border the various streams and drainageways. There are two exceptions to this general rule in the vicinity of Milo and Liberty Center, where level or gently undulating areas are rather extensively developed. Along the southeastern slopes of the Middle River and the South River, the bluffs are more abrupt, and the hills are higher than to the north and northwest where the
uplands are more gently undulating in topography.
Terraces are developed along the larger streams, the most extensive formation being found along the Middle, the South and the Des Moines Rivers. There are small isolated areas along many of the larger creeks. The surface of these terraces is flat except on the older more eroded terrace near Wick. Broad first bottoms or flood plains are developed along the various streams, and many of these areas are wide. Along the South, the Middle and the Des Moines Rivers, many of the bottoms are one mile or one and one-half miles in width. They slope gently toward the streams and in some areas are somewhat hillocky.

The drainage of the county is carried by the Des Moines River which forms the boundary of the county along the northeast township. This river flows thru a wide flood plain which is subject to local overflow. The present level of the valley is 70 or 80 feet below that of the bordering uplands. Small creeks and drainage-ways extend into all parts of the county except the practically level areas in the vicinity of Milo and Liberty Center. The main streams flowing thru the county are the North, the Middle and the South Rivers. With their chief tributaries, Middle Creek, Clanton Creek, Butcher Creek, Broadhorn Creek, Painter Creek, Squaw Creek, Otter Creek, Wolf Creek, Mill Branch, Stony Creek, White Breast Creek, Flank Creek and Cold Creek, these branches of the Des Moines River bring about the drainage of the county. The general slope of the land is northeastward, the direction which the major streams flow toward the Des Moines River.

In the more undulating or moderately rolling uplands, drainage is usually adequate. In the flat areas in Otter, Belmont, Liberty, White Breast and some of the other southern townships tiling is necessary for the best growth of crops. In general, it may be said that in many of the areas of Grundy silt loam, tiling would prove of value. Tiling would improve the crop yields on the Muscatine silt loam in many cases. Some of the terrace and bottomland soils are also poorly drained, particularly the Bremer, Calhoun and Wabash types. The latter soils are subject to overflow and must be protected from flooding before drainage will give the best results. The accompanying drainage map indicates the extent of the natural drainage system of the county. In the rougher sections of the county, the soils are frequently seriously injured by erosion, both sheet washing and gullying.

THE SOILS OF WARREN COUNTY

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

Drift soils cover more than one-third of the total area, 37.4 percent of the
TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN WARREN COUNTY

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>136,960</td>
<td>37.4</td>
</tr>
<tr>
<td>Loess Soils</td>
<td>163,392</td>
<td>44.8</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>10,368</td>
<td>3.0</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>54,080</td>
<td>14.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>364,800</td>
<td></td>
</tr>
</tbody>
</table>

The loess soils are somewhat more extensively developed, covering 44.8 percent of the total area. Terrace soils are limited in occurrence and cover only 3.0 percent of the county. Rather extensive areas of swamp and bottomland soils cover 14.8 percent of the total area.

There are 26 soil types in the county and these with the shallow phase of the Tama silt loam make a total of 27 soil areas. Each soil type is distinguished on the basis of certain definite characteristics which are discussed in the appendix to this report. The areas of the different soil types are shown in table III.

There are six drift soils, classified in the Shelby, Carrington and Lindley series. The Shelby loam is the largest drift soil and the most extensively developed type in the county. It covers 29.1 percent of the total area. The Carrington silt loam is the second largest drift soil but is very much smaller in area, covering only 3.5 percent of the county. The Carrington loam is the third drift type, covering 2.3 percent of the total area. The three remaining drift soils, the Lindley silt loam, the Shelby silt loam and the Carrington fine sand cover 1.5, 0.9 and 0.1 percent of the total area respectively.

There are four loess soils, classified in the Tama, Grundy, Muscatine and Clinton series. The Tama silt loam with the shallow phase which is quite limited in area is the second largest soil type in the county and the most extensively developed loess soil. It covers 25.1 percent of the total area. The Grundy silt loam is the second largest loess soil and the fourth largest type in the county, covering 11.1 percent of the total area. The Muscatine silt loam is the third largest loess soil, covering 5.9 percent of the county. The Clinton silt loam is the smallest of the loess types and covers 2.7 percent of the total area.

The Bremer silt loam is the largest of the terrace soils, but it is quite limited in area, covering only 1.6 percent of the county. The remaining loess types, classified in the Waukesha, Bremer, Judson, Calhoun and Jackson series, all cover less than 1 percent of the total area.

The Wabash silt loam is the most extensively developed bottomland type and the third largest soil in the county, covering 11.6 percent of the total area. The Wabash silt clay loam is the second largest bottomland soil but is much smaller in area. It covers 2.1 percent of the county. The remaining bottomland soils, classified in the Sarpy, Wabash and Genesee series, cover less than 1 percent of the total area.

Some relationship is evidenced between the development of the various soil types and the topographic features of the uplands. The Shelby soils occur on the more strongly rolling to rough areas in the drift uplands. The Lindley silt loam
also occurs on the more rolling areas. These soils are all affected to a considerable extent by erosion. The Carrington types are found on the more gently rolling to slightly undulating drift uplands. On the loessial uplands the Grundy silt loam and the Muscatine silt loam occur on the level to flat areas, and the drainage of both of these types is apt to be somewhat deficient. The Clinton silt loam is found on the more strongly rolling to rough loessial uplands, while the Tama silt loam occurs on the gently rolling to undulating areas. These types are affected to some extent by erosion, and the shallow phase of the Tama silt loam has been formed by the extensive washing away of the surface soil. The terrace and bottomland types are usually quite level in topography and few topographic features are developed. On the higher terraces are some variations, and the Waukesha, Judson and Jackson soils sometimes show a gently rolling surface. Topographic features are generally lacking on the bottoms.

The Fertility in Warren County Soils

Samples were taken for analysis from each of the soil types in Warren County except the Carrington fine sand on the drift uplands and the Wabash loam on the bottoms. These types were not analyzed because of their limited occurrence and

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelby loam</td>
<td>106,304</td>
<td>29.1</td>
</tr>
<tr>
<td>Carrington silt loam</td>
<td>12,736</td>
<td>3.5</td>
</tr>
<tr>
<td>Carrington loam</td>
<td>8,384</td>
<td>2.3</td>
</tr>
<tr>
<td>Lindley silt loam</td>
<td>5,696</td>
<td>1.5</td>
</tr>
<tr>
<td>Shelby silt loam</td>
<td>3,392</td>
<td>0.9</td>
</tr>
<tr>
<td>Carrington fine sand</td>
<td>448</td>
<td>0.1</td>
</tr>
<tr>
<td>Tama silt loam</td>
<td>88,960</td>
<td>25.1</td>
</tr>
<tr>
<td>Tama silt loam (shallow phase)</td>
<td>2,624</td>
<td>11.1</td>
</tr>
<tr>
<td>Grundy silt loam</td>
<td>21,568</td>
<td>5.9</td>
</tr>
<tr>
<td>Muscatine silt loam</td>
<td>9,856</td>
<td>2.7</td>
</tr>
<tr>
<td>Clinton silt loam</td>
<td>5,952</td>
<td>1.6</td>
</tr>
<tr>
<td>Bremer silt loam</td>
<td>2,752</td>
<td>0.8</td>
</tr>
<tr>
<td>Waukesha silt loam</td>
<td>256</td>
<td>0.1</td>
</tr>
<tr>
<td>Bremer silty clay loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>Bremer loam</td>
<td>192</td>
<td>0.1</td>
</tr>
<tr>
<td>Calhoun silt loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>Jackson silt loam</td>
<td>192</td>
<td>0.1</td>
</tr>
<tr>
<td>Wabash silt loam</td>
<td>42,240</td>
<td>11.6</td>
</tr>
<tr>
<td>Wabash silty clay loam</td>
<td>7,744</td>
<td>2.1</td>
</tr>
<tr>
<td>Wabash silty clay</td>
<td>1,152</td>
<td>0.3</td>
</tr>
<tr>
<td>Sarpy silt loam</td>
<td>1,088</td>
<td>0.3</td>
</tr>
<tr>
<td>Sarpy very fine sandy loam</td>
<td>640</td>
<td>0.2</td>
</tr>
<tr>
<td>Wabash loam</td>
<td>192</td>
<td>0.1</td>
</tr>
<tr>
<td>Genesee silt loam</td>
<td>448</td>
<td>0.1</td>
</tr>
<tr>
<td>Sarpy fine sandy loam</td>
<td>576</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Total | 364,800 | —— |
their unimportance agriculturally. The more extensive soil types were sampled in triplicate, but only one sample was taken from the minor types. The samplings were all made with care so that the results would be representative of the particular soil types and that variations which might arise from abnormal soil conditions or previous treatments would be avoided. The samples were taken at three depths, 0 to 6\(\frac{2}{3}\) inches, 6\(\frac{2}{3}\) to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement.

The official methods were employed in the nitrogen, phosphorus and carbon determinations, and the Truog qualitative test was used for the determination of the limestone requirements. The figures given in the tables are the averages of duplicate determinations on all samples of each type; therefore they represent the averages of two or six determinations.

**THE SURFACE SOIL**

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

Some variations in the phosphorus content in the various soils are noted. The amount present ranges from 767 pounds per acre in the Shelby silt loam up to 2,316 pounds per acre in the Wabash silty clay. There is some evidence of a relationship between the phosphorus content of the soils and the various soil groups. The bottomland types are higher on the average than the upland or terrace soils. This might be expected, inasmuch as there has been less crop growth on the bottomlands and a smaller removal of the plant food constituents from the soil. The loess soils are somewhat higher on the average than the drift types, probably due mainly to the origin of the soil and the less extent to which they have been eroded. The terrace types average somewhat lower than the bottomlands and slightly higher than the upland soils. In general, however, the variations within groups are much more striking than those between the various groups of soils.

The characteristics which serve as a basis for the separation of the various soil series seem to have some influence on the phosphorus supply. Thus, on the drift uplands the Carrington soils which are less rolling to rough in topography are richer than the Shelby and Lindley types. On the loessial uplands the Muscatine, Grundy and Tama soils are richer than the Clinton which is rolling to rough in topography and has been developed under forested conditions. On the terraces the differences among the various soil series are not pronounced, but the Calhoun silt loam is the lowest. The Bremer and Judson soils will average somewhat higher than the other types. On the bottomlands the Wabash soils are higher than the Sarpy or Genesee types, and the Genesee silt loam is better supplied than the Sarpy soils.

The general characteristics of the soils, the color, the topographic position and the character of the subsoil, all play an important part in determining the phosphorus content. Soil types which are dark in color, are level to flat or depressed in topography and have heavy subsoils, usually may be expected to show a higher content of phosphorus than soils which are light in color, are rolling to steep in topography or have sandy or gravelly subsoils.
<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>875</td>
<td>3,120</td>
<td>32,042</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,064</td>
<td>4,760</td>
<td>49,740</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>848</td>
<td>3,280</td>
<td>39,214</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>956</td>
<td>2,800</td>
<td>26,424</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>93</td>
<td>Shelby silt loam</td>
<td>767</td>
<td>3,240</td>
<td>31,715</td>
<td>6,000</td>
<td>6,000</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>1,515</td>
<td>4,960</td>
<td>45,036</td>
<td></td>
<td>5,500</td>
</tr>
<tr>
<td>143</td>
<td>Tama silt loam (shallow phase)</td>
<td>1,050</td>
<td>3,440</td>
<td>33,923</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,293</td>
<td>4,080</td>
<td>46,222</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>1,212</td>
<td>4,160</td>
<td>45,949</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>915</td>
<td>2,200</td>
<td>21,216</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>1,616</td>
<td>5,920</td>
<td>52,112</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,387</td>
<td>4,280</td>
<td>40,032</td>
<td></td>
<td>7,000</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,549</td>
<td>2,960</td>
<td>30,569</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silt clay loam</td>
<td>1,549</td>
<td>6,360</td>
<td>59,939</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>1,347</td>
<td>4,040</td>
<td>43,168</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>190</td>
<td>Judson loam</td>
<td>1,481</td>
<td>3,960</td>
<td>43,154</td>
<td></td>
<td>5,500</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,118</td>
<td>3,400</td>
<td>38,696</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>1,737</td>
<td>4,200</td>
<td>40,795</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,938</td>
<td>5,200</td>
<td>54,076</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silt clay loam</td>
<td>2,113</td>
<td>6,040</td>
<td>61,848</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>2,316</td>
<td>4,040</td>
<td>43,659</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>1,293</td>
<td>2,560</td>
<td>23,571</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>942</td>
<td>1,520</td>
<td>13,577</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>1,306</td>
<td>1,720</td>
<td>13,212</td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>102</td>
<td>Sarpy fine sandy loam</td>
<td>1,118</td>
<td>1,920</td>
<td>16,681</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

Variations in the texture of the surface soil also influence the phosphorus content. The Carrington silt loam on the drift upland is richer than the Carrington loam. There is little difference between the Shelby loam and the Shelby silt loam, but usually the silt loam is a little better supplied. On the loessial upland the shallow phase of the Tama silt loam is much lower in phosphorus as might be expected. On the terraces the Bremer silt loam and silty clay loam are higher than the Bremer loam, the silt loam being slightly higher than the silty clay loam. Generally the silty clay loam will contain somewhat more phosphorus than the silt loam. The Waukesha loam is a little better supplied than the silt loam, which is contrary to the usual results. On the bottomlands the Wabash silty clay is the richest in phosphorus and is followed by the silty clay loam, which in turn is higher than the silt loams. The Sarpy silt loam is better supplied than the fine sandy loam which is richer than the very fine sandy loam. It appears, therefore, that fine textured types are generally richer in plant food constituents than coarse textured soils. Silty clays and silty clay loams are usually richer than silt loams. Silt loams are generally higher in phosphorus than loams, and loams are commonly better supplied than sandy loams or fine sandy loams.

Considering the results of the analyses of all the types for phosphorus, it is
apparent that there is no large content of this element in any of the soils. Phosphorus will certainly be needed on these types very soon, and available evidence indicates that certain phosphorus fertilizers might be used in many cases at the present time with value.

The nitrogen content of the soils ranges from 1,520 pounds per acre in the Sarpy very fine sandy loam up to 6,360 pounds in the Bremer silty clay loam. As was noted in the case of phosphorus, the bottomland soils are somewhat better supplied with nitrogen on the average than the upland types. This again might be expected because of the lower crop growth on the bottomland soils. The loess types are a little better supplied on the average than the drift soils. There is little difference between the terrace soils and the bottomland types. Quite as large differences occur within the soil groups as between the various groups.

Again it is evident that the characteristics which serve to determine the various soil series affect the nitrogen content of the soils. Those types which are darker in color, more level in topography and have heavier subsoils are richer in nitrogen. Thus the Carrington soils on the drift uplands are richer than the Shelby and Lindley types. The Tama, Grundy and Muscatine soils are better supplied than the Clinton types on the loessial uplands. The Bremer soils are much better supplied than the other terrace types. The Waukesha soils are richer than the Judson, Calhoun and Jackson soils. The Calhoun silt loam is the lowest of the terrace types. On the bottomlands the Wabash soils which are darker in color are much richer in nitrogen than the Sarpy and Genesee types.

The nitrogen content is also influenced by the texture of the surface soil. On the drift uplands the Carrington silt loam is richer than the Carrington loam, and the Shelby silt loam is richer than the Shelby loam. On the terraces the Bremer silty clay loam is higher than the Bremer silt loam which in turn is better supplied than the loam. The Waukesha silt loam is richer than the Waukesha loam. On the bottomlands the Wabash silty clay loam is richer than the Wabash silt loam, but the Wabash silty clay is lower than the other two types which is rather unusual as silty clays are usually higher than silt loams. The Sarpy silt loam is richer than the Sarpy fine sandy loam which in turn is better supplied than loams and loams are higher in nitrogen than sandy loams.

Most of the soils in this county are fairly well supplied with nitrogen, and only in the case of some of the sandy soils on the bottomland is there any striking deficiency of this element. Nitrogen must be taken into account, however, when systems of permanent soil fertility are being planned.

The organic carbon content of the soils varies from 13,212 pounds per acre in the Genesee silt loam up to 61,848 pounds per acre in the Wabash silty clay loam. The relationships between the various soil types and the content of organic carbon are much the same as those noted in the case of nitrogen. The bottomland soils will average a little higher than the upland types. The loess soils are somewhat richer than the drift soils. There are much greater differences, however, between the soils within the various groups than between the groups. The characteristics which determine the soil series affect the content of organic carbon very much as
they do the nitrogen supply. The color of the soil, the topographic position and the subsoil characteristics all influence the supply of organic carbon. Thus, the Carrington soils on the drift uplands are richer than the Shelby and Lindley types. The Tama, Grundy and Muscatine soils on the loessial uplands are much higher than the Clinton silt loam. The Bremer soils are the highest of the terrace types, and the Calhoun soils are the lowest. The Wabash types are the highest of the bottomland soils, being much better supplied than the Sarpy or Genesee soils. In the latter case the soils of the Wabash series are not only darker in color, but they have heavier subsoils than the Sarpy types.

The differences in texture among the soils also influences the content of organic matter. The Carrington silt loam is much higher in organic carbon than the loam. The Shelby loam and the Shelby silt loam contain about the same amount. The Bremer silty clay loam is richer than the Bremer silt loam which in turn is better supplied than the Bremer loam. The Waukesha silt loam is richer than the loam. The Wabash silty clay loam is higher than the silt loam and the silty clay is lower than the silt loam or the silty clay loam, which is contrary to the usual results. The Sarpy silt loam is richer than the fine sandy loam which in turn is better supplied than the very fine sandy loam. The results in general bear out the previous conclusions that fine textured soils are richer in organic matter than are coarse textured types. Thus silty clay loams are richer than silt loams, silt loams are better supplied than loams and loams are higher in organic matter than are sandy soils.

Many of the soil types in the county are apparently fairly well supplied with organic matter. In some cases, however, the content of organic carbon is rather low and the application of some fertilizing material supplying organic carbon is necessary. It is important that organic matter be supplied regularly to all the soils of the county if the supply is to be kept up.
The rate at which the various plant food constituents are being made available in the soil is indicated by the relationship between the content of nitrogen and organic carbon. If this relationship is not optimum, crops may suffer for lack of needed food. In some of the Warren County soils there is evidence of improper production of available constituents. This condition is true with the Shelby loam and silt loam, the Lindley silt loam, the Tama silt loam, the Clinton silt loam and a number of the terrace and bottomland soils. In all such cases the application of farm manure would prove of particularly large value by stimulating the production of available plant food. On all of the soil types in the county, however, the application of farm manure in normal amounts will aid materially in the maintenance of the fertility of the soil.

None of the surface soils in this county showed any content of inorganic carbon. The soils are all acid in reaction and it is very necessary that they be tested to determine their needs for additions of lime. If the best yields of general farm crops and particularly of legumes are to be secured, applications of lime as indicated by the tests, are necessary.

The lime requirements of the individual soil types as given in table IV are

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>1,131</td>
<td>4,320</td>
<td>42,650</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,293</td>
<td>4,560</td>
<td>50,667</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,670</td>
<td>6,320</td>
<td>63,102</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>2,478</td>
<td>3,360</td>
<td>26,888</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Shelby silt loam</td>
<td>942</td>
<td>3,440</td>
<td>31,851</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,410</td>
<td>6,280</td>
<td>61,766</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>143</td>
<td>Tama silt loam (shallow phase)</td>
<td>1,912</td>
<td>4,560</td>
<td>42,759</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>2,046</td>
<td>5,520</td>
<td>60,212</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>2,074</td>
<td>6,000</td>
<td>67,629</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,884</td>
<td>2,720</td>
<td>20,616</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,288</td>
<td>8,480</td>
<td>97,081</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,478</td>
<td>7,520</td>
<td>75,701</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>2,478</td>
<td>4,560</td>
<td>49,958</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>2,504</td>
<td>8,080</td>
<td>97,781</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>2,640</td>
<td>7,360</td>
<td>79,246</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>Judson loam</td>
<td>2,935</td>
<td>7,000</td>
<td>78,128</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,724</td>
<td>3,280</td>
<td>33,869</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>3,502</td>
<td>6,080</td>
<td>31,660</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,502</td>
<td>7,840</td>
<td>93,645</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,747</td>
<td>4,560</td>
<td>62,121</td>
<td>6,000</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>3,448</td>
<td>4,880</td>
<td>52,303</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Sarpy silt loam</td>
<td>2,342</td>
<td>2,560</td>
<td>27,033</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>2,154</td>
<td>4,160</td>
<td>36,482</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>2,504</td>
<td>2,720</td>
<td>21,842</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>Sarpy fine sandy loam</td>
<td>1,454</td>
<td>1,040</td>
<td>8,844</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
indicative only of the general needs of the soils. Before an application of lime is made to any area, the soil in that area should be tested to determine the proper amount which should be applied. There is a wide variation in the lime requirements of different soils and even in the requirements of the same soil type in different fields. It is recommended that farmers have their soils tested for lime needs and that they apply the amount of lime that is necessary in order that they may secure the most satisfactory crop yields. It is usually preferable to test the soil preceding the growing of the legume crop of the rotation. The lime may then be applied as needed and bring about the largest beneficial effect.

THE SUBSURFACE SOILS AND SUBSOILS

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

The supply of the essential plant food constituents is not overly high in any of the lower soil layers in Warren County nor are there any distinct deficiencies. The exact content of the various plant food elements in the subsurface soils and subsoils will have little effect on the fertility of the soil; therefore the analyses

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>2,301</td>
<td>2,460</td>
<td>16,607</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>83</td>
<td>Carrington silt loam</td>
<td>1,657</td>
<td>4,780</td>
<td>44,095</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>1</td>
<td>Carrington loam</td>
<td>1,938</td>
<td>7,820</td>
<td>63,566</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>32</td>
<td>Lindley silt loam</td>
<td>4,887</td>
<td>5,740</td>
<td>25,033</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>93</td>
<td>Shelby silt loam</td>
<td>1,131</td>
<td>5,100</td>
<td>30,678</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,635</td>
<td>7,330</td>
<td>55,508</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>143</td>
<td>Tama silt loam (shallow phase)</td>
<td>2,787</td>
<td>6,860</td>
<td>52,685</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>2,745</td>
<td>6,700</td>
<td>54,240</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>30</td>
<td>Muscatine silt loam</td>
<td>2,745</td>
<td>6,860</td>
<td>50,313</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>4,200</td>
<td>4,440</td>
<td>25,279</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,667</td>
<td>10,220</td>
<td>110,116</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>2,745</td>
<td>8,300</td>
<td>63,648</td>
<td></td>
<td>7,000</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>2,706</td>
<td>3,800</td>
<td>51,785</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>43</td>
<td>Bremer silty clay loam</td>
<td>3,069</td>
<td>13,420</td>
<td>111,097</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>3,717</td>
<td>10,220</td>
<td>56,394</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>190</td>
<td>Judson loam</td>
<td>3,939</td>
<td>10,940</td>
<td>98,581</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>3,150</td>
<td>4,940</td>
<td>36,078</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>4,806</td>
<td>7,820</td>
<td>42,050</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,879</td>
<td>11,500</td>
<td>117,989</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>4,200</td>
<td>8,620</td>
<td>73,056</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>4,848</td>
<td>6,700</td>
<td>57,103</td>
<td></td>
<td>8,000</td>
</tr>
<tr>
<td>89</td>
<td>Sarpy silt loam</td>
<td>2,949</td>
<td>2,620</td>
<td>16,901</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>2,301</td>
<td>3,640</td>
<td>31,250</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>71</td>
<td>Genesee silt loam</td>
<td>3,717</td>
<td>4,600</td>
<td>32,003</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>102</td>
<td>Sarpy fine sandy loam</td>
<td>2,058</td>
<td>1,120</td>
<td>7,438</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>
of the surface soils may be considered to indicate quite accurately their needs. The analyses of the lower soil layers will not be considered in detail, as they merely serve to emphasize the needs of the various soil types.

**Greenhouse Experiments**

Two greenhouse experiments were carried out on soils from Warren County in order to secure some information regarding the needs of the soils and the value of certain fertilizing materials. The Shelby loam and the Tama silt loam, the two most extensively developed soils, were used in this work.

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

**RESULTS ON THE SHELBY LOAM**

The results secured in the experiment on the Shelby loam from Warren County are given in table VII. The superphosphate increased the yield of wheat slightly and brought about a very large increase on the clover. Limestone with the superphosphate showed a large effect on the wheat but had no influence on the clover. Ordinarily lime will bring about the largest effect on the legume crop. The manure increased the yield of both the wheat and clover to a very large extent. The

**TABLE VII. GREENHOUSE EXPERIMENT, SHELBY LOAM, WARREN COUNTY**

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>10.3</td>
<td>59.3</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>10.7</td>
<td>80.8</td>
</tr>
<tr>
<td>3</td>
<td>Limestone + superphosphate</td>
<td>13.6</td>
<td>79.4</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>13.3</td>
<td>88.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>16.2</td>
<td>97.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>16.4</td>
<td>91.7</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>16.7</td>
<td>109.8</td>
</tr>
</tbody>
</table>
superphosphate with the manure showed a large effect on both crops. Limestone applied with the manure and the superphosphate had little influence. The muriate of potash with the manure, limestone and the superphosphate, gave a small increase on the wheat but brought about a very pronounced gain in the clover.

RESULTS ON THE TAMÁ SILT LOAM

The results of the experiment on the Tamá silt loam from Warren County are given in table VIII. The superphosphate increased the yield of wheat in a very pronounced way and brought about an enormous increase in the clover.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight of wheat grain in grams</th>
<th>Weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>12.6</td>
<td>28.3</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>13.6</td>
<td>78.4</td>
</tr>
<tr>
<td>3</td>
<td>Limestone + superphosphate</td>
<td>15.8</td>
<td>108.3</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>16.1</td>
<td>65.9</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>18.8</td>
<td>101.8</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>18.5</td>
<td>124.2</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>18.1</td>
<td>126.4</td>
</tr>
</tbody>
</table>

Fig. 6. Clover on Tamá silt loam from Warren County, greenhouse experiment.

Fig. 7. Wheat in greenhouse experiment on Tamá silt loam, Warren County.
stone with the superphosphate gave a large increase in the wheat and had a very large effect on the clover. The manure increased both crops considerably, showing an especially large effect on the clover. The superphosphate with the manure increased both crops to a large extent, having the greatest effect on the clover. Limestone with the manure and the superphosphate had no effect on the wheat but brought about a large increase in the clover. The muriate of potash with the manure, limestone and the superphosphate showed no effect on the wheat and had a very slight influence on the clover.

Field Experiments

No field experiments have been carried out in Warren County, but the results of tests which are under way in adjacent counties on the same soil types as those which occur extensively in Warren County will be given in this report to indicate the effects of certain fertilizer treatments. The data obtained on the Shelby loam on the Millerton Field, Series I, in Wayne County, on Tama silt loam on the Newton Field in Jasper County, on the Tama silt loam on the Greenfield Field in Adair County, on the Tama silt loam on the Winterset Field, Series I, in Madison County, on the Tama silt loam on the Hudson Field in Black Hawk County, on the Grundy silt loam on the Agency Field in Wapello County, on the Grundy silt loam on the Mt. Pleasant Field, Series 200, in Henry County, on the Grundy silt loam on the Cedar Field in Mahaska County, on the Muscatine silt loam on the Delmar Field in Clinton County and on the Carrington loam on the Dallas Center Field in Dallas County are included. The results obtained on these fields may be considered definitely applicable to conditions in this county.

These field experiments are planned to determine the relative value of various soil treatments, and they are laid out on land which is representative of the individual soil types. They are permanently located by the installation of corner stakes, and all precautions are taken in the application of fertilizers and in the harvesting of the crops to insure the securing of accurate results. On some of
these fields tests are included under both the livestock and the grain systems of farming, manure being applied in the former and crop residues being utilized in the latter. In most of the tests only the livestock system is considered. Other fertilizing materials tested include limestone, rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. Manure is applied at the rate of 8 tons per acre once in the rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a four-year rotation. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in a four-year rotation. Superphosphate is added at the rate of 120 pounds per acre of a 20 percent material, three times in the four-year rotation. Until 1923, 16 percent superphosphate was added at the rate of 200 pounds per acre annually. In 1929, 20 percent material was first employed. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. From 1923 to 1929 a standard 2-12-2 brand was employed, the applications being made at the rate of 200 pounds per acre annually thus supplying the same amount of phosphorus as that contained in the superphosphate. Beginning in 1929 a 2-12-6 fertilizer is being used on the Tama, Grundy and Carrington soils, a 2-16-2 on the Muscatine types and a 4-16-4 on the Shelby soils. The muriate of potash is applied at the rate of 50 pounds per acre three years out of four in the four-year rotation.

THE MILLERTON FIELD

The results secured in the field experiment on the Shelby loam on the Millerton Field, Series I, in Wayne County are given in table IX. The application of manure increased the crop yields on this soil in most seasons, and the largest effects were evidenced on the corn in 1925. There was little effect on the clover in 1929. Limestone applied with the manure brought about increases in some cases on the

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 Corn bu. per A. (1)</th>
<th>1923 W. wheat bu. per A.</th>
<th>1924 Clover tons per A.</th>
<th>1925 Corn bu. per A.</th>
<th>1926 Corn bu. per A.</th>
<th>1927 Oats bu. per A.</th>
<th>1928 Alfalfa tons per A.</th>
<th>1929 Alfalfa tons per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>60.8</td>
<td>10.3</td>
<td>0.76</td>
<td>58.3</td>
<td>34.0</td>
<td>30.7</td>
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</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>63.0</td>
<td>14.5</td>
<td>0.69</td>
<td>65.3</td>
<td>36.0</td>
<td>30.7</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>63.4</td>
<td>10.3</td>
<td>0.86</td>
<td>64.3</td>
<td>44.4</td>
<td>24.9</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>64.2</td>
<td>15.1</td>
<td>1.09</td>
<td>72.3</td>
<td>49.2</td>
<td>31.9</td>
<td>1.16</td>
<td>1.72</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>58.1</td>
<td>9.6</td>
<td>0.92</td>
<td>60.6</td>
<td>35.2</td>
<td>29.9</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>60.5</td>
<td>16.4</td>
<td>1.32</td>
<td>64.2</td>
<td>41.6</td>
<td>36.7</td>
<td>1.33</td>
<td>2.40</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>64.7</td>
<td>17.0</td>
<td>1.54</td>
<td>60.6</td>
<td>43.6</td>
<td>38.3</td>
<td>1.40</td>
<td>2.34</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>65.6</td>
<td>17.6</td>
<td>1.29</td>
<td>59.3</td>
<td>46.0</td>
<td>41.6</td>
<td>1.28</td>
<td>2.47</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>59.8</td>
<td>10.9</td>
<td>1.03</td>
<td>54.7</td>
<td>36.8</td>
<td>31.2</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

(1) No limestone applied for the 1922 corn.
(2) Few scattered plants on plots 1, 2, 3, 5 and 9. First cutting clipped back. Results on 1 cutting in August.
(3) Total of 3 cuttings. Plots 1, 2, 5 and 9 mostly timothy. Plot 3 partly timothy.
grain crops particularly on the corn in 1926. It had very little effect, however, on the clover in 1924 and on the alfalfa in 1929. The rock phosphate with the manure and lime increased the crop yields in all seasons, showing large effects on the clover in 1924, on the alfalfa in 1929, on the corn in 1925 and on the oats in 1927. The superphosphate with the manure and lime showed larger effects than the rock phosphate on the wheat in 1923, the clover in 1924, the oats in 1927 and the alfalfa in 1928 and 1929. On the corn crops, however, the rock phosphate seemed to have somewhat larger effects. The muriate of potash with the manure, lime and the superphosphate increased the crop yields to a small extent in most seasons. It had no large effects except on the clover in 1924. In two cases there was no influence from the potash. The complete commercial fertilizer with the manure and limestone had slightly larger effects than the superphosphate in several seasons. It showed less effect on the clover in 1924, on the corn in 1925 and on the alfalfa in 1928.

THE NEWTON FIELD

The results secured on the Tama silt loam on the Newton Field in Jasper County are given in table X. The application of manure increased the crop yields on this soil in practically all cases. The largest effects were evidenced on the clover in 1927 and on the corn in 1928 and 1929. Limestone applied with the manure had a beneficial effect in practically all seasons. The clover crop in 1927 was increased and large effects were also evidenced on the corn in 1928. The rock phosphate with the manure and lime gave increases in all cases except on the corn in 1928 and 1929. The largest effect was shown on the clover in 1927. The superphosphate with the manure and lime showed somewhat better effects than the rock phosphate on the corn in 1924, 1925 and 1929, and on the oats in 1926. In the other seasons the rock phosphate was slightly superior. The differences were not great in any case. The muriate of potash with the manure, lime and the superphosphate showed little or no value. Very slight increases were secured in three cases. The complete commercial fertilizer gave somewhat larger effects than the

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 Red Clover</th>
<th>1924 Corn</th>
<th>1925 Corn</th>
<th>1926 Oats</th>
<th>1927 Corn</th>
<th>1928 Corn</th>
<th>1929 Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>1.28</td>
<td>58.5</td>
<td>52.5</td>
<td>57.9</td>
<td>1.13</td>
<td>69.4</td>
<td>57.3</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>1.36</td>
<td>59.8</td>
<td>51.7</td>
<td>56.8</td>
<td>1.37</td>
<td>75.9</td>
<td>64.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>1.35</td>
<td>61.7</td>
<td>55.5</td>
<td>56.8</td>
<td>1.44</td>
<td>81.7</td>
<td>66.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>1.45</td>
<td>66.0</td>
<td>57.9</td>
<td>62.6</td>
<td>1.79</td>
<td>79.2</td>
<td>64.8</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>1.42</td>
<td>57.8</td>
<td>53.3</td>
<td>49.4</td>
<td>1.27</td>
<td>69.3</td>
<td>56.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>1.32</td>
<td>66.3</td>
<td>58.9</td>
<td>67.3</td>
<td>1.79</td>
<td>78.2</td>
<td>67.7</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>1.35</td>
<td>65.9</td>
<td>58.7</td>
<td>63.3</td>
<td>1.81</td>
<td>78.2</td>
<td>68.3</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>1.34</td>
<td>66.1</td>
<td>53.6</td>
<td>76.9</td>
<td>1.72</td>
<td>81.2</td>
<td>67.2</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>1.20</td>
<td>56.0</td>
<td>49.6</td>
<td>51.9</td>
<td>1.20</td>
<td>73.4</td>
<td>59.7</td>
</tr>
</tbody>
</table>

(1) Plots 8 and 9 damaged considerably by hail.
### TABLE XI. FIELD EXPERIMENT, TAMA SILT LOAM, ADAIR COUNTY, GREENFIELD FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 Corn bu. per A.</th>
<th>1923 Corn bu. per A.</th>
<th>1924 Corn bu. per A.</th>
<th>1925 Clover and Timothy tons per A. (1)</th>
<th>1926 Corn bu. per A.</th>
<th>1927 Corn bu. per A.</th>
<th>1928 Oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>78.6</td>
<td>50.9</td>
<td>54.1</td>
<td>45.0</td>
<td>41.1</td>
<td>70.4</td>
<td>3.21</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>84.0</td>
<td>53.7</td>
<td>57.0</td>
<td>50.1</td>
<td>44.3</td>
<td>79.5</td>
<td>3.49</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>90.4</td>
<td>56.9</td>
<td>57.0</td>
<td>48.8</td>
<td>48.1</td>
<td>79.5</td>
<td>3.87</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>84.5</td>
<td>60.1</td>
<td>57.0</td>
<td>44.3</td>
<td>52.9</td>
<td>93.1</td>
<td>4.24</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>85.7</td>
<td>51.3</td>
<td>46.8</td>
<td>43.5</td>
<td>39.2</td>
<td>65.9</td>
<td>3.72</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>78.7</td>
<td>60.4</td>
<td>59.1</td>
<td>49.3</td>
<td>58.4</td>
<td>88.6</td>
<td>4.20</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>82.9</td>
<td>57.2</td>
<td>70.6</td>
<td>45.9</td>
<td>58.3</td>
<td>93.1</td>
<td>4.23</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>89.4</td>
<td>52.4</td>
<td>58.4</td>
<td>48.8</td>
<td>56.0</td>
<td>86.2</td>
<td>4.11</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>86.6</td>
<td>50.6</td>
<td>51.8</td>
<td>48.2</td>
<td>48.3</td>
<td>77.1</td>
<td>3.70</td>
</tr>
</tbody>
</table>

(1) Plots were pastured, no results taken.
(2) Total of two cuttings.

superphosphate on the oats in 1926 and on the corn in 1928. In the other seasons it had about the same effect as the superphosphate. In most cases the differences were not large.

THE GREENFIELD FIELD

The results secured in the field experiment on the Tama silt loam on the Greenfield Field, Series I, in Adair County are shown in table XI.

The application of manure increased the crop yields on this soil in every season, showing particularly large effects on the corn in 1922, the oats in 1928 and the timothy and clover in 1929. Limestone with the manure increased the crop yields in most cases. It showed the largest effect on the timothy and clover in 1929. No beneficial effect was indicated on the oats in 1924 or 1928, or on the corn in 1926. The rock phosphate with the manure and limestone gave increased crop yields in most seasons. The largest influence of the phosphate appeared on the oats in 1928 and on the timothy and clover in 1929. The oats in 1924 and the corn in 1926 showed no beneficial effects. The superphosphate with the manure and limestone increased the crop yields in practically all seasons. It showed larger effects than the rock phosphate on all the crops except the oats in 1928 and the timothy and clover in 1929. In these latter cases there was little difference in the yields under the two treatments. The muriate of potash with the manure, lime and the superphosphate increased the oats in 1924 and 1928, and showed a beneficial effect on the corn in 1922. In the other seasons it showed no beneficial influence. The complete commercial fertilizer with the manure and limestone showed smaller effects than the superphosphate in all but one case.

THE WINTerset FIELD

The results secured on the Tama silt loam on the Winterset Field, Series I, in Madison County are given in table XII. The application of manure increased the crop yields in practically all seasons, but in most cases the effects were not very
<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 Corn bu. per A. (1)</th>
<th>1923 Corn bu. per A.</th>
<th>1924 Corn bu. per A.</th>
<th>1925 Clover tons per A.</th>
<th>1926 Corn bu. per A. (2)</th>
<th>1927 Corn bu. per A.</th>
<th>1928 Corn bu. per A.</th>
<th>1929 Oats bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rock phosphate + manure...</td>
<td>77.1</td>
<td>43.9</td>
<td>54.8</td>
<td>1.50</td>
<td>58.1</td>
<td>58.5</td>
<td>65.3</td>
<td>65.9</td>
</tr>
<tr>
<td>1</td>
<td>Check........................</td>
<td>77.2</td>
<td>46.6</td>
<td>59.2</td>
<td>1.58</td>
<td>63.5</td>
<td>57.6</td>
<td>59.5</td>
<td>59.0</td>
</tr>
<tr>
<td>2</td>
<td>Manure........................</td>
<td>76.1</td>
<td>47.2</td>
<td>67.1</td>
<td>1.60</td>
<td>56.8</td>
<td>54.8</td>
<td>62.4</td>
<td>65.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>76.5</td>
<td>50.4</td>
<td>71.6</td>
<td>1.76</td>
<td>59.7</td>
<td>61.0</td>
<td>69.1</td>
<td>64.6</td>
</tr>
<tr>
<td>5</td>
<td>Check........................</td>
<td>72.9</td>
<td>45.1</td>
<td>55.9</td>
<td>1.54</td>
<td>52.5</td>
<td>53.6</td>
<td>58.9</td>
<td>54.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>79.7</td>
<td>49.8</td>
<td>67.6</td>
<td>1.61</td>
<td>53.0</td>
<td>57.9</td>
<td>64.8</td>
<td>68.1</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>81.0</td>
<td>50.9</td>
<td>65.5</td>
<td>1.63</td>
<td>55.0</td>
<td>60.0</td>
<td>62.9</td>
<td>67.0</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>72.1</td>
<td>52.0</td>
<td>68.2</td>
<td>1.55</td>
<td>51.5</td>
<td>51.1</td>
<td>63.5</td>
<td>68.1</td>
</tr>
<tr>
<td>9</td>
<td>Check........................</td>
<td>72.7</td>
<td>43.9</td>
<td>52.6</td>
<td>1.54</td>
<td>46.4</td>
<td>47.8</td>
<td>63.7</td>
<td>56.8</td>
</tr>
</tbody>
</table>

(1) Limestone not applied till 1923.
(2) Unable to account for high yield on plot 2.

pronounced. Limestone with the manure gave increases in most cases, the largest effects appearing on the oats in 1924 and in 1929. The rock phosphate with the manure and limestone gave considerable increases in some cases, and it proved beneficial on all but one crop. The largest effects were shown on the clover in 1925. The superphosphate with the manure and limestone showed a slightly smaller influence than the rock phosphate in all but one case, but in most seasons the treatment brought about an increase in the crop yields. The muriate of potash with the manure, lime and the superphosphate gave slight increases in some seasons. The effects, however, were not very large. The complete commercial fertilizer with the manure and lime showed smaller effects than the superphosphate in most cases; hence it would not prove as desirable for use on this soil.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk County are given in table XIII. The value of manure on this soil is evidenced by the results secured on the various crops grown on this field. Increased yields were secured in every season from the use of manure, and in many cases the increases were very large. The application of lime with the manure brought about increases in crop yields in every case, the legume crop showing particularly large benefits.

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

The crop residues showed little effect on the yields, increases being noted in only one or two cases. Lime with the crop residues increased the crop yields in every season, showing large effects on the clover and timothy in 1925 and 1926 and on the corn in 1927, 1928, and 1929. Beneficial effects were also evidenced in other seasons on the oats and corn. Rock phosphate applied with the residues and lime increased the crop yields in several seasons. In a few cases no gains were noted. Superphosphate with the crop residues and lime showed very similar effects to those brought about by the rock phosphate, the increases being somewhat more pronounced in some seasons but not so definite in others. The complete commercial fertilizer with the crop residues and lime had a greater effect than the superphosphate in several cases, particularly on the clover and timothy in 1925 and 1926. In several other seasons the effect was less than that of the phosphate.

THE AGENCY FIELD

The results secured on the Grundy silt loam on the Agency Field, Series I, in Wapello County are given in table XIV. The application of manure proved of value on this soil as is indicated by the increased crop yields secured in practically

### TABLE XIII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD, SERIES II

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 Corn bu. per A. (1)</th>
<th>1919 Oats bu. per A.</th>
<th>1920 Corn bu. per A. (2)</th>
<th>1921 Corn bu. per A.</th>
<th>1922 Corn bu. per A. (3)</th>
<th>1923 Corn bu. per A. (4)</th>
<th>1924 Oats bu. per A.</th>
<th>1925 Clover and Timothy tons per A.</th>
<th>1926 Timothy tons per A.</th>
<th>1927 Corn bu. per A.</th>
<th>1928 Corn bu. per A. (7)</th>
<th>1929 Corn bu. per A. (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>45.8</td>
<td>47.6</td>
<td>53.2</td>
<td>44.8</td>
<td>54.0</td>
<td>40.3</td>
<td>1.43</td>
<td>0.88</td>
<td>45.7</td>
<td>50.8</td>
<td>47.7</td>
<td>49.3</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>49.3</td>
<td>54.7</td>
<td>62.8</td>
<td>53.1</td>
<td>59.6</td>
<td>65.2</td>
<td>2.03</td>
<td>1.56</td>
<td>64.3</td>
<td>57.2</td>
<td>50.6</td>
<td>57.9</td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>54.4</td>
<td>59.2</td>
<td>67.4</td>
<td>59.6</td>
<td>66.5</td>
<td>52.2</td>
<td>2.20</td>
<td>1.74</td>
<td>67.8</td>
<td>54.6</td>
<td>57.8</td>
<td>65.2</td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock</td>
<td>56.5</td>
<td>64.9</td>
<td>73.3</td>
<td>58.1</td>
<td>61.4</td>
<td>63.4</td>
<td>2.02</td>
<td>1.55</td>
<td>75.5</td>
<td>60.4</td>
<td>56.3</td>
<td>58.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + superphosphate</td>
<td>57.4</td>
<td>62.2</td>
<td>73.3</td>
<td>53.2</td>
<td>59.6</td>
<td>66.3</td>
<td>2.35</td>
<td>1.81</td>
<td>78.3</td>
<td>63.4</td>
<td>60.6</td>
<td>63.5</td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + complete commercial fertilizer</td>
<td>58.5</td>
<td>57.5</td>
<td>72.4</td>
<td>62.2</td>
<td>68.4</td>
<td>60.0</td>
<td>2.09</td>
<td>1.49</td>
<td>75.3</td>
<td>64.0</td>
<td>56.6</td>
<td>58.4</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>56.9</td>
<td>62.2</td>
<td>2.44</td>
<td>41.4</td>
<td>54.8</td>
<td>50.6</td>
<td>2.24</td>
<td>1.57</td>
<td>71.5</td>
<td>58.4</td>
<td>54.7</td>
<td>57.9</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>54.7</td>
<td>62.2</td>
<td>65.2</td>
<td>49.0</td>
<td>53.1</td>
<td>49.5</td>
<td>2.25</td>
<td>1.49</td>
<td>75.5</td>
<td>64.0</td>
<td>56.6</td>
<td>58.4</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + lime</td>
<td>57.9</td>
<td>64.6</td>
<td>71.3</td>
<td>62.4</td>
<td>66.7</td>
<td>57.7</td>
<td>2.72</td>
<td>2.11</td>
<td>78.2</td>
<td>63.4</td>
<td>60.6</td>
<td>63.5</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + lime + rock phosphate</td>
<td>62.8</td>
<td>58.1</td>
<td>74.9</td>
<td>59.6</td>
<td>65.7</td>
<td>66.4</td>
<td>2.32</td>
<td>1.70</td>
<td>70.5</td>
<td>59.3</td>
<td>56.5</td>
<td>58.4</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + lime + superphosphate</td>
<td>55.6</td>
<td>65.5</td>
<td>87.4</td>
<td>64.4</td>
<td>62.8</td>
<td>60.9</td>
<td>2.36</td>
<td>1.79</td>
<td>74.1</td>
<td>58.5</td>
<td>56.8</td>
<td>58.4</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + lime + complete commercial fertilizer</td>
<td>52.5</td>
<td>57.5</td>
<td>74.1</td>
<td>71.3</td>
<td>63.2</td>
<td>61.5</td>
<td>2.52</td>
<td>2.03</td>
<td>70.3</td>
<td>62.6</td>
<td>57.7</td>
<td>58.4</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>54.5</td>
<td>57.0</td>
<td>71.3</td>
<td>59.7</td>
<td>58.0</td>
<td>48.7</td>
<td>2.34</td>
<td>1.71</td>
<td>70.7</td>
<td>59.3</td>
<td>56.8</td>
<td>58.4</td>
</tr>
</tbody>
</table>

(1) Four tons of lime. Hail damaged corn.
(2) Yield on plot 7 evidently an error.
(3) Corn cut and put in silo.
(4) Not very ripe when cut.
(5) Dry season.
(6) High yields on crop residue series due to lower ground and more moisture.
(7) Large number of missing hills on plot 4.
(8) Yields on a 15 percent moisture basis.
TABLE XIV. FIELD EXPERIMENT, GRUNDY SILT LOAM, WAPELLO COUNTY, AGENCY FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1921 Corn bu. per A. (1)</th>
<th>1920 Oats bu. per A.</th>
<th>1920 W. Wheat bu. per A. (2)</th>
<th>1921 Clover and Timothy tons per A. (3)</th>
<th>1922 Corn bu. per A.</th>
<th>1921 Oats bu. per A.</th>
<th>1920 W. Wheat bu. per A. (5)</th>
<th>1921 Clover and Timothy tons per A. (6)</th>
<th>1922 Corn bu. per A.</th>
<th>1921 Oats bu. per A.</th>
<th>1920 W. Wheat bu. per A. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>63.5</td>
<td>44.9</td>
<td>22.7</td>
<td>1.92</td>
<td>66.2</td>
<td>21.7</td>
<td>1.28</td>
<td>83.3</td>
<td>66.8</td>
<td>22.6</td>
<td>1.92</td>
</tr>
<tr>
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<td>Manure</td>
<td>64.5</td>
<td>62.2</td>
<td>31.5</td>
<td>2.09</td>
<td>20.7</td>
<td>71.8</td>
<td>51.9</td>
<td>70.8</td>
<td>81.9</td>
<td>1.96</td>
<td>89.4</td>
</tr>
<tr>
<td>3</td>
<td>Manure + lime</td>
<td>66.8</td>
<td>58.3</td>
<td>36.7</td>
<td>2.20</td>
<td>2.5</td>
<td>79.2</td>
<td>52.2</td>
<td>73.8</td>
<td>82.1</td>
<td>2.28</td>
<td>100.5</td>
</tr>
<tr>
<td>4</td>
<td>Manure + lime + rock phosphate</td>
<td>68.8</td>
<td>63.6</td>
<td>38.7</td>
<td>2.52</td>
<td>2.0</td>
<td>86.5</td>
<td>85.4</td>
<td>80.6</td>
<td>63.5</td>
<td>3.14</td>
<td>105.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure + lime + super-phosphate</td>
<td>70.0</td>
<td>66.4</td>
<td>40.0</td>
<td>3.32</td>
<td>2.8</td>
<td>85.6</td>
<td>60.2</td>
<td>77.9</td>
<td>38.9</td>
<td>2.05</td>
<td>97.8</td>
</tr>
<tr>
<td>6</td>
<td>Manure + lime + complete fertilizer</td>
<td>66.0</td>
<td>65.6</td>
<td>34.7</td>
<td>2.52</td>
<td>2.5</td>
<td>83.0</td>
<td>55.4</td>
<td>77.3</td>
<td>30.2</td>
<td>2.47</td>
<td>101.0</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>59.3</td>
<td>54.5</td>
<td>38.5</td>
<td>1.82</td>
<td>2.0</td>
<td>69.7</td>
<td>74.3</td>
<td>81.4</td>
<td>1.74</td>
<td>2.99</td>
<td>74.6</td>
</tr>
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<td>8</td>
<td>Crop residues</td>
<td>58.5</td>
<td>49.0</td>
<td>31.4</td>
<td>1.81</td>
<td>2.0</td>
<td>66.3</td>
<td>43.7</td>
<td>66.4</td>
<td>1.87</td>
<td>2.88</td>
<td>76.4</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + lime</td>
<td>61.3</td>
<td>59.4</td>
<td>34.8</td>
<td>2.02</td>
<td>2.4</td>
<td>71.3</td>
<td>50.7</td>
<td>72.1</td>
<td>1.86</td>
<td>2.69</td>
<td>83.5</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + lime + rock phosphate</td>
<td>61.8</td>
<td>61.2</td>
<td>36.4</td>
<td>2.33</td>
<td>2.6</td>
<td>75.3</td>
<td>54.9</td>
<td>79.2</td>
<td>2.14</td>
<td>96.6</td>
<td>77.5</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + lime + super-phosphate</td>
<td>63.5</td>
<td>61.2</td>
<td>36.3</td>
<td>2.19</td>
<td>2.7</td>
<td>80.7</td>
<td>55.5</td>
<td>74.6</td>
<td>2.26</td>
<td>93.4</td>
<td>69.0</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + lime + complete fertilizer</td>
<td>62.5</td>
<td>63.6</td>
<td>35.6</td>
<td>2.17</td>
<td>2.2</td>
<td>65.4</td>
<td>45.4</td>
<td>78.4</td>
<td>2.14</td>
<td>93.6</td>
<td>77.3</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>52.5</td>
<td>52.0</td>
<td>22.8</td>
<td>1.56</td>
<td>2.4</td>
<td>63.9</td>
<td>42.7</td>
<td>58.5</td>
<td>0.91</td>
<td>67.0</td>
<td>56.5</td>
</tr>
</tbody>
</table>

(1) Corn damaged slightly by hail in July and dry weather in August.
(2) Sample No. 7 lost in transit; wheat badly down. Light dressing of manure to all plots by mistake in winter of 1920. Lime applied in November.
(3) Pastured after first crop.
(4) Pastured after first crop.
(5) Wet weather prevented seeding of plots 11, 12 and 13.
(6) Mostly timothy.

All seasons. The largest increases were shown in the oats in 1919, the hay in 1921 and 1922, the oats in 1925, the clover and timothy in 1927 and the corn in 1928 and 1929. The use of lime with the manure brought about crop increases in practically all cases. The beneficial effects of the lime were particularly evident on the hay crop, but large increases were also shown on the corn and oats.

The rock phosphate with the manure and lime increased the crop yields in every season, in some cases very large effects being noted. The hay crop was particularly benefited by the rock phosphate, and considerable increases were secured on the oats in 1919, on the corn in 1923 and 1929 and on the wheat in 1926. The superphosphate showed larger effects than the rock phosphate in practically all seasons. There were no strikingly large differences except in the case of the hay crop in 1922. In 1921, 1923, 1928 and 1929, the rock phosphate gave somewhat larger effects on the corn and in 1925 on the oats. The complete commercial fertilizer generally showed somewhat smaller effects than the superphosphate. Only on the hay crop in 1921, the clover and timothy in 1927 and the corn in 1928 and 1929 was there any greater effect from the complete fertilizer. In some cases the rock phosphate gave larger effects than did the complete fertilizer.

The crop residues showed little effect on the various crops grown. Lime with the residues brought about increased crop yields in practically every season. Only in the case of the wheat in 1926 was there no increase from the use of the lime.
In some seasons and on certain of the crops, the beneficial effects were definite. This was particularly true of the hay crops in 1921 and 1922, of the clover in 1927 and of the corn in 1928 and 1929.

The application of rock phosphate gave increases in crop yields in practically every season. In some instances the increases were very distinct as on the hay crop in 1921, 1922 and 1927, on the wheat in 1926 and on the corn in 1928 and 1929. The superphosphate showed larger effects than the rock phosphate in several seasons. It had smaller effects than the rock phosphate, however, on the clover in 1921, on the oats in 1925 and on the corn in 1928 and 1929, and had practically the same effect on the oats in 1919 and on the wheat in 1920. The complete commercial fertilizer gave very similar increases to those brought about by the superphosphate. Only in one case was there a striking difference. On the corn in 1923 the complete commercial fertilizer showed no effect.

THE MOUNT PLEASANT FIELD

The results secured on the Grundy silt loam on the Mount Pleasant Field, Series 200, in Henry County are given in table XV. The beneficial effects of manure are evident in the increased crop yields secured in all but one season. Large increases were noted on the oats in 1921, on the clover in 1926 and on the corn in 1927. The application of lime along with the manure increased the crop yields in nearly all seasons. In some cases considerable crop increases were secured, as for example on the corn in 1920, 1924, 1927 and 1928 and on the clover in 1926.

TABLE XV. FIELD EXPERIMENT, GRUNDY SILT LOAM, HENRY COUNTY, MT. PLEASANT FIELD, SERIES 200*

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1919 Corn bu. per A</th>
<th>1920 Corn bu. per A</th>
<th>1921 Oats bu. per A (1)</th>
<th>1922 Clover tons per A (2)</th>
<th>1923 Corn bu. per A</th>
<th>1924 Corn bu. per A</th>
<th>1925 Oats bu. per A</th>
<th>1926 Clover tons per A (3)</th>
<th>1927 Corn bu. per A</th>
<th>1928 Corn bu. per A (4)</th>
<th>1929 Oats bu. per A (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>55.7</td>
<td>48.1</td>
<td>36.9</td>
<td>1.6</td>
<td>61.3</td>
<td>49.3</td>
<td>35.0</td>
<td>0.9</td>
<td>50.6</td>
<td>64.1</td>
<td>33.7</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>66.5</td>
<td>51.2</td>
<td>46.9</td>
<td>1.9</td>
<td>77.3</td>
<td>58.0</td>
<td>55.0</td>
<td>0.6</td>
<td>60.0</td>
<td>44.3</td>
<td>42.3</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>74.1</td>
<td>69.8</td>
<td>35.3</td>
<td>2.1</td>
<td>85.0</td>
<td>75.0</td>
<td>91.0</td>
<td>0.8</td>
<td>68.0</td>
<td>56.0</td>
<td>57.4</td>
</tr>
<tr>
<td>4</td>
<td>Manure+rock phosphate</td>
<td>78.6</td>
<td>66.4</td>
<td>42.6</td>
<td>2.4</td>
<td>84.5</td>
<td>70.4</td>
<td>65.9</td>
<td>1.3</td>
<td>71.2</td>
<td>55.3</td>
<td>53.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure+superphosphate</td>
<td>75.3</td>
<td>77.2</td>
<td>48.9</td>
<td>2.4</td>
<td>77.6</td>
<td>73.3</td>
<td>64.8</td>
<td>1.4</td>
<td>76.7</td>
<td>76.6</td>
<td>77.3</td>
</tr>
<tr>
<td>6</td>
<td>Manure+complete commercial fertilizer</td>
<td>66.5</td>
<td>81.2</td>
<td>46.5</td>
<td>2.7</td>
<td>80.0</td>
<td>65.7</td>
<td>59.4</td>
<td>0.9</td>
<td>76.0</td>
<td>47.6</td>
<td>54.7</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>50.6</td>
<td>64.1</td>
<td>33.7</td>
<td>2.1</td>
<td>58.3</td>
<td>44.3</td>
<td>47.1</td>
<td>0.5</td>
<td>40.6</td>
<td>47.3</td>
<td>32.9</td>
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<tr>
<td>8</td>
<td>Crop residues</td>
<td>65.3</td>
<td>75.5</td>
<td>43.1</td>
<td>2.3</td>
<td>64.6</td>
<td>35.3</td>
<td>34.7</td>
<td>1.0</td>
<td>52.4</td>
<td>40.6</td>
<td>47.3</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+lime</td>
<td>71.0</td>
<td>76.3</td>
<td>40.0</td>
<td>2.6</td>
<td>73.3</td>
<td>34.7</td>
<td>56.1</td>
<td>1.0</td>
<td>76.7</td>
<td>67.5</td>
<td>79.3</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+rock phosphate</td>
<td>75.1</td>
<td>75.1</td>
<td>43.8</td>
<td>2.5</td>
<td>69.0</td>
<td>38.0</td>
<td>52.5</td>
<td>0.8</td>
<td>86.9</td>
<td>59.7</td>
<td>68.0</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+superphosphate</td>
<td>81.1</td>
<td>85.1</td>
<td>43.5</td>
<td>2.5</td>
<td>68.0</td>
<td>40.7</td>
<td>63.2</td>
<td>2.0</td>
<td>96.3</td>
<td>58.3</td>
<td>64.0</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+complete commercial fertilizer</td>
<td>78.5</td>
<td>90.1</td>
<td>42.2</td>
<td>2.6</td>
<td>74.3</td>
<td>41.3</td>
<td>60.4</td>
<td>0.9</td>
<td>97.2</td>
<td>70.0</td>
<td>21.2</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>65.8</td>
<td>65.4</td>
<td>31.1</td>
<td>1.1</td>
<td>76.0</td>
<td>39.3</td>
<td>43.8</td>
<td>0.8</td>
<td>80.3</td>
<td>37.1</td>
<td>21.0</td>
</tr>
</tbody>
</table>

* Yields for 1915, 1916, 1917 and 1918 not included due to irregularities.
(1) Three tons lime applied; oats lodged in spots.
(2) Two crops on all but crop residue plots.
(3) Plots 7 to 13 were partly burned off in April. Check plots badly infested with weeds.
(4) Low yield in plot 2 due to wet spot in field.
(5) Wet season cut oat yield.
The use of rock phosphate with the manure and lime brought about increases in some seasons, showing up particularly well on the oats in 1921, 1925 and 1929, on the clover in 1922 and 1926 and on the corn in 1927 and 1928. The superphosphate showed a greater effect than the rock phosphate in some seasons, especially on the corn in 1920, on the oats in 1921, on the clover in 1926 and on the oats in 1929. In other seasons the effects were less or similar to those brought about by the rock phosphate. The complete commercial fertilizer had larger effects than the superphosphate in one or two cases, notably on the corn in 1920 and on the clover in 1922. In most of the other seasons the effects were less evident than those brought about by the superphosphate.

The influence of the residues on crop growth was not great. The use of lime along with the crop residues showed beneficial effects on most of the crops. The clover in 1922 and 1926 was definitely increased. The corn was increased in 1923, 1927 and 1928, and the oats showed a gain in 1925. In other seasons the effects of the lime were small and not definite.

The use of rock phosphate proved of value on practically all of the crops grown. In some cases the increases were not large, and in one or two instances no increases at all were secured. The superphosphate showed larger effects than the rock phosphate in practically all seasons. The influence was much greater on the corn in 1920, on the oats in 1925 and on the clover in 1926. In the other seasons the effects were about the same or slightly less than those brought about by the rock phosphate. The complete commercial fertilizer showed a larger effect than the superphosphate in one or two cases, but in general the differences were small and there was no evidence of superiority of the complete fertilizer over the phosphate.

THE CEDAR FIELD

The results of the experiment carried out on the Grundy silt loam on the Cedar Field in Mahaska County are given in table XVI. The manure increased the crop

**TABLE XVI. FIELD EXPERIMENT, GRUNDY SILT LOAM, MAHASKA COUNTY, CEDAR FIELD, SERIES I**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 Corn bu. per A.</th>
<th>1923 Oats bu. per A.</th>
<th>1924 W. Wheat bu. per A.</th>
<th>1925 W. Wheat bu. per A.</th>
<th>1926 Clover tons per A.</th>
<th>1927 Corn bu. per A.</th>
<th>1928 Corn bu. per A.</th>
<th>1929 Corn bu. per A.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>54.6</td>
<td>39.0</td>
<td>33.0</td>
<td>22.9</td>
<td>73.2</td>
<td>65.7</td>
<td>70.3</td>
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<tr>
<td>2</td>
<td>Manure</td>
<td>50.8</td>
<td>46.0</td>
<td>41.5</td>
<td>24.4</td>
<td>68.3</td>
<td>79.4</td>
<td>62.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>57.8</td>
<td>54.7</td>
<td>38.7</td>
<td>24.5</td>
<td>72.6</td>
<td>81.3</td>
<td>60.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphorus</td>
<td>58.7</td>
<td>46.0</td>
<td>43.0</td>
<td>28.7</td>
<td>72.6</td>
<td>76.6</td>
<td>64.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>51.1</td>
<td>40.8</td>
<td>37.6</td>
<td>22.2</td>
<td>66.9</td>
<td>55.3</td>
<td>50.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>54.9</td>
<td>46.0</td>
<td>40.8</td>
<td>28.2</td>
<td>73.1</td>
<td>71.7</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + potassium</td>
<td>60.3</td>
<td>46.0</td>
<td>42.3</td>
<td>31.2</td>
<td>78.4</td>
<td>69.0</td>
<td>67.7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>56.8</td>
<td>42.5</td>
<td>36.8</td>
<td>30.9</td>
<td>60.7</td>
<td>67.4</td>
<td>63.2</td>
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</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>65.3</td>
<td>38.1</td>
<td>35.2</td>
<td>22.8</td>
<td>62.5</td>
<td>67.8</td>
<td>49.4</td>
<td></td>
</tr>
</tbody>
</table>

(1) Field pastured; no results.
(2) High yield on plot 1 due to better drainage.
### TABLE XVII. FIELD EXPERIMENT, MUSCATINE SILT LOAM, CLINTON COUNTY, DELMAR FIELD, SERIES I

<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 Barley bu. per A</th>
<th>1921 W. Wheat bu. per A</th>
<th>1922 Corn bu. per A</th>
<th>1923 Oats bu. per A</th>
<th>1924 Timothy and Clover tons per A</th>
<th>1925 Corn bu. per A</th>
<th>1926 Oats bu. per A (1)</th>
<th>1927 Alfalfa tons per A (2)</th>
<th>1928 Alfalfa tons per A (2)</th>
<th>1929 Alfalfa tons per A (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>77.7 69.6 25.3 33.5 55.4 49.3 1.04 74.4 15.4 0.41 1.22 1.59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>81.1 65.8 28.1 28.4 65.1 54.3 1.08 78.9 17.4 1.52 2.04 3.42</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>83.3 76.1 24.9 34.9 64.6 66.1 1.10 82.7 15.6 2.58 2.77 3.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>88.8 75.3 32.7 30.0 71.1 61.1 1.57 91.2 23.2 2.75 2.93 3.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure + limestone + superphosphate</td>
<td>81.1 72.2 23.7 27.8 71.6 56.1 1.52 96.5 23.2 2.82 2.68 3.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>75.0 77.4 40.3 32.9 73.6 67.7 1.44 99.4 28.3 15.3 23.3 9.7</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>66.7 67.3 1.27 2.25 8.68 8.42 5.1 0.88 2.12 0.62 1.56 3.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>75.0 65.8 28.7 21.9 68.4 84.4 2.1 0.82 28.0 5.9 8.1 20.1 3.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>9</td>
<td>Crop residues + limestone</td>
<td>76.6 70.9 27.2 33.6 67.4 45.8 1.17 88.0 17.2 2.62 1.34 3.99</td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td>Crop residues + limestone + rock phosphate</td>
<td>78.3 69.2 23.4 9.27 6.0 62.8 1.31 94.9 17.2 3.03 3.03 3.83</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11</td>
<td>Crop residues + limestone + superphosphate</td>
<td>76.6 71.4 32.1 23.4 71.3 69.7 1.44 92.9 23.3 6.22 2.82 7.13 80</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>12</td>
<td>Crop residues + limestone + complete commercial fertilizer</td>
<td>70.5 57.5 38.5 23.2 73.7 65.4 1.56 91.1 20.1 5.2 2.86 3.71</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>64.4 67.9 52.4 52.3 4.68 0.45 0.80 98.7 5.0 60.6 30.0 1.04 3.00</td>
<td></td>
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</tbody>
</table>

(1) Oats were late and badly lodged at harvest time and also affected with rust.
(2) Most of the check plot yields represent alsike clover and timothy. Total of two cuttings.

Yields in most seasons on this field, showing very large effects on the oats in 1923, on the winter wheat in 1924 and on the corn in 1928. Limestone with the manure increased crop yields in most seasons, showing the largest effect on the corn in 1922 and on the oats in 1923. The rock phosphate with the manure and lime increased the crop yields in most cases. The superphosphate with the manure and limestone showed about the same effect as the rock phosphate, having slightly greater influence in some seasons and somewhat smaller effects in others. No large differences between the two treatments appeared. The muriate of potash with the manure, lime and the superphosphate gave increases in the crop yields in all seasons, but in most cases the gains were not very large. The complete commercial fertilizer with the manure and limestone had very little effect over the superphosphate on the various crops grown. In two cases small increases were secured, but in the other seasons the results were very similar to those secured with the superphosphate.

### THE DELMAR FIELD

The results secured on the Muscatine silt loam on the Delmar Field in Clinton County are given in table XVII. The application of manure to this soil brought about increased crop yields in most seasons. The largest effects were evidenced on the corn in 1922, on the oats in 1923 and on the alfalfa in 1927, 1928 and 1929. The application of lime along with the green manure proved valuable on this soil, bringing about increased yields in most seasons. Particularly large effects were shown on the alfalfa in 1927, 1928 and 1929, but increases were also obtained on the corn in 1919, on the winter wheat in 1921 and on the oats in 1923.
The rock phosphate with the manure and lime increased the crop yields in practically all cases. Very pronounced gains were secured on the barley in 1920, on the corn in 1922, on the clover and timothy in 1924, on the corn in 1925, on the oats in 1926 and on the alfalfa in 1927, 1928 and 1929. The superphosphate with the manure and lime showed no greater effect than the rock phosphate in most cases and in several seasons had a smaller influence. In general the differences between the effects of these two phosphates were not very large. The complete commercial fertilizer with the manure and lime showed a greater effect than the phosphates in one or two cases, but in general the differences were not very great, and in several seasons there was less effect from the complete fertilizer than from the phosphates.

The crop residues had little effect on the various crops grown on this field. Lime with the residues increased the crop yield to a considerable extent in some seasons, for example, the winter wheat in 1921, the clover and timothy in 1924 and the alfalfa in 1927, 1928 and 1929.

The rock phosphate with the crop residues and lime showed a beneficial effect on the crops grown in most seasons. In some cases very pronounced gains were secured, for example, on the oats in 1923, on the clover and timothy in 1924 and on the alfalfa in 1927 and 1928. In several cases no large effects were evidenced from the rock phosphate. The superphosphate with the crop residues and lime showed a larger effect on the crops grown in several seasons, but no striking differences were noted. The complete commercial fertilizer with the crop residues and lime had a smaller effect than the superphosphate in most seasons.

THE DALLAS CENTER FIELD

The results secured on the Carrington loam on the Dallas Center Field in Dallas County are given in table XVIII. The application of manure increased the crop yields.

**TABLE XVIII. FIELD EXPERIMENT, CARRINGTON LOAM, DALLAS COUNTY, DALLAS CENTER FIELD, SERIES I**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 W. Wheat bu. per A.</th>
<th>1924 Clover tons per A. (1)</th>
<th>1925 Corn bu. per A.</th>
<th>1926 Corn bu. per A.</th>
<th>1927 Oats bu. per A.</th>
<th>1928 Sweet Clover tons per A.</th>
<th>1929 Corn bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>24.8</td>
<td>50.3</td>
<td>69.9</td>
<td>52.6</td>
<td>1.81</td>
<td>69.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>25.9</td>
<td>51.2</td>
<td>73.0</td>
<td>51.7</td>
<td>2.00</td>
<td>75.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>29.6</td>
<td>54.1</td>
<td>78.9</td>
<td>50.2</td>
<td>1.97</td>
<td>79.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rock phosphate</td>
<td>30.9</td>
<td>58.8</td>
<td>79.2</td>
<td>68.2</td>
<td>2.29</td>
<td>78.3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>21.8</td>
<td>51.9</td>
<td>76.0</td>
<td>53.4</td>
<td>1.78</td>
<td>69.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone+superphosphate</td>
<td>33.8</td>
<td>58.8</td>
<td>76.8</td>
<td>64.3</td>
<td>2.42</td>
<td>82.2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manure+limestone+superphosphate+potassium</td>
<td>34.5</td>
<td>59.6</td>
<td>78.9</td>
<td>62.4</td>
<td>2.17</td>
<td>80.4</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>30.4</td>
<td>59.5</td>
<td>73.6</td>
<td>64.4</td>
<td>2.69</td>
<td>80.2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>20.6</td>
<td>53.3</td>
<td>65.3</td>
<td>46.3</td>
<td>1.65</td>
<td>74.1</td>
<td></td>
</tr>
</tbody>
</table>

(1) Field was pastured; no results.
(2) Total of two cuttings.
(3) Yield on 15 percent moisture basis.
yields to a considerable extent in practically all seasons. The largest influence was evidenced on the sweet clover in 1928 and on the corn in 1929. Limestone with the manure increased the yields in most seasons, showing appreciable effects on the grain crops. Ordinarily the legume crops show the largest benefit but on this field there was no influence on the sweet clover. The rock phosphate with the manure and lime increased the crop yields in all but one season. It showed the largest effect on the sweet clover in 1928 and on the oats in 1927. The superphosphate with the manure and lime had somewhat greater effect than the rock phosphate in some seasons, especially on the sweet clover in 1928, but in some cases the rock phosphate gave larger effects. The muriate of potash with the manure, lime and the superphosphate gave small increases in crop yields in some seasons but not in all cases. The material apparently had very little effect. The complete commercial fertilizer with the manure and lime showed a slightly greater influence than the superphosphate on sweet clover in 1928 but had smaller effects than the superphosphate in all other seasons.

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

Some indications regarding the fertilizer treatment most desirable for use on the soils of this county have been secured in the laboratory, greenhouse and field experiments which have been discussed earlier in this report. It is possible, therefore, to make a few more or less general recommendations for the handling of the more important soil types. In the following pages certain suggestions which are based upon the results of experiments and also upon the experiences of many farmers will be offered. Any of the treatments suggested may be put into operation on any farm.

Liming

All of the soil types in Warren County are acid in reaction and in need of lime as has been indicated by the analyses discussed earlier in this report. Not only are the surface soils acid, but the acidity extends down thru the lower soil layers. The figures given in table IV indicate roughly the lime requirements of the various soil types. Before lime is applied to any soil, however, tests should be made of that particular soil. Such a wide variation in acidity and the need for lime prevails that even soils of the same type from different fields often show different needs. Only by testing samples from a particular area will it be possible to supply the exact amount of lime needed by that soil. Farmers may test their soils for acidity or lime requirement but it usually will be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station, where it will be tested free of charge.

Generally, the most satisfactory yields of farm crops cannot be secured on soils which are acid in reaction. Legumes such as sweet clover, alfalfa and red clover are particularly sensitive to acidity and may fail on acid soils if the acidity is very high. Increases in yield are also secured from the use of lime on acid soils when corn and small grain crops are grown. It is important that lime be applied to the
acid soils in this county in the amount which tests show are necessary if the yields of general farm crops and particularly of legumes are to be satisfactory.

In the experiments which have been reported earlier, large crop increases have been secured from the application of lime to some of the more extensively developed soil types in the county. Beneficial effects were shown on the Tama silt loam, the Grundy silt loam, the Shelby loam, the Muscatine silt loam and the Carrington loam. Other soil types in the county would also undoubtedly be benefited to a large extent by the application of lime. Numerous tests and the practical experiences of many farmers have shown the importance of applying lime to acid soils in this county.

It is important that lime be applied to soils regularly if they are to be kept satisfactorily productive. One application will not suffice for an indefinite period. It is recommended that soils be tested for lime needs at least once in a rotation, preferably preceding the growing of a legume crop. The lime may then be applied where it is most needed and where it will bring about the greatest effects. The influence of the application will be evident, however, not only on the legume crop of the rotation but also on the succeeding grain crop.

**Manuring**

Many of the soils in Warren County are fairly well supplied with organic matter as is indicated by their dark color. Some of the types, however, are light in color and rather poorly supplied with organic matter. These soils are the lowest in crop producing power. On the light colored types, such as the Clinton, Lindley, Calhoun, Jackson, Genesee and Sarpy soils, the need for organic matter is very evident. Even the better supplied types such as the Tama, Grundy, Muscatine, Carrington and Shelby soils will be benefited to a very large extent by applications of fertilizing material supplying organic matter. On all of these soils organic matter must be supplied at regular intervals if the supply is to be kept up. On the poorer, light colored soils, applications are very necessary at the present time.

The cheapest and best means of building up and maintaining the supply of organic matter in the soils is by the proper preservation and application of all the farm manure produced. Under the livestock system of farming the manure if properly used will aid materially in maintaining the fertility of the soil. Large increases in the yields of general farm crops follow its application. Experiments which have been discussed earlier have shown the large influence of farm manure on the Shelby loam, the Tama silt loam, the Grundy silt loam, the Muscatine silt loam and the Carrington loam. Many of the other types in the county would show quite as large or even greater effects from the addition of manure. The liberal application of farm manure to the soils of this county is strongly recommended if the best crop yields are to be secured, and the land is to be kept permanently productive.

The thorough utilization of all crop residues aids materially in maintaining the supply of organic matter in the soil. On the livestock farms the residues are used for feed or bedding and are returned to the land with the manure. Under the grain system of farming the residues are stored and frequently allowed to de-
compose partially before being applied, or they may be applied directly to the land. Under both types of farming, all the residues should be utilized because of their large fertility value.

On many livestock farms the manure produced is insufficient to permit regular applications to all of the land. On the grain farms little or no manure is produced, and some other source of organic matter must be sought if the supply is to be kept up. On practically all livestock farms, therefore, and on all grain farms, the use of inoculated legumes as green manures is very desirable to provide for the maintenance of an adequate supply of organic matter in the soil. When inoculated legumes are utilized as green manures, they not only supply organic matter to the land, but they also add nitrogen which they have taken from the atmosphere.

Green manuring would undoubtedly prove profitable on many of the soils of Warren County at the present time. On the light colored, sandy soils, the influence of green manuring is particularly great, but the yields of general farm crops may be increased materially thru this treatment on practically all of the soils of the county. The practice of green manuring should not be followed carelessly, however, as undesirable effects on the soil may result if the green materials are not properly decomposed. It is very important that farmers in this county take steps to provide for the maintenance of the proper supply of organic matter in the soils by the utilization of farm manure, crop residues and green manures.

The Use of Commercial Fertilizers

The soils of Warren County are rather low in content of total phosphorus as has been indicated by the analyses discussed earlier in this report, and it is apparent that the supply of this necessary plant food constituent will not prove adequate to meet the needs of crops over any long period of years. The use of a phosphate fertilizer will certainly be needed on these soils in the very near future, and it is quite possible that the application of a phosphorus carrier might prove of very large value at the present time.

The two fertilizers which supply phosphorus commercially are rock phosphate and superphosphate. Rock phosphate is usually applied at the rate of 1,000 to 2,000 pounds per acre once in four years. The superphosphate is ordinarily applied at 150 pounds per acre annually or three years out of four in a four-year rotation. In the rock phosphate the phosphorus is only slowly available, while the superphosphate carries the element in a readily available form. The rock phosphate often does not show its largest effect until the second year after its application, while the superphosphate gives immediate returns. The latter is much more expensive, but the smaller application means that the fertilizer addition is actually less costly. The rock phosphate must, therefore, bring about larger beneficial effects on the crops grown if it is to prove as economically desirable.

The experiments which have been described earlier in this report have shown that one or the other of these phosphate fertilizers may be used profitably on the more extensively developed soils in Warren County. Beneficial effects were shown on the Tama silt loam, the Grundy silt loam, the Muscatine silt loam, the Carring- ton loam and the Shelby loam, and quite as large or even larger effects can un-
doubtedly be secured on some of the other soil types in the county. In some cases
the superphosphate proved preferable, but in other instances the rock phosphate
gave quite as profitable returns. At the present time definite conclusions regarding
the relative value of the two phosphates on the soils of this county cannot be
drawn. Simple tests along this line may be carried out easily on any farm, and
farmers are urged to carry out tests on their own soils. They may thus determine
for their particular conditions, the need for phosphorus and the relative value of
the two materials.

Some of the soil types in Warren County are apparently fairly well supplied
with nitrogen, but in some cases the amount of this constituent present is rather
low. In all cases, however, nitrogen must be considered when systems of permanent
fertility are planned. The element disappears from the soil continually, being
carried away by the crops grown and in the drainage waters. On all of the soils
of the county, therefore, it is important that some fertilizing materials supplying
nitrogen be used regularly, and where the supply is low at the present time, some
nitrogenous fertilizer is especially necessary.

Farm manure aids materially in keeping up the supply of nitrogen in the soil.
The turning under of crop residues also aids in this connection, but the most
desirable method of building up and maintaining the nitrogen content of soils is by
the use of leguminous crops as green manures. When well inoculated, legumes
take up from the atmosphere much of the nitrogen which they contain, and when
they are turned under in the soil a large increase in nitrogen is secured. Green
manuring is also of value because organic matter is supplied. Thus, the practice
has a double value. On the lighter colored, poorer soils in the county, green manur­
ing will prove particularly desirable. By the proper growing and handling of
legume crops for green manuring purposes, the nitrogen content of the soil may
be increased and kept up without the use of expensive commercial nitrogenous
fertilizers. The latter cannot be recommended for general use in the county at
the present time. For truck crops and garden crops they may prove profitable, and
in small amounts as top dressings their use may be desirable, but in all cases these
fertilizers should not be employed on a large scale until tests on small areas have
shown them to be of value.

Most of the soils of the county are apparently very well supplied with potassium,
and commercial potassium fertilizers are probably unnecessary for use at the
present time. If the soil is kept in the best condition from the standpoints of drain­
age, cultivation, supply of organic matter, reaction and plant food content, the
production of available potassium will usually be sufficient for crop needs. For
general farm crops the addition of commercial potassium fertilizers should not be
made until tests have been carried out on small areas and the value of the applica­
tion proved. For special crops such as garden or truck crops, the use of potassium
fertilizers may be desirable now.

Complete commercial fertilizers cannot be recommended for general use in the
county at the present time. From the experiments which have been carried out
and from the experiences of some farmers, it would seem that superphosphate may
bring about quite as large crop increases, and its application is less expensive.
Complete fertilizers are more expensive than superphosphate; hence they must have a larger effect on crop yields to prove profitable. Probably for general farm crops the phosphorus fertilizers would prove more desirable. For truck crops and other special crops, certain brands of complete fertilizers may be used very profitably. It is very desirable, however, that in all cases where complete commercial fertilizers are to be employed, tests be carried out on small areas in comparison with superphosphate in order to determine the actual crop effect of the treatment. There is no objection which can be raised to the use of a complete fertilizer. It is merely a question of the profit which can be secured from its application.

Drainage

On most of the uplands in the county the natural drainage is quite satisfactory. The larger streams with their tributaries and intermittent drainageways extend into nearly all parts of the upland. There are, however, a number of poorly drained areas at the heads of drainageways, near the small streams and also in the level to flat or depressed areas in the broad upland divides between the streams. The Muscatine silt loam on the loessial upland is apt to be poorly drained, and there are many areas in the Grundy silt loam where drainage is inadequate. On the terraces the Bremer and Calhoun soils are poorly drained, and on the bottomlands the Wabash types are in need of drainage. The latter soils should be protected from overflow if they are to be satisfactorily productive.

Wherever the soil is too wet crop yields will not be entirely satisfactory. The first treatment needed on the soil types mentioned and in all other cases where drainage is inadequate is the installation of tile. The expense of tiling may be considerable, but the increased crop yields secured soon pay for the installation. No fertilizing material will have a large effect on soils which are too wet. For maximum crop yields and continued fertility, adequate drainage should always be provided.

The Rotation of Crops

The continuous growing of any one crop will very quickly reduce the fertility of the soil and is a very undesirable practice. The large money value of some individual crop, however, often leads farmers to follow this system. Many experiments and the experiences of a large number of farmers have shown definitely that under continuous, single cropping, yields rapidly decrease and very soon the crop proves unprofitable. It has been shown further that when a rotation of crops is practiced, the profits are much greater in spite of the fact that certain crops of lower money value are included in the rotation. Furthermore, under a good crop rotation the fertility of the soil may be maintained much more readily.

No rotation experiments have been carried out in Warren County but some rotations may be suggested which will undoubtedly prove acceptable. The following are desirable rotations which may be used in the county and any of them may serve as a basis upon which a suitable rotation may be devised to fit individual farm conditions.

1. SIX-YEAR ROTATION

First Year—Corn
Second Year—Corn
Third Year—Wheat or oats (with 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 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 is less harmful and is usually more easily
Erosion occurs to some extent in the soils of Warren County. On the drift uplands the Carrington soils are affected to some extent, and the Lindley and Shelby types are frequently badly washed. On the loessial uplands the Clinton soils are often seriously eroded, and in some areas of the Tama silt loam considerable washing has occurred. The shallow phase of the latter type has been formed thru the carrying away of the surface soil by erosion. Wherever erosion occurs, some means of prevention or control 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 dead furrows, and in level areas this process may be 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 3 or 4 inches apart. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru but holding the fine soil.
Earth Dams—Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but in many cases they may be effective in preventing erosion in dead furrows.

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands or at any place where water runs over the surface of the land. Small gullies may be filled in several ways, but it is not practicable to fill them with soil for this method takes much work and is not lasting.

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

"Staking In"—The simplest and most satisfactory method of controlling small or moderate sized gullies is the staking in operation recommended for the control of dead furrow gullies.

The Straw Dam—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, the dam 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,
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 2 or 3 feet above the bottom of the gully. Large 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 the dam, such as sorghum, or even oats or rye. A later seeding of grass is a good practice.

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 for that reason 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 the method is a very unsightly one.

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 drainageways often prevents these channels from washing into gullies as the sod serves to hold
the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve as well; for quick results thickly planted sorghum may be employed.

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

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

LARGE GULLIES
Erosion in large gullies or ravines, in general, may 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. Where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tilling—The straightening of the larger streams in bottomland areas may be accomplished by community action, and in this way, while the cost is considerable, large areas of land may 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 also aid materially in securing satisfactory crop growth.

Use of Organic Matter—Organic matter or humus is the most effective means of increasing the water absorbing power of the soil; 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.

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

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 has proved satisfactory.

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 when done in the fall.
INDIVIDUAL SOIL TYPES IN WARREN COUNTY* **

There are 26 soil types in Warren County and these with the shallow phase of the Tama silt loam make a total of 27 soil areas. They are divided into four large groups according to their origin and location. The groups are loess soils, drift soils, terrace soils and swamp and bottomland soils.

Drift Soils

There are six drift soils in the county, classified in the Shelby, Carrington and Lindley series. Together they cover 37.4 percent of the total area.

SHELBY LOAM (79)

The Shelby loam is the largest drift soil and the most extensively developed individual soil type in the county. It covers 29.1 percent of the total area. It occurs in large areas in the southwestern part of the county. There are also extensive areas in the southeastern part. It is developed in ribbon-like strips bordering most of the rivers and creeks throughout the northern townships. The largest individual areas occur in Jackson, White Oak, Virginia and Squaw Townships, where it occupies the major portion of the upland.

The surface soil of the Shelby loam is a dark grayish-brown or very dark grayish-brown, fine textured loam one or two inches in thickness. This surface layer is underlaid to a depth of from 5 to 7 inches by a slightly darker colored layer. The upper subsoil is a yellowish-brown, silty clay loam or gritty, silty clay mottled with gray, rusty brown and a few iron stains. Below 20 or 24 inches the subsoil is a yellowish-brown, sandy clay mottled with rusty-brown, gray and some red. Below 4 or 5 feet the substratum consists of a gray clay mottled with rusty brown, yellow and red.

In cultivated areas the surface soil is a dark brown or brown when dry and a very dark brown or black when wet. There are minor variations in the texture of the surface soil in different topographic positions. Along the upper slopes where the soil occurs adjacent to the Grundy silt loam and the Tama silt loam, there has been a wash from these soils over the Shelby, and narrow bands of silt loam might have been separated had they been large enough to show on the map. On the slopes where the erosion has been most active, the surface soil in places is a sandy clay loam, and near the bottoms of the slopes the texture approaches a fine sandy loam. In the southern half of the county, there are many places where the lower subsoil is mottled with a bright yellow. This subsoil is somewhat different in texture, owing to the presence of a sandy shale below the glacial drift which appears within the 3-foot section.

In topography the Shelby loam is rough or broken and drainage is excessive. In many areas the surface soil has been washed away, and the soil is frequently badly gullied or eroded.

About 33 percent of the type has been cleared and is used for general farm crops.

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

**Warren County adjoins Polk County on the north and Madison County on the west. In a few places the soil maps do not agree. Small areas of soil in Warren County adjoining large areas in the counties named were not continued in Warren County but were combined with similar soils. For instance, the Chariton silt loam in Polk County is mapped as Calhoun silt loam and the Lindley loam in Madison County is mapped as Lindley silt loam in Warren County.
The remainder is in its natural condition and is used for pasture purposes. There is a growth of oak and elm on these areas and a rather scanty growth of blue grass. On the cultivated areas corn, oats and hay are grown. Corn yields from 30 to 35 bushels per acre, oats from 20 to 30 bushels per acre and hay from 1 to 1½ tons per acre. Some sweet clover is grown and occasionally alfalfa is produced.

This soil is chiefly in need of protection from erosion if it is to be successfully cultivated. The steeper slopes should not be cultivated but preferably should be kept in pasture. Where the soil is badly gullied, some means of filling the gullies should be adopted. On the cultivated areas the type is in need of organic matter and liberal additions of farm manure are recommended. The turning under of leguminous crops as green manures would also prove of value. The type is generally acid in reaction and in need of lime. The use of a phosphate fertilizer would undoubtedly be desirable, and tests of superphosphate are recommended.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the second largest drift soil, covering 3.5 percent of the total area. It occurs in all parts of the county, being developed along the lower part of the more gentle slopes in comparatively narrow bands bordering the bottomlands along the streams and drainageways. The largest areas of the type are found in Linn, Palmyra, Union and Whitebreast Townships.

The surface soil of the Carrington silt loam is a dark grayish-brown or very dark grayish-brown, even textured silt loam to a depth of 12 or 14 inches. The lower part of this surface layer is somewhat more mellow, friable and granular. The upper subsoil is a dark brown or dark yellowish-brown, finely granular silt loam. At 18 or 20 inches there is a yellowish-brown, slightly friable silty clay loam or silty clay. This layer is usually 1½ to 2 feet in depth. In the lower depths there are faint gray mottlings. Below a depth of 40 to 60 inches the sub-stratum consists of a yellowish-brown, gritty silty clay mottled with gray, rusty brown and red.

In the more rolling areas, erosion has occurred to some extent and the surface soil is somewhat thinner and the color slightly lighter. In some areas the subsoil at a depth of three feet is a gritty silty clay mottled with gray, rusty brown and red. In the southern part of the county, especially in Otter, Whitebreast and Belmont Townships, the lower subsoil layers are more mottled with yellow, owing to the presence of small quantities of yellow shale. The surface of the type is gently sloping or undulating and drainage is well established.

The Carrington silt loam is practically all in cultivation or in pasture. The only tree growth consists of wind breaks which have been set out north and west of farm buildings. Corn, oats and hay are the chief crops grown and the yields are
much the same as on the Tama silt loam on the adjacent uplands. Corn averages 39 bushels per acre, oats from 35 to 60 bushels and hay from 1 to 2 tons per acre.

This soil will respond very profitably to applications of farm manure, and liberal additions of this fertilizing material are recommended. The type is acid and in need of lime for the best growth of general farm crops and particularly of legumes. The use of a phosphate fertilizer would be very desirable.

**CARRINGTON LOAM (1)**

The Carrington loam is the third largest drift soil and covers 2.3 percent of the total area of the county. It is found in small isolated areas scattered throughout all parts of the county. The larger more continuous areas occur along Middle Creek north of Norwalk, in the southeastern townships along Wolf Creek and bordering the bottomlands of Squaw Creek west of Medora and along South River northwest of Medford.

The Carrington loam is a dark grayish-brown or very dark grayish-brown, mellow, granular loam varying from 8 to 14 inches in depth. The upper subsoil is a yellowish-brown, friable, crumbly silty clay loam extending to a depth of 22 to 26 inches. Below that point the subsoil is a yellowish-brown sandy clay mottled with gray, reddish-brown and some iron stains. Occasionally boulders are found throughout the soil. Usually the soil is rather uniform in color and texture, but slight variations sometimes occur where the topographic conditions are different. Along the upper part of the slopes, the content of silt is higher while near the bottom of the slopes there is more grit and sand. Included with areas of this soil are some small spots of Carrington silt loam and Shelby loam which are too small to separate on the map.

In topography the Carrington loam is gently undulating to rolling. It is somewhat more rolling usually than the Carrington silt loam. Drainage is good. Erosion occurs to some extent on the rougher areas; there are some gullies and occasionally the surface soil has been washed considerably.

Practically all of the type is under cultivation, and general farm crops are grown, corn, oats and hay being produced chiefly. Barley, rye, rape and sorghum are minor crops, and some garden crops are produced on practically all farms. Yields are much the same as on the Carrington silt loam and the Tama silt loam.
The Carrington loam will respond in a large way to applications of farm manure, and liberal additions of this material are recommended. The type is acid in reaction, and applications of lime are very necessary for the best growth of general farm crops and particularly for legumes. The use of a phosphate fertilizer would undoubtedly prove desirable, and tests of rock phosphate and superphosphate are urged.

**LINDLEY SILT LOAM (32)**

The Lindley silt loam is a minor type in the county, covering 1.5 percent of the total area. It occurs in only a few widely scattered isolated areas. The more extensive areas are found in the northeastern corner of the county as narrow, ribbon-like bands bordering the bottomlands of the Des Moines and Middle Rivers. It occurs in association with the Clinton silt loam and frequently the boundary lines between the two types are established rather arbitrarily owing to the washing of the Clinton soils over the lower-lying Lindley.

The surface soil of the Lindley silt loam to a depth of 1 or 2 inches is a brown or grayish-brown silt loam. This is underlaid by a light brownish-gray or pale yellowish-gray, floury silt loam 3 or 4 inches in thickness. The upper subsoil is a pale, yellowish-brown silt loam with a rather granular structure, and the lower subsoil below 16 or 18 inches is a light yellow or yellowish-brown, compact, friable silty clay or fine sandy clay, slightly mottled with gray. Rock fragments are found throughout the lower subsoil. In many places the soil at a depth of about 3 feet is distinctly calcareous.

In some areas the surface soil has been largely washed away. It is quite shallow on the steeper slopes, and often the subsoil is exposed. At the bottoms of the slopes, the soil is somewhat deeper, owing to the wash from above. Included with the type are a few patches which might have been separated as Lindley loam, Shelby loam or Shelby silt loam had they been sufficiently large to show on the map. The surface of the type is rough or broken and the soils are badly gullied. Drainage is excessive.

Practically none of the type is under cultivation but all is left in its natural condition and is utilized for pasture. The forest growth consists mainly of elm, oak, hickory, aspen and maple. Blue grass makes an excellent growth, especially on the more gentle slopes. In most of the areas the type should undoubtedly be kept in pasture as it is too rough to be cultivated. Precautions should be taken to keep it covered with pasture grasses in order to prevent such serious erosion as is likely to occur.

**SHELDON SILT LOAM (93)**

The Shelby silt loam is a minor type, covering 0.9 percent of the total area. It occurs only in the southeastern and northwestern parts of the county. The largest areas are found along the south side of the Middle River north...
of St. Marys. In general the areas are comparatively small and isolated.

The surface soil of the Shelby silt loam is a dark grayish-brown, mellow, granular silt loam extending to a depth of 5 to 7 inches. The subsoil is a yellowish-brown, gritty sandy clay loam, underlain at a depth of 24 or 26 inches by a yellowish-brown or light brown, gritty clay, mottled with yellowish-brown, gray and red. Fragments of parent till including some calcareous material occur in pockets and streaks near a depth of 3 feet.

There are some variations in the texture of the soil in the different areas. In some cases it is much more silty, and in other areas approaches a loam in texture. Included with the type are areas of Carrington silt loam and Carrington loam which are too small to show on the map. The surface of the type is rolling but not as strongly rolling as that of the Shelby loam, and erosion is not as extensive. Drainage is good to excessive.

About 50 percent of the soil is under cultivation, the remainder being left in its natural condition and used for pasture. Corn, oats and hay are the chief crops grown on the cultivated areas. The yields are somewhat lower than those obtained on the adjacent areas of Grundy silt loam and Tama silt loam. Blue grass makes an excellent growth and provides good pasturage.

On the cultivated portions of the Shelby silt loam, applications of farm manure would be of particularly large value to build up the supply of organic matter and reduce the injurious effects of erosion. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended. In all cases where this soil is cultivated, precautions are necessary to prevent the destructive action of erosion.

CARRINGTON FINE SAND (86)

The Carrington fine sand is a minor type, covering only 0.1 percent of the total area. It occurs in close association with the Tama silt loam and the Clinton silt loam on the uplands. The two most extensive areas are 2 miles northeast of Summerset along the south side of the Middle River and south of Norwalk on the south side of the North River. Small isolated areas occur in Richland andWhitebreast Townships.

The surface soil of the Carrington fine sand is a medium dark grayish-brown or very dark grayish-brown fine sand or loamy fine sand, extending to a depth of 6 or 8 inches. The subsoil is a yellowish-brown or yellowish, loose textured, fine sand, extending to a depth of 4 or 5 feet without appreciable change.

Where the type is found associated with the Tama silt loam or the Shelby loam, the color is darker, but in Sections 8 and 35 of Richland Township, the surface has much the same color as the adjacent Clinton silt loam and Lindley silt loam. Along the Lucas County line in Section 36 of Whitebreast Township, the typical soil
High Acidity

The Carrington fine sand consists of a dark brown, loose textured, loamy fine sand, underlaid at a depth of 10 or 12 inches by a yellowish-brown, sticky, fine sand which in turn grades at a depth of 20 or 22 inches into a fine sand and gravel layer. The surface of the type is rolling to broken, and gullies occur on many of the slopes. Drainage is excessive and the soil is drouthy.

The Carrington fine sand is utilized to some extent for the production of melons and truck crops. Corn is grown on a small acreage and some clover is produced. Native pastures are of little value and grasses make a poor growth. On the virgin areas there is a scant growth of grass with some oak and jack pine. The yields of crops on this soil are low owing to the drouthiness of the type.

The soil is mainly in need of organic matter to be made more productive and to reduce the danger of drouth injury in dry seasons. Liberal applications of farm manure are recommended, and the turning under of leguminous crops as green manures would also be of value. The type is acid and in need of lime, especially for the growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value, and superphosphate should be used for general farm crops. For special crops and particularly truck crops, the use of a good complete fertilizer would certainly prove profitable. The particular brand which should be employed should be selected by carrying out tests on small areas.

Loess Soils

There are four loess types, classified in the Tama, Grundy, Muscatine and Clinton series, and these together with the shallow phase of the Tama silt loam make a total of five individual loess areas. Together they cover 44.8 percent of the total area of the county.

TAMA SILT LOAM (120)

The Tama silt loam is the largest loess type and the second largest soil in the county. Together with the shallow phase which is small in area, it covers 25.1 percent of the total area. It is found extensively developed on the uplands in the northern part of the county, being the chief upland type in that section. Smaller isolated areas of the type occur in the southern townships. In the northern part the areas are extensive and are broken only by the narrow ribbon-like patches of Carrington silt loam and Carrington loam along the lower slopes to the streams and the Wabash silt loam bordering the streams.

The surface soil of the Tama silt loam is a very dark grayish-brown or almost black friable silt loam 2 or 3 inches thick. Below this point to a depth ranging from 14 to 18 inches, the material is somewhat darker in color. The upper subsoil to a depth of 24 to 30 inches is brown or yellowish-brown and a heavy silt loam to silty clay loam in texture. The lower subsoil which in general is 2½ or 3 feet
in thickness, differs from the upper subsoil in that it is faintly mottled with gray and contains some iron stains. The substratum below this lower subsoil consists of a brown, yellowish-brown or yellow heavy silt loam faintly mottled with gray.

In the cultivated areas of the type, the surface soil to a depth of 14 or 18 inches is a friable silt loam, brown or dark brown when dry and dark brown or almost black when wet. The boundary lines between this type and the Grundy and Muscatine soils are placed rather arbitrarily as there are gradual transitions into these types. In these areas the lower part of the subsoil is more strongly mottled and contains more rusty brown iron stains. Included in the areas of Tama silt loam are small patches of Muscatine silt loam and Grundy silt loam that are too small to show on the map.

In topography the Tama silt loam is undulating or gently rolling. Even in the areas where the topography is more rolling, in the vicinity of Hartford in the northeastern corner of the county, and near Martensdale, the crests of the hills are rounded and the slopes even. Drainage is good. Erosion occurs to some extent but is not so serious as on the rougher types.

Practically all of the Tama silt loam is under cultivation or in pasture. Corn, wheat, oats and timothy are the chief crops grown. Corn yields 39 bushels per acre on the average, but in favorable seasons yields of 90 bushels per acre have been reported. Wheat yields from 18 to 28 bushels per acre, oats from 35 to 60 bushels per acre and hay from 1 to 2 tons per acre.

Applications of farm manure are of value on this soil and will bring about considerable increases in the yields of general farm crops. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of rock phosphate or superphosphate are urged. The experiments discussed earlier in this report indicate the beneficial effects of manure, lime and a phosphate fertilizer on this soil.

**TAMA SILT LOAM (SHALLOW PHASE) (143)**

The shallow phase of the Tama silt loam is limited in area, covering less than 1 percent of the county. It occurs only in the northern third, the most extensive areas being found along the Polk County line north of Cumming and along the south side of Butcher Creek just west of Palmyra.

The soil differs from the typical Tama silt loam only in the depth and color of the surface layer and in the lack of gray mottlings at a depth of 3 feet. The surface soil is a brown or dark brown silt loam, extending to a depth of 6 to 10 inches. When wet the surface appears dark brown to black in color. The subsoil is a yellowish-brown, heavy silt loam underlaid at about 24 inches by a light yellowish-
brown silty clay loam. The surface of the type is more rolling than that of the
typical soil, and erosion has been more extensive.

About half of the type is in its natural condition and utilized for pasture. The
areas which are cultivated are used for general farm crops, but the yields are
somewhat lower than on the typical soil.

This soil is chiefly in need of protection from erosion if it is to be cultivated, and
wherever gullies occur some method should be followed for their control. The type
will respond to applications of farm manure and liberal additions of this fertilizing
material are recommended. The use of a phosphate fertilizer will prove of value,
and tests of superphosphate are recommended. The use of lime is necessary for
the best growth of legumes and may prove of value also for other general farm
crops.

GRUNDY Silt Loam (64)

The Grundy silt loam is the second largest loess type and the fourth most
extensively developed soil type in the county. It covers 11.1 percent of the total
area. With the exception of a few small isolated areas and one rather extensive
development northwest of Ackworth in the northern part of the county, this type
is found only in the eight southern townships. The most extensive areas occur in
the southeastern townships in the vicinity of Milo and Liberty Center in Otter,
Belmont, Liberty and Whitebreast Townships.

The surface soil of the Grundy silt loam is a very dark grayish-brown silt loam
to a depth of 10 or 12 inches. The upper subsoil below this point and extending
for 6 or 8 inches is dark grayish-brown in color with some rusty brown and gray
mottlings. The texture is somewhat heavier than that of the surface soil. Below
18 or 20 inches and continuing for 6 or 8 inches is a dark grayish-brown or slate-
colored, heavy, plastic silty clay. This layer grades into a mottled gray, rusty
brown and yellow silty clay mottled with bright yellow splotches and iron stains.
In many places this layer is 10 or 12 inches thick. The substratum to a depth of
about 5 feet is a drab to yellowish-gray silt loam. The parent material
consists of a gray, structureless, heavy silt loam mottled with dark brown and yellow.

There are variations in the thickness of the
surface soil in different areas, and the color
of the upper subsoil varies somewhat in the
different parts of the county. The transition
from the Grundy silt loam to the Muscatine
is gradual, and the boundary lines are fre-
quently placed quite arbitrarily. In topography
the type is flat to gently undulating, and drain-
age is usually not adequate.

About 95 percent of the type is under cul-
tivation, and general farm crops are grown.
The only tree growth is a few willows along
old fence rows. Corn yields average between
37 and 40 bushels per acre, altho yields as high
WARREN COUNTY SOILS  

as 80 or 90 bushels have been reported under favorable conditions. Wheat yields from 18 to 25 bushels per acre, oats from 40 to 55 bushels per acre and hay from 1½ to 2 tons per acre. Some barley and rye are grown and occasionally soybeans are produced. Alfalfa is raised on a few farms. Garden vegetables and small fruits are produced chiefly to supply the home needs.

The chief need of this soil is drainage. The installation of tile is required on many areas if satisfactory crop yields are to be secured. Applications of farm manure are of value and bring about large increases in crop yields. The use of lime is necessary as the type is acid. Applications of a phosphate fertilizer would undoubtedly prove profitable, and tests of rock phosphate and superphosphate are recommended.

MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the third largest loess soil and the fifth largest type in the county. It covers 5.9 percent of the total area. It is developed in all parts of the county, occurring mainly on the narrow, level or undulating divides between the streams. The largest development of the type is in the southwestern townships. The more continuous areas are found in the vicinity of Cool and Medford.

The surface soil of the Muscatine silt loam is a very dark brown, mellow, friable silt loam, extending to a depth of 18 or 20 inches. When wet the soil appears nearly black. The upper subsoil which is generally 8 or 10 inches in thickness consists of a yellowish-brown or brown silty clay loam faintly mottled with gray. The lower subsoil beginning at a depth of 28 or 30 inches and continuing to a depth of 45 or more inches consists of a mottled gray, rusty brown and yellowish-brown silty clay, containing iron stains and concretions. The substratum is a gray silty clay mottled with rusty brown and yellow.

In the flatter areas the surface soils are thicker, varying from 20 to 22 inches, and the mottlings at a depth of 3 feet are more pronounced. Where the surface is slightly rolling and some erosion has occurred, the color is slightly lighter than typical. In many places the transition between this soil and the Tama silt loam is very gradual, and the boundary lines are established quite arbitrarily. Included with the type are a few small areas of Tama silt loam and Grundy silt loam which are too small to show on the map. In topography the type is level to undulating and surface drainage is good.

Practically 90 percent of the type is under cultivation, corn, oats, wheat and hay being the chief crops grown. Corn yields from 35 to 41 bushels per acre, oats from 35 to 55 bushels per acre, wheat from 18 to 36 bushels per acre and hay from 1½ to 2 tons per acre. Barley, rye, buckwheat, sorghum and rape are minor crops. Some alfalfa is grown and excellent yields are secured. Blue grass grows well and affords excellent pasturage.
Many areas of this type are in need of drainage to be made most productive. Small applications of farm manure would be of value, especially on newly-drained areas. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly be desirable, and tests of rock phosphate and superphosphate are recommended.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type, covering 2.7 percent of the total area of the county. It occurs most extensively in the extreme northeastern corner of the county and south of Indianola in Otter and White Oak Townships, but small, isolated areas are found in all parts.

The surface soil of the Clinton silt loam is a light yellowish-gray, mellow silt loam having a pale ash-gray appearance and a floury feel when dry. It extends to a depth of 8 to 12 inches. When wet the soil is much darker and resembles the lighter colored areas of Tama silt loam. The upper subsoil is a fine, granular, pale yellowish or dull yellowish-brown, friable, heavy silt loam or silty clay loam. Below a depth of 20 to 24 inches the lower subsoil consists of a pale yellowish-brown or brownish-yellow, tough, compact, crumbly silty clay loam mottled with gray and containing some iron stains. The subsoil extends to a depth of 4 or 5 feet. Below this point the parent material is a light gray, yellowish-brown and rusty brown friable, heavy silt loam streaked with iron stains.

Variations occur in the thickness of the surface soil and in the color in different areas. The mottling at a depth of 3 feet is greater in some areas than in others. In wooded areas the surface soil to a depth of 2 or 3 inches is a light brown or light grayish-brown fine textured silt loam. Below this layer to a depth of 8 or 12 inches is a light grayish-yellow or pale grayish-yellow, floury silt loam. Along the Marion County line, just south of the Des Moines River bottoms are a few areas in which the soil is almost a very fine sandy loam, but on account of their small extent they are not separated.

In topography the Clinton silt loam is flat to gently rolling and drainage is good. Erosion occurs to some extent, especially on the more rolling areas. The type is found mostly on the tops of ridges and narrow divides just back from the rough broken land.

About 80 percent of the type is under cultivation and used for pasture land. The wooded areas support a tree growth consisting mainly of elm, hickory, black oak, white oak and aspen. Corn, oats, timothy and clover, barley and rye are the chief crops grown. The yields are somewhat lower than those obtained on the Tama silt loam.

This type is low in organic matter and is particularly in need of applications of farm manure or the turning under of leguminous crops as green manures to make it more productive. It is acid in reaction and the use of
lime is essential not only for the growth of legumes but for the best yields of general farm crops. The use of a phosphate fertilizer would undoubtedly be desirable, and tests of superphosphate are recommended. In the rougher areas care should be taken to protect the soil from the injurious action of erosion.

**Terrace Soils**

There are eight terrace soils, classified in the Bremer, Waukesha, Judson, Calhoun and Jackson series. Together they cover 3 percent of the total area.

**BREMER SILT LOAM (88)**

The Bremer silt loam is the largest of the terrace soils but is limited in area, covering only 1.6 percent of the total area of the county. It occurs on the terraces of all the rivers and larger creeks being developed most extensively in the vicinity of Carlisle west of Summerset, and in the northern part of Allen Township.

The surface soil of the Bremer silt loam is a very dark brown or black mellow silt loam extending to a depth of 16 or 18 inches. The upper subsoil is a dark brown to a dark grayish-brown, heavy silt loam or silty clay loam faintly mottled with gray. The lower subsoil below 24 to 28 inches is a dark grayish-brown silty clay loam or silty clay mottled with rusty brown, bluish-gray and yellowish-brown. At the lower depths there are more mottlings and iron concretions are numerous.

The soil is fairly uniform in the various areas. The surface soils naturally vary somewhat in texture and thickness but these variations are of little significance. Along the outer edges of the areas adjacent to the Shelby loam, the surface soil contains more sand which has been washed down from the higher lands. There are some small areas which resemble a loam and some a silty clay loam in texture but these areas are too small to separate on the map.

The surface of the type is flat or very gently sloping toward the streams. The soil usually occupies a position 2 or 3 feet above the first bottoms, but frequently the boundary line between the type and the bottomland soils is placed rather arbitrarily. Drainage of the soil is very apt to be poor.

About 80 percent of the Bremer silt loam is under cultivation. The remainder is in grass and is used for pasture. A few areas are wooded with willow, oak, cottonwood and elm. Corn, oats, wheat and hay are the principal crops. Corn yields from 38 to 45 bushels per acre, oats from 35 to 55 bushels per acre, wheat from 20 to 30 bushels per acre and hay from 1½ to 2 tons per acre.

Drainage is of great importance on this soil. All the areas should be tiled and ditched if the land is to be satisfactorily productive. Small applications of farm manure would be of value on newly drained areas, but large applications should not be made as they may cause small grain crops to lodge. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly
prove of value, and tests of rock phosphate and superphosphate are recommended.

WAUKEsha silt loam (75)

The Waukesha silt loam is the second largest terrace type, covering 0.8 percent of the total area of the county. It occurs on the terraces of the Des Moines, the North, the Middle and the South Rivers and some of the larger creeks, lying slightly higher than the associated Bremer silt loam. The larger areas occur near Wick, Lida and southeast of Clarkson.

The surface soil of the Waukesha silt loam is a dark grayish-brown or very dark grayish-brown, mellow, friable silt loam 16 or 18 inches in depth. When dry the soil is dark brown, and when wet it has a distinct black color. The subsoil is a yellowish-brown silty clay loam faintly mottled with gray, continuing to a depth of 4 feet or more without change. In some places the subsoils become more friable at the lower depths and grade into a yellowish-brown, loamy, fine sand at a depth of 3 or 4 feet. There are also some variations in the color and thickness of the surface soil in different areas.

In topography the Waukesha silt loam is level or gently sloping, except for the area at Wick where the surface is somewhat rolling. It lies above the level of ordinary overflow, having an elevation of 10 or 12 feet above the normal level of the rivers and 6 or 8 feet above that of the creeks. At Wick it occurs on a high terrace 20 or 25 feet above the lower terrace. Drainage is adequate.

Practically all of the soil is used for general farm crops or for pasture. Corn is the chief crop and occupies the largest acreage. Yields range from 38 to 45 bushels per acre. In some cases on the better areas, yields as high as 65 to 85 bushels per acre are secured. Wheat, oats, clover and timothy are also important crops.

This soil is naturally productive, but it will be benefited by applications of farm manure. Applications of lime are of value, especially for legumes. The use of a phosphate fertilizer would undoubtedly increase yields, and tests of rock phosphate and superphosphate are recommended.

Waukesha loam (60)

The Waukesha loam is a minor type, covering 0.1 percent of the total area. It is found only on the terraces of the Des Moines and the North Rivers. Except for one tract of about 40 acres lying just east of Carlisle, the soil occurs as small knolls scattered throughout areas of the Bremer silt loam.

The surface soil of the Waukesha loam is a dark grayish-brown or very dark grayish-brown, friable loam 15 to 18 inches in depth. The upper subsoil to a depth of 20 to 22 inches is a finely granular, brown or yellowish-brown loam. The lower subsoil is a yellowish-brown, fine sandy clay loam continuing to a depth of 38 inches, where it grades into a layer of yellowish, loamy, fine sand. In topography the
Waukesha loam is level or gently undulating, and drainage is well established. The greater part of this soil is under cultivation, and general farm crops are grown. Yields are usually slightly less than those obtained on the Waukesha silt loam. In dry seasons there is some injury to the crops as the soil is inclined to be drouthy.

The chief need of this soil is the addition of organic matter, and liberal additions of farm manure would prove of value. The turning under of leguminous crops as green manures would also help. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of rock phosphate and superphosphate are recommended.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor type covering 0.1 percent of the total area. It occurs only on the terraces of the Des Moines, the North, and the South Rivers in a position slightly lower than that of the adjoining Bremer silt loam and 1 or 2 feet higher than that of the Wabash silt loam. The largest area is approximately 2 1/2 miles northeast of Summerset. Three smaller areas occur in the vicinity of Carlisle.

The Bremer silty clay loam is a dark brown or almost black silty clay loam extending to a depth of 10 or 12 inches. The subsoil to a depth of 3 feet or more is a dark slate colored or dark brownish-gray, heavy, compact, silty clay with some iron stains and concretions. The surface of the soil is flat or very gently sloping. The natural drainage is poor.

The Bremer silty clay loam is of little agricultural importance, but it is all under cultivation and is farmed with the adjacent areas. Yields are lower than on the silt loam. The type is particularly in need of drainage if it is to be made more productive, and care must be exercised in plowing and cultivation to keep the soil in the best physical condition. Small applications of manure would be of value on newly drained areas, but large additions should not be made. The use of lime would be of value as the type is acid in reaction. A phosphate fertilizer would prove desirable, and tests of rock phosphate and superphosphate are recommended.

BREMER LOAM (12)

The Bremer loam is a minor type, covering
0.1 percent of the total area. It occurs only in four comparatively small areas east and northeast of Carlisle.

The surface soil of the Bremer loam is a very dark brown, friable loam. When wet the surface appears black in color. The upper subsoil is a grayish-brown silty clay loam which at a depth of 20 to 28 inches grades into a yellowish-brown, gray and rusty-brown heavier silt loam.

In the higher areas the surface soils are slightly lighter in color, and there is more mottling with yellow in the lower subsoil. Along the Polk County line in the extreme northeastern corner of Allen Township, some grit is found in the lower part of the subsoil. Within areas of this soil are patches of Bremer silt loam and Bremer silty clay loam which are too small to show on the map.

Practically all of the Bremer loam is under cultivation, and yields of general farm crops are much the same as on the silt loam. The treatments desirable on this type are also similar. It is in need of drainage in many cases, and small amounts of farm manure would be of value on newly drained areas. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly help, and tests of rock phosphate and superphosphate are urged.

JUDSON LOAM (190)

The Judson loam is a minor type, covering 0.1 percent of the county. It occurs in small isolated areas on the terraces of the Middle River and Coal Creek. It lies slightly higher than the adjoining Waukesha silt loam and is 2 or 3 feet above the level of the first bottoms.

The surface soil of the Judson loam consists of a dark brown or dark grayish-brown, friable loam 16 to 18 inches in depth. The subsoil to a depth of 3 feet or more is very similar except that the color becomes somewhat more yellowish with depth. Cultivated areas are quite black in color at the surface when wet. There is some slight variation in the color and texture of the soil. Small areas of the Judson fine sandy loam are included, owing to their small extent. These areas are found in Sections 14 and 73 of Jefferson Township and in Section 15 of Allen Township. Small areas of the Judson silt loam found in Sections 35 and 36 of Richland Township are combined with the type. The surface soil of the type is flat or very gently sloping and drainage is good.

Practically all of the Judson loam is under cultivation or in pasture. There is a sparse growth of wild grasses and willows on the small, uncultivated areas. Corn is the chief crop grown and yields are lower than on the adjacent soils. The type is in need of organic matter, and liberal additions of farm manure and the turning under of leguminous crops as green manures would be of value. The soil is acid and in need of lime. The use of a phosphate fertilizer would prove of value, and tests of superphosphate are recommended.
CALHOUN SILT LOAM (42)

The Calhoun silt loam is a minor type, covering 0.1 percent of the total area. It occurs on the terraces along the North, the Middle and the South Rivers and White-breast and Otter Creeks.

The surface soil of the Calhoun silt loam is a light brown or light brownish-gray, floury silt loam extending to a depth of 10 or 12 inches. The subsurface is a gray, distinctly floury layer, varying from 6 to 10 inches in thickness. The gray color is tinged with yellow and appears pale yellowish or yellowish-gray. The subsoil is a grayish-yellow, compact silty clay loam mottled with gray, rusty brown and yellowish-brown, extending to a depth of 30 or 33 inches. Below this point the substratum is a heavier textured, more strongly mottled material.

Variations from the typical soil are common. In the area in Section 9 in Otter Township, the gray layer is less evident and faint iron stains occur. Here the color of the surface soil is variable and considerable material has been washed in from the darker colored, adjacent uplands. Where the soil occurs in association with the Carrington fine sand as in Section 22 of Richland Township the outer edges of the terrace are loamy.

In topography the soil is level or gently sloping. It occurs on terraces 3 or 4 feet above the first bottoms. Some of the areas are fairly well drained, but the natural drainage of the type is poor and in most instances tiling is the first treatment needed to make the soil properly productive.

Practically all of the soil is in cultivation to corn, oats and clover. Some winter wheat is grown. The yields are lower than on the adjacent Grundy silt loam and Tama silt loam upland.

The chief need of the soil is drainage. It will be benefited also by liberal applications of manure or the turning under of legumes as green manures. It is acid and will be benefited by liming. The use of a phosphate fertilizer would be desirable, and tests of superphosphate are recommended.

JACKSON SILT LOAM (81)

The Jackson silt loam is a minor type, covering 0.1 percent of the total area. It occurs only in small isolated patches on the terraces of the Des Moines and the South Rivers.

The surface soil of the Jackson silt loam is a gray or brownish-gray, friable silt loam, extending to a depth of 8 or 12 inches. The subsurface soil is a brown or yellowish-brown, heavy loam to clay.
friable silt loam or loam from 8 to 12 inches in thickness. The subsoil at a depth of 20 to 24 inches is a pale yellowish, heavy silt loam or friable clay loam, continuing to a depth of 3 or 4 feet with little change other than an increased number of brown mottlings and a few iron stains. Many small areas of the loam and fine sandy loam too small to show on the map have been included with the type.

The surface of the soil is level to slightly hilly or ridgy, and drainage is good. The soil occurs on terraces 1 1/2 or 2 feet above the first bottoms and 12 or 15 feet above the normal level of the streams. It is, therefore, well above overflow.

About 95 percent of the soil is under cultivation, the remainder being covered by wild grasses and a scrawny growth of willow. Corn is the chief crop but some wheat and clover are grown. Corn yields from 32 to 36 bushels per acre, wheat from 12 to 15 bushels per acre and hay from 1 to 1 1/2 tons per acre.

This soil is particularly in need of organic matter, and liberal applications of farm manure will be of value. The turning under of leguminous crops as green manure would also help. The type is acid and in need of lime. The use of a phosphate fertilizer would be desirable, and tests of superphosphate are recommended.

Swamp and Bottomland Soils

There are eight swamp and bottomland soils, classified in the Wabash, Sarpy and Genesee series. Together they cover 14.8 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest bottomland soil and the third largest type in the county, covering 11.6 percent of the total area. It occurs on the bottomlands along practically all of the larger rivers and creeks. It is most extensively developed along the North, the South and the Middle Rivers where many areas range from 1/4 to 1 1/2 miles in width. Along the creeks the bands are narrower, and the strips along the intermittent streams are rarely more than 350 feet in width.

The surface soil of the Wabash silt loam is a dark grayish-brown or very dark grayish-brown, mellow, even-textured silt loam, extending to a depth of 14 to 16 inches. When wet the surface soil appears intensely black in color. The subsoil is predominantly a dark slate colored or very dark grayish-brown silty clay loam or silty clay, grading at a depth of 28 or 30 inches into a layer mottled with iron stains and containing iron concretions.

There are many variations from the typical soil. South of Lacona along Mill Branch are a few areas that differ from the typical in that the soil to a depth of 2 or 3 inches is a light brown or grayish in color and the subsoil is not so heavy. Similar areas are mapped in Section 26 of Richland Township. Along Clanton Creek half a mile southwest of Wick, the soil to a depth of 12 or 15 inches is a brown, mellow loam, underlaid by a dark brown silty clay loam which changes
abruptly at 18 or 20 inches into a black silty clay. Where the Wabash silt loam is associated with the silty clay loam and the silty clay, the transition from one type to the other is gradual, and the boundaries are usually placed quite arbitrarily.

The surface soil of the Wabash silt loam is level or gently sloping toward the streams. It lies 10 or 12 feet above the normal level of the rivers and four or five feet above the level of the creeks. Since many of the rivers and larger streams have been straightened and deepened, the land is rarely flooded and water stands only on the low areas during flood periods. Along the smaller creeks overflows are more common. In a few places natural drainage is sufficient, but generally tiling is necessary for the best crop growth on this type.

About 70 to 80 percent of the soil is under cultivation or in pasture. The wooded areas afford a tree growth which consists chiefly of cottonwood, elm, ash, oak, hickory and some willow. Average yields of corn amount to 40 to 45 bushels per acre. Winter wheat yields from 18 to 28 bushels per acre, oats from 40 to 60 bushels per acre and hay from 1½ to 2 tons per acre.

The soil is chiefly in need of drainage to be made more productive, and in some cases it should be protected from overflow also. Small applications of farm manure would prove of value on newly drained areas. Applications of lime are needed as the soil is acid. The use of a phosphate fertilizer would prove of value, and tests of superphosphate are recommended.

**WABASH SILTY CLAY LOAM (48)**

The Wabash silty clay loam is the second largest bottomland soil but is relatively small in area, covering only 2.1 percent of the county. It occurs along practically all of the rivers and larger creeks, the largest areas being found in the northern half of the county along the North River and the Middle River.

The surface soil of the Wabash silty clay loam is a dark grayish-brown or very dark grayish-brown silty clay loam extending to a depth of 12 to 16 inches. The subsoil is a dark slate colored or dark brownish-gray silty clay loam slightly mottled with rusty brown. In some areas the surface soil is almost flat and is heavier textured than typical, while in other areas the surface layer is a medium dark brown in color. In many places the boundary lines between the type and the Wabash silt loam are established rather arbitrarily. The soil is found on the bottomland and, therefore, is subject to overflow. Drainage is poor.

About 55 percent of the type is still in its natural condition and is utilized for pasture. Usually it supports a heavy growth of slough grass, and a few areas are timbered with oak, hickory, elm, cottonwood and willow. Corn, wheat, oats and timothy are grown on the cultivated areas. The yields are usually somewhat lower than on the Wabash silt loam, owing to poor drainage and heavy texture.
Drainage is the treatment most needed by this soil, and it is essential if the type is to be cultivated. Care in plowing and cultivation is necessary if the soil is to be kept in the best physical condition. Small amounts of farm manure would be of value on newly drained areas to stimulate the production of available plant food. The type is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly prove of value and tests of superphosphate and rock phosphate are recommended.

**WABASH SILTY CLAY (27)**

The Wabash silty clay is a minor type, covering 0.3 percent of the total area. It occurs on the bottoms of the South River, the Middle River, and Otter Creek. The more extensive areas are found near Conger and on the bottoms of the South River east of Hartford.

The surface soil of the Wabash silty clay is a very dark grayish-brown or almost black silty clay or clay. The subsoil is a grayish-brown or dark slate colored silty clay or clay mottled with iron stains. Below 24 to 28 inches the subsoil is somewhat heavier and is more mottled with rusty brown and iron stains. A few areas of Wabash silty clay loam and Wabash silt loam are included as they are too small to show on the map.

The type is found on the outer edges of the bottoms in somewhat depressed or basin-like areas surrounded by the Wabash silt loam. The natural drainage is poor. Overflows are rare since the streams have been ditched and straightened, but water often stands on the surface.

A small part of the Wabash silty clay loam is in cultivation, some corn and winter wheat being grown. The yields are very similar to those secured on the Wabash silty clay loam and are usually lower than the yields on the silt loam. The greater part of the type is in its natural condition and is utilized for pasture. It supports a rank growth of slough grass and a few scattered willow, elm and oak trees.

This type is primarily in need of drainage if it is to be cultivated. Care in plowing and cultivation are necessary if a good seed bed is to be prepared. Small applications of manure are of value on newly drained areas. Lime is needed to neutralize the acidity of the soil. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of rock phosphate and superphosphate are urged.
SARPY SILT LOAM (89)

The Sarpy silt loam is a minor type, covering 0.3 percent of the total area. It occurs on the bottomland along the Des Moines River in Richland Township.

The surface soil of the Sarpy silt loam is a light grayish-brown, yellow or pale grayish-yellow, mellow silt loam, 8 or 10 inches thick. The upper subsoil is a pale yellow or brown, very fine sandy loam, which, at a depth of 30 to 33 inches grades into the lower subsoil of fine or medium fine sand. In some places the fine sand in the subsoil shows some lime content. In a few areas the upper subsoil is somewhat darker than typical, ranging from a light brown to a brownish-gray. The depth at which the sandy layer is encountered is variable. When wet the surface soil appears much darker than typical. The soil occurs on the bottomlands 7 to 10 feet above the normal water level, and it is subject to overflow. Drainage is adequate.

About 50 percent of the Sarpy silt loam is in the original cover of wild grasses, willow, oak and cottonwood and is used for pasture. Corn, oats, wheat and clover are grown on the cultivated areas. Corn yields from 35 to 40 bushels per acre, oats from 30 to 45 bushels per acre, wheat from 15 to 22 bushels per acre and clover from 1 to 2 tons per acre.

The Sarpy silt loam needs to be protected from overflow if it is to be successfully cultivated. Applications of farm manure would prove of value, and the turning under of leguminous crops as green manures would also improve the fertility of the soil. It is acid in reaction and in need of lime. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

SARPY VERY FINE SANDY LOAM (28)

The Sarpy very fine sandy loam is a minor type, covering 0.2 percent of the total area. It occurs on the bottomlands along the Des Moines River in Richland Township, being associated with the Sarpy silt loam and the Sarpy fine sandy loam.

The surface soil of the Sarpy very fine sandy loam is a light yellowish-brown or light grayish-brown, mellow, very fine sandy loam, 16 or 18 inches thick. The upper subsoil is a light brownish-yellow or grayish-yellow, very fine sandy loam which at a depth of 28 or 32 inches grades into a yellowish fine sand. Variations in the color and the texture of the surface soil are found. The boundary lines between the type, the Sarpy silt loam and Sarpy fine sandy loam are placed rather arbitrarily. The fine sand subsoil frequently contains small amounts of lime. The type is level in topography and is subject to overflow. The soil is inclined to be dry and rocky.

Most of the soil is under cultivation, corn being the chief crop grown. Some wheat and oats are also produced. Yields of crops are low. In its native condition the land supports...
a rather scant growth of blue grass and wild grasses. There are a few wooded areas on which the tree growth consists of oak, elm, ash, cottonwood and willow.

This soil should be protected from overflow if it is to be made satisfactorily productive. Liberal applications of farm manure will prove of value, and the turning under of leguminous crops as green manures will provide better conditions for crop growth. The surface soil is acid and applications of lime are necessary. The use of a phosphate fertilizer would be desirable, and applications of superphosphate are recommended. If truck crops are grown the use of a complete fertilizer might be very profitable. The type would be well adapted to the production of melons and all truck crops.

**WABASH LOAM (49)**

The Wabash loam is a minor type, covering 0.1 percent of the total area. It occurs in a number of small areas, the largest being found southeast of Hartford on the bottoms of the South River. Two small areas occur north of Carlisle along the Polk County line.

The surface soil of the Wabash loam is a dark grayish-brown, mellow loam, extending to a depth of 15 or 17 inches. The subsoil is a dark brown loam which at a depth of 22 or 24 inches grades into a brownish, or dark grayish-brown, friable clay loam faintly mottled with rusty brown. At a depth of 3 feet some fine and coarse sand occur. There are variations in the color and texture of the soil in different areas. The surface of the type is level and the soil is subject to overflow. Drainage is usually adequate.

About 80 percent of the soil is under cultivation, corn being the chief crop grown. Forty to 45 bushels per acre are the yields usually secured with this crop. Some wheat and oats are grown and fair yields are secured. The wooded areas support a growth of willow, oak, elm, hickory, cottonwood and locust and are used mainly for pasture.

This soil needs protection from overflow if crop yields are to be satisfactory. Farm manure will prove of value. The soil is acid and in need of lime. The use of a phosphate fertilizer would be desirable, and tests of superphosphate and rock phosphate are recommended.

**GENESEE SILT LOAM (71)**

The Genesee silt loam is a minor type, covering 0.1 percent of the total area. It occurs in a few small areas; two are found on the first
bottoms of the Des Moines River near Ford, two occur along the South River and the largest area is found along Coal Creek.

The surface soil of the Genesee silt loam is a grayish-yellow or light grayish-brown silt loam containing a high percentage of very fine sand. The subsoil below 10 to 14 inches is a pale yellowish silt loam or very fine sandy loam. There are some variations in the soil in the different areas. In Section 26 of Richland Township the surface soil is a gray, friable loam 10 or 12 inches thick, and the subsoil is composed of alternate layers of a pale yellowish silt and very fine sand. The area east of Ackworth is very similar. Along Coal Creek, where the soil is associated with the Wabash silt loam, the surface is often much darker than typical and the boundary lines between the two types are located rather arbitrarily.

The topography of the type is level or very slightly hillocky, and areas occur 8 or 10 feet above the normal level of the rivers and 4 or 5 feet above the creeks. Drainage is fair in some cases but the soil is apt to be poorly drained. It is subject to overflow.

Most of the type is still in its natural condition and is used for pasture. The areas adjoining the Wabash silt loam are under cultivation and corn and oats are grown. The yields are lower than on the Wabash silt loam.

The type should be protected from overflow if it is to be cultivated. It would then be benefited by drainage. Liberal applications of farm manure would prove of value, and the turning under of leguminous crops as green manures would also improve the fertility conditions. The type is acid and in need of lime. The use of a phosphate fertilizer would be desirable, and superphosphate is recommended.

SARPY FINE SANDY LOAM (102)

The Sarpy fine sandy loam is a minor type, covering 0.1 percent of the total area. It occurs on the bottomlands of the Des Moines River in Richland Township in association with the Sarpy silt loam and the Sarpy very fine sandy loam.

The surface soil of the Sarpy fine sandy loam is a light brown or light grayish-brown fine sandy loam 10 or 12 inches thick. The upper subsoil is a brown or yellowish-brown, heavy fine sandy loam or very fine sandy loam. The lower subsoil at a depth of 28 or 30 inches is a fine sand or very fine sand. At a depth of 3 feet the sand usually contains some lime. In some areas the subsoil is darker in color than typical. In Section 14 of Richland Township an area is included which consists of a grayish-brown, fine sandy loam 10 or 12 inches thick underlain by a dark brown silt loam mottled with gray and some iron stains.

In topography the type is level to uneven. It often consists of low ridges and depressions. It is found about 12 or 14 feet above the normal water level. Drainage is excessive. The type, however, is subject to overflow.

About 85 percent of this soil is in its natural condition and is used for pasture. It supports
a scant growth of wild grasses and some elm, oak and willow trees. Corn is grown on the cultivated areas, but the yields are low. Truck crops, especially watermelons and cantaloupes, might be grown profitably on this type. The soil should be protected from overflow if it is to be cultivated. Liberal applications of farm manure will prove of value. The turning under of leguminous crops as green manures would also increase the fertility of the type. Additions of lime are necessary as the surface soil is acid. The use of a phosphate fertilizer would undoubtedly prove of value and applications of superphosphate are recommended. When truck crops are grown the use of a complete commercial fertilizer might prove of value.

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<tr>
<th>SAPI FINE SANDY LOAM</th>
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<td>Yellow fine sand</td>
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APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

Following the survey, systems of soil management which should be adopted in the various
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.

**PLANT FOOD IN SOILS**

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

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

**THE “SOIL DERIVED” ELEMENTS**

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

**AVAILABLE AND UNAVAILABLE PLANT FOOD**

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

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

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

**REMOVAL OF PLANT FOOD BY CROPS**

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

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

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

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

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Plant Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn, crop</td>
<td>--------</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>--------</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>--------</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>--------</td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>--------</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

Phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

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

### REMOVAL FROM IOWA SOILS

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

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

### PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being...
obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

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

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

CULTIVATION AND DRAINAGE

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

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

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

THE ROTATION OF CROPS

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

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

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

MANURING

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

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

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

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

**THE USE OF PHOSPHORUS**

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

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

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

**LIMING**

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.

**SOIL AREAS IN IOWA**

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

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large

![Map showing the principal soil areas in Iowa.](image)
areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, 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, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical 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
1. All partially destroyed or decomposed vegetable and animal material.
   - Stones—over 32 mm.*
   - Gravel—32—2.0 mm.
   - Very coarse sand—2.0—1.0 mm.
Inorganic matter
   - 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.

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

Sandy Clay Loams—20 percent silt and small amounts of clay up to 30 percent.

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

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

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

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

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

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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