Soil Survey of Iowa, Report No. 72—Calhoun County Soils

P. E. Brown
Iowa State College

T. H. Benton
Iowa State College

W. J. Leighty
Iowa State College

H. R. Meldrum
Iowa State College

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SOIL SURVEY OF IOWA
CALHOUN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Farm Crops and Soils Section
Soils Subsection

Soil Survey Report No. 72
June, 1933
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

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SOIL SURVEY OF IOWA

Report No. 72—CALHOUN COUNTY SOILS

By P. E. Brown, T. H. Benton, W. J. Leighty and H. R. Meldrum

IOWA AGRICULTURAL EXPERIMENT STATION
R. M. Hughes, Acting Director
Ames, Iowa
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CALHOUN COUNTY SOILS

BY P. E. BROWN, T. H. BENTON, W. J. LEIGHTY AND H. R. MELDRUM

Calhoun County is located in northwestern Iowa in the fourth tier of counties south of Minnesota and in the fourth tier east of the Missouri River. It is all in the Wisconsin drift soil area and hence the soils are all of glacial origin.

The total area of the county is 568 square miles, or 363,520 acres. Of this area 351,133 acres, or 96.6 percent, are in farm land. The total number of farms is 1,959, and the average size of the farms is 179 acres. Owners operate 30.2 percent of the total farm land and renters the remaining 69.8 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1931 show the utilization of the farm land in the county:

<table>
<thead>
<tr>
<th>Description</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage in general farm crops</td>
<td>285,666</td>
</tr>
<tr>
<td>Acreage in farm buildings, public highways and feedlots</td>
<td>18,866</td>
</tr>
<tr>
<td>Acreage in pasture</td>
<td>49,675</td>
</tr>
<tr>
<td>Acreage in waste land not utilized for any purpose</td>
<td>1,084</td>
</tr>
<tr>
<td>Acreage in farm woodlots used for timber only</td>
<td>15</td>
</tr>
<tr>
<td>Acreage in crop land lying idle</td>
<td>15</td>
</tr>
<tr>
<td>Acreage in crops not otherwise listed</td>
<td>17</td>
</tr>
</tbody>
</table>

THE TYPE OF AGRICULTURE IN CALHOUN COUNTY

The type of agriculture practiced in Calhoun County at present consists of a system of what may be called general farming, with the production of corn, oats and other grain crops as "cash crops" and the raising and feeding of hogs and cattle. There is also some dairying in the county. The farm income is derived mainly from the sale of corn, oats and hogs. On a few farms in each township the feeding of cattle is a regular part of the farm operations, but in general the sale of hogs provides the chief source of income. The sale of milk and cream provides some income on many farms. Cream buying stations are maintained in every town by the large creamery companies and packing houses. Poultry production is important as an aid to the farm income and the industry is receiving more and more attention as its value becomes evident. The most important special crop is popcorn. Some sweet corn is grown to supply the canning factory at Rockwell City. These crops add to the income on some farms.

There is a rather large acreage in waste land, not utilized for any purpose, and some method of treatment should be adopted for the reclamation of these areas. General recommendations cannot be given for the handling of such land as the causes for unproductivity are widely different and treatments of value in one area might be of no importance under other conditions. Special treatments which may be desirable under individual soil conditions will be suggested later.

1 See Soil Survey of Calhoun County, Iowa, by W. E. Tharp, of the Bureau of Chemistry and Soils, and T. H. Benton and W. J. Leighty, of the Iowa Agricultural Experiment Station.
in this report. Advice regarding soil treatments which would be most effective in special cases, may be secured from the Soils Subsection of the Iowa Agricultural Experiment Station, upon request.

THE FARMS CROPS GROWN IN CALHOUN COUNTY

The general farm crops grown in Calhoun County in the order of their importance are corn, oats, alfalfa, hay, popcorn, barley, potatoes, rye, wheat and sweet clover. The acreage, yield and value of these crops in 1931 are given in Table I.

**TABLE I. ACREAGE, YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN CALHOUN COUNTY, IOWA**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreage</th>
<th>Percent of total farm land of county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price**</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>153,821</td>
<td>43.81</td>
<td>33.0</td>
<td>5,076,093</td>
<td>$ 0.37</td>
<td>$1,878,154</td>
</tr>
<tr>
<td>Oats</td>
<td>113,639</td>
<td>32.36</td>
<td>35.9</td>
<td>4,084,537</td>
<td>$0.20</td>
<td>816,907</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>180</td>
<td>0.05</td>
<td>21.3</td>
<td>3,840</td>
<td>$0.48</td>
<td>1,543</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>78</td>
<td>0.02</td>
<td>16.1</td>
<td>1,258</td>
<td>$0.54</td>
<td>687</td>
</tr>
<tr>
<td>Barley</td>
<td>958</td>
<td>0.27</td>
<td>28.9</td>
<td>27,095</td>
<td>$0.32</td>
<td>8,670</td>
</tr>
<tr>
<td>Rye</td>
<td>307</td>
<td>0.09</td>
<td>24.3</td>
<td>7,438</td>
<td>$0.36</td>
<td>2,685</td>
</tr>
<tr>
<td>Clover hay**</td>
<td>777</td>
<td>0.22</td>
<td>1.05</td>
<td>816</td>
<td>10.48</td>
<td>8,552</td>
</tr>
<tr>
<td>Timothy hay</td>
<td>1,800</td>
<td>0.51</td>
<td>0.96</td>
<td>1,726</td>
<td>10.48</td>
<td>18,088</td>
</tr>
<tr>
<td>Clover and timothy hay (mixed)</td>
<td>1,950</td>
<td>0.55</td>
<td>0.97</td>
<td>1,892</td>
<td>10.48</td>
<td>18,328</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>6,216</td>
<td>1.77</td>
<td>1.96</td>
<td>12,183</td>
<td>10.48</td>
<td>127,578</td>
</tr>
<tr>
<td>All other tame hay</td>
<td>346</td>
<td>0.10</td>
<td>0.92</td>
<td>318</td>
<td>10.48</td>
<td>3,333</td>
</tr>
<tr>
<td>Wild hay</td>
<td>558</td>
<td>0.15</td>
<td>1.36</td>
<td>718</td>
<td>7.00</td>
<td>5,026</td>
</tr>
<tr>
<td>Soybeans grown with other crops</td>
<td>284</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans grown alone</td>
<td>103</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans grown for seed</td>
<td>20</td>
<td>0.01</td>
<td>12.5</td>
<td>250</td>
<td>0.60</td>
<td>150</td>
</tr>
<tr>
<td>Potatoes</td>
<td>166</td>
<td>0.05</td>
<td>66.0</td>
<td>10,956</td>
<td>0.60</td>
<td>6,574</td>
</tr>
<tr>
<td>Popcorn</td>
<td>503</td>
<td>0.15</td>
<td>17.6</td>
<td>8,856</td>
<td>2.10</td>
<td>18,598</td>
</tr>
<tr>
<td>Timothy seed</td>
<td>34</td>
<td>0.01</td>
<td>3.6</td>
<td>122</td>
<td>2.86</td>
<td>349</td>
</tr>
<tr>
<td>Clover seed**</td>
<td>17</td>
<td>0.01</td>
<td>0.53</td>
<td>9</td>
<td>10.66</td>
<td>96</td>
</tr>
<tr>
<td>Sweet clover seed</td>
<td>58</td>
<td>0.11</td>
<td>0.60</td>
<td>350</td>
<td>3.00</td>
<td>1,050</td>
</tr>
<tr>
<td>Sweet clover****</td>
<td>4,263</td>
<td>1.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Iowa Yearbook of Agriculture, 1931.*

**Average county farm price for corn, oats, winter wheat, spring wheat, barley, rye, all tame hay (including alfalfa), popcorn, timothy seed and clover seed. Average state farm price for soybeans, wild hay and potatoes. Sweet clover seed price estimated.

***Sweet clover not included.

****All varieties for all purposes.

Corn is the most important crop in the county, both in acreage and value. In 1931, it was grown on 43.81 percent of the total farm land. The average yield in that year was 33 bushels per acre. About 95 percent of the corn crop is husked and cribbed, less than 1 percent fills the silos, and thousands of acres are hogged-down. Most of the corn delivered to the elevators is shelled on the farm. About three-fifths of the corn is sold direct from the farm.

The second crop in acreage and value is oats. In 1931 oats were grown on 32.36 percent of the total farm land with average yields of 35.9 bushels per acre. The principal varieties of oats grown are Iowa 103 and Green Russian. More than three-fifths of the oats crop is marketed directly from the farms.

Alfalfa is the third crop in acreage and value in the county. In 1931 it was grown on 1.77 percent of the total farm land with average yields of 1.96 tons per acre. Under the most favorable conditions much larger yields may be ob-
Hay is the third crop in value in the county. It includes clover and timothy mixed, clover alone, timothy alone and some wild hay. The mixture of clover and timothy is grown on 0.55 percent of the total farm land and average yields of the crop in 1931 amounted to 0.97 ton per acre. Clover alone was grown on 0.22 percent of the farm land in 1931, and the yield was 1.05 tons per acre on the average. Timothy alone was grown on 0.51 percent of the farm land in 1931 and yielded 0.96 ton per acre. Some clover was grown for seed and some timothy was also grown for seed. Wild hay was grown on 0.15 percent of the farm land with yields of 1.36 tons per acre in 1931. Sweet clover was grown for all purposes on 1.21 percent of the total farm land in 1931, and average yields were large. Some soybeans are grown. The hay produced is all utilized on the farms, and hay is often purchased by operators of the large farms.

Popcorn is a special crop, grown in 1931 on 503 acres with an average yield of 17.6 bushels per acre. It is grown chiefly in the southwest townships. There are several hundred acres in sweet corn which is grown for the canning factory at Rockwell City.

Barley and rye are grown on limited areas, but they are not important crops. Buckwheat, sorghum, cane and millet are largely catch crops and are not grown extensively. Very little wheat is grown. Potatoes are produced on most farms to supply the home demand. Average yields of 66 bushels per acre were reported in 1931.

THE LIVESTOCK INDUSTRY IN CALHOUN COUNTY

The chief livestock industries in Calhoun County in the order of their importance are the raising of hogs, the feeding of beef cattle, dairying, the raising of horses and mules and to a small extent, the raising and feeding of sheep.

Hog raising is practiced on all farms, and the sale of hogs provides the chief source of income in many cases. The leading breeds include Duroc Jersey, Poland China, Chester White, Spotted Poland China and Tamworth. Some feeders are shipped in from Omaha and Sioux City in the fall and are fed and sold. The hogs are usually disposed of through the cooperative livestock shipping associations.

The raising and feeding of beef cattle is an important industry. The most common breeds are the Hereford and Shorthorn. There are a few Angus. Some farmers ship in one or two carloads of feeders from the western range, and occasionally as many as 5 or 6 carloads each year. These animals are fed through the winter and marketed after 60 to 90 days. A few purebred cattle are raised for sale.

Dairying is rather generally practiced but usually as a sideline. From one to three milk cows are kept on most farms, and in a few cases larger herds are maintained. The milk and cream are sold at local cream buying stations in the different towns. The dairy cows are generally of the Holstein, Jersey and Guernsey breeds.

A few farmers raise some horses and mules to maintain their own supply of work stock. Few animals are sold. The sheep industry is relatively unimpor-
tant. Sometimes a carload of western sheep is shipped in for feeding, but only a few farmers raise sheep.

The sale of poultry and poultry products adds considerable income on most farms, and while little attention has been paid to the industry in the past, it is receiving more consideration now as its value is being recognized. The chickens and eggs are generally sold to the produce houses.

THE FERTILITY SITUATION IN CALHOUN COUNTY

On the well-drained upland soils in Calhoun County, the yields of general farm crops are usually satisfactory. Large increases in crop yields may be secured, however, by the adoption of better methods of soil management than those in vogue at present.

The natural drainage system of the county is very poorly developed, but the system has been so extended and improved artificially that even the lowest lands do not retain water on the surface for any extended periods following heavy rains. The present combined system of natural and artificial drainage reaches every farm. Only in limited areas is there need for further attention to the drainage situation. Wherever drainage is not adequate, it should be made so. Areas of soil in the Webster, Fargo, Lamoure and Wabash series may need drainage, and the areas of muck may also require more adequate drainage.

Most of the soils in the county are acid in reaction, and therefore, in need of applications of limestone for the best growth of general farm crops. The Webster soils on the uplands, except the Webster silty clay loam, the Clarion soils on the uplands, and the Pierce, and Dickinson types are all acid, at least in the surface soils, and therefore in need of lime. The Sioux, O'Neill and Waukesha soils on the terraces and the Wabash soils on the bottomlands are also acid in the surface soil. All these types need liming, especially for the best growth of legumes such as sweet clover and alfalfa. Some of the types show lime in the lower soil layers. This is true of the steep phase Clarion loam and of some of the other types in certain areas although the particular samples analyzed and reported on later in this report do not show any lime in the subsoils. The Sioux soils, the Clarion loam and the Webster loam often contain some lime in the lower soil layers. But these soils should be tested to determine the lime needs of the surface soil, and lime should be applied if the most satisfactory crop yields are to be obtained, regardless of the lime content of the subsoil. It is very important that all the soils in the county, except the Webster silty clay loam, the Benoit loam, the Fargo clay, the Lamoure silty clay loam and the Cass fine sandy loam, be tested for acidity and need of lime. Some may show acidity in the surface soil. For the best crop yields and for the maintenance of the fertility of the soils the addition of limestone is necessary on all soils that show any acidity.

The supply of phosphorus in the soils of the county is rather low, and it seems certain that the amount of the element being changed into an available form is inadequate to supply the needs of crops even at present. The need for applications of phosphorus fertilizers will surely be evident in the near future even if they are not absolutely necessary now. There is evidence, however,
from experiments and the experiences of many farmers, that one or the other of the phosphorus carriers may be applied to the soils with profit. Whether rock phosphate or superphosphate should be employed can only be determined for individual conditions. In some tests rock phosphate has proved the better while in many other cases superphosphate has shown some superiority, especially from the economic standpoint. The results with the two phosphates seem to vary widely depending upon the particular conditions. Farmers are urged to test both materials under their own farm conditions and thus learn which will give the greater profit.

In general the soils of Calhoun County are well supplied with organic matter, and some of the types are very high in this constituent. The sandy soils, however, are rather low in organic matter and therefore in need of additions of some fertilizing material which will supply the deficiency. Those soils which are lighter in color are also low and need additions. The Webster and Clarion soils on the uplands, the Benoit, Waukesha and Fargo types on the terraces and the Lamoure and Wabash soils on the bottomlands are usually fairly well supplied. But the Clarion sandy loam, the Pierce and Dickinson types on the uplands, the Sioux loam and O'Neill loam on the terraces and the Cass soil on the bottomlands are low in organic matter and especially in need of additions. On all the soils, however, it is very important that the content of organic matter be kept up by regular additions, if the soils are not to become deficient. When heavily cropped and, in fact, when under cultivation at all, soils lose organic matter very rapidly through decomposition and leaching.

The proper preservation and application of all the farm manure produced on the farm will aid materially in building up and keeping up the supply of organic matter in soils. It has been found in many experiments and from general farm experience that applications of farm manure bring about large increases in the yields of crops. It is certainly one of the most profitable fertilizing materials which can be used. Larger applications may be made to the lighter colored, coarse textured types, but small applications will be of use also on the darker colored, richer soils.

Green manuring is a very important farm practice on the grain farm, where little or no farm manure is produced, in order to supply organic matter. It may also be desirable on livestock farms to supplement the use of farm manure. Leguminous crops should be used as green manures because of their superior value from the standpoint of supplying nitrogen to the soil as well as organic matter. The practice of green manuring may be of value on many of the farms in Calhoun County, for the soils especially deficient in organic matter and also to make up for any lack of farm manure. Crop residues also aid in keeping up the supply of organic matter in soils, and all residues should be utilized and not destroyed nor wasted.

The use of complete commercial fertilizers may be of value on some of the soils in the county for certain crops. In general, however, superphosphate will probably give quite as large crop increases, and as it is less costly the profit from it will be greater. The general use of complete fertilizers cannot be recommended, therefore. They may be tested on small areas in comparison with superphosphate and if found to be profitable, there is no objection to their use.
Commercial potassium fertilizers are of value on muck soils and on so-called “alkali” soils, but their use on normal soils cannot be recommended until tests have been carried out on small areas and the value of the treatment definitely proved. Ordinarily potassium fertilizers do not bring about profitable crop increases. There is no evidence available to show any value from the application of commercial nitrogenous fertilizers to the soils of this county. Such materials should not be used, therefore, until tests have been carried out on small areas and the particular fertilizer shown to be profitable. In general leguminous crops used as green manures will supply all the nitrogen to the land that is necessary, and green manuring is much cheaper than purchasing commercial nitrogen.

Erosion is not particularly significant in the county, but some soil washing occurs, and wherever it takes place some method should be adopted to prevent it and protect the soil. The Clarion loam and the Dickinson types may be eroded somewhat. From among the methods referred to later in this report, some means of protecting the soils from the injurious action may readily be taken and future difficulties avoided.
THE GEOLOGY OF CALHOUN COUNTY

It is not necessary to consider the geological history of Calhoun County, in any detail, as the rocks underlying the soil have been so deeply buried by the glacial deposits that they have no influence on the characteristics of the soils, and the glacial age is the only one which has exerted any appreciable influence.

At least two great glaciers swept over the county, in the glacial age, and they left behind great deposits of till or glacial drift on the surface of the land. The first of these glaciers was the Kansan, and the native rocks and areas of pre-Kansan sand and gravel which occurred in some sections were buried deeply by the deposit left by this glacier. Old hills were leveled and old valleys filled in with drift material. Glacial drift or till is the accumulation of materials gathered up by the glacier in its movement over the surface of the land, and hence it is extremely variable in composition and contains sand, gravel and boulders. The original Kansan drift was typically a very stiff and impervious blue clay, containing many pebbles and boulders. Upon weathering the material changes to a reddish-brown or yellow in color. The depth of the deposit is variable, ranging from a few feet in some areas to over a hundred in others. None of the soil types occurring in the county at the present time are derived from the Kansan till, but there has been some effect on the subsoil of some types, particularly the Dickinson and Pierce soils.

The second glacier, the Wisconsin, moved over the area at a much later date, and it left behind a deposit varying widely in thickness. In the lower layers of this drift material in old valleys and drainage channels there are deposits known as the Wisconsin gravels. These may now appear as isolated mounds on the sides of hills or in low ridges, far removed from the present drainageways. Generally the drift covering is so deep that the gravel is not encountered in the 3-foot section of the soils. The Pierce soil is the only one which contains enough of this gravelly material to give the soil a definite characteristic.

The Wisconsin drift deposit is variable, ranging from a few feet to 15 or more in depth. In some rare cases it may be much deeper. The till is a mixture of pale yellow, yellowish-brown and gray clay, silt and sand with some fine gravel and boulders. Calcareous material and fragments of limestone are abundant. The surface of the deposit has been modified considerably by leaching and by the accumulation of organic matter, and the color of the soils is now a very dark brown to black. The heavy subsoils and the high moisture content have limited decomposition of the organic matter, and this has led to the large accumulation and the black color of the soils. The lower soil layers are typically a gray or yellow calcareous clay containing some gravel and boulders. The lime has been very largely leached out of the surface soils, where drainage has been well established, and in some cases the surface soils are now acid in reaction while there is still an abundance of lime in the subsoils.

The upland soils mapped in the county are derived from the Wisconsin drift material. They are classified in the Webster, Clarion, Pierce and Dickinson series. The Webster soils occur on the more nearly level, poorly drained areas, and they are black in color or almost black with gray to grayish-white subsoils. The Clarion types are found on the more rolling uplands, and they are dark brown
in color with yellow or grayish-yellow subsoils. The Dickinson soil occurs on rolling uplands and is lighter in color than the Clarion soils, and the subsoil is sandy to gravelly. The Pierce soil is developed on knobs or high points and has a high gravel content. The subsoil is practically all gravel.

When large amounts of water from the melting glacier passed through the drainage channels coarse materials were deposited and formed terraces. Thus the Sioux soils were formed with gravelly subsoils and a high lime content while the O'Neill types were formed with gravelly subsoils without any content of lime. The Benoit and Waukesha soils are also found on the terraces and the Fargo clay in old lake beds. The first bottomlands are mapped in the Lamoure, Wabash and Cass series and areas of muck are found throughout the upland in low swampy areas, or former swamps where water stood for long periods of time.

**PHYSIOGRAPHY AND DRAINAGE**

In topography Calhoun County is a rather level plain, without striking features, with little slope and rather poor drainage. The predominant features are broad uneven ridges and low knolls, most of which do not rise more than 20
or 30 feet above the intervening depressions. The depressions range from mere sags a few acres in extent, to wide, ill-defined flats with numerous extensions which grade into the surrounding slopes or connect with some of the waterways. The southeastern townships include much rather flat land, consisting of wide depressions with comparatively low divides. In the southwestern townships there is a somewhat larger proportion of rolling and almost hilly land, nearly all of which is along the streams. The valley of the Raccoon River, which is from 1 to 2 miles wide, cuts off about 12 square miles of the southwestern corner of the county. The flood plain of the river is about one-fourth of a mile wide in most places, where the widest areas are found, but the terrace lands extend back much further to the upland slopes which rise to an elevation of 40 or 50 feet.

The natural drainage system of the county is very poorly developed, and formerly the surface run-off and the seepage from the hillsides collected in depressions where the water stood for long periods. About two-thirds of the smaller creeks are now artificially enlarged ditches from 5 to 15 feet deep. The improvement in the drainage conditions has been so great that even the lowest lands are now soon drained. The original marshy condition of much of the land has been changed, and even in the areas more remote from the tile drains and ditches, water does not remain in the depressions for long periods. In some areas the sandy or gravelly nature of the subsoil aids in promoting the drainage of the soils. The drainage system of the county is shown in the accompanying map. The Webster, Fargo, Lamoure and Wabash types and the areas of muck are the only soils in which drainage is likely to be lacking.
THE SOILS OF CALHOUN COUNTY

The soils of Calhoun County are grouped into three classes according to their origin and location. The groups are drift soils, terrace soils and swamp and bottomland soils. Drift soils are deposited by glaciers upon their retreat, and they contain material from various sources with pebbles and boulders occurring both in the subsoil and often in the surface soil. Terraces are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the river channel or both. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams, and they are subject to overflow more or less frequently. The total acreage and percentage of the area of the county included in each of these groups of soils are given in table II.

<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>340,096</td>
<td>93.5</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>6,592</td>
<td>2.0</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>16,832</td>
<td>4.5</td>
</tr>
<tr>
<td>Total</td>
<td>363,520</td>
<td></td>
</tr>
</tbody>
</table>

Over nine-tenths of the total area, 93.5 percent, are covered by the drift soils. Terrace soils cover only 2 percent of the county. Swamp and bottomland soils are a little more extensive, covering 4.5 percent of the county.

There are 17 soil types in the county, and these with the steep phase Clarion loam and the areas of muck and shallow phase muck make a total of 20 separate soil areas. There are 7 drift soils including the steep phase Clarion loam, 6 terrace soils and 7 areas of swamp and bottomland soils including the areas of muck. The different soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The names given to the various types indicate the characteristics of the soils. The areas of the types are shown in table III.

The Webster silty clay loam is the largest drift soil and the largest individual soil type in the county, covering 39.1 percent of the total area. The Clarion loam is the second largest drift type and the second largest type in the county, covering 34.7 percent of the area. The Webster loam is the third drift soil, covering 18 percent of the county. The steep phase of the Clarion loam is much smaller in area, covering 1.3 percent of the total area. The Pierce loam covers 0.2 percent of the county and the Clarion sandy loam and Dickinson fine sandy loam each cover 0.1 percent of the area.

The Sioux loam is the largest terrace soil, covering 1.2 percent of the total area of the county. The O'Neill loam, the Benoit loam, and the Waukesha loam each cover 0.2 percent of the county. The Sioux sandy loam and the Fargo clay each cover 0.1 percent of the total area.

The Lamoure silty clay loam is the largest of the bottomland soils, covering 1.7 percent of the total area. Muck and Wabash loam each cover 1.1 percent of the county. The Cass fine sandy loam and the Wabash silty clay loam each
### Table III. Areas of Different Soil Types in Calhoun County

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>142,080</td>
<td>39.1</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>126,336</td>
<td>34.7</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>65,280</td>
<td>18.0</td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>4,672</td>
<td>1.3</td>
</tr>
<tr>
<td>173</td>
<td>Pierce loam</td>
<td>506</td>
<td>0.2</td>
</tr>
<tr>
<td>253</td>
<td>Clarion sandy loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>175</td>
<td>Dickinson fine sandy loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>4,480</td>
<td>1.2</td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>704</td>
<td>0.2</td>
</tr>
<tr>
<td>254</td>
<td>Benoit loam</td>
<td>576</td>
<td>0.2</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>576</td>
<td>0.2</td>
</tr>
<tr>
<td>14</td>
<td>Sioux sandy loam</td>
<td>192</td>
<td>0.1</td>
</tr>
<tr>
<td>255</td>
<td>Fargo clay</td>
<td>64</td>
<td>0.1</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>6,336</td>
<td>1.7</td>
</tr>
<tr>
<td>21</td>
<td>Muck</td>
<td>4,096</td>
<td>1.1</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>3,840</td>
<td>1.1</td>
</tr>
<tr>
<td>130</td>
<td>Cass fine sandy loam</td>
<td>896</td>
<td>0.2</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>768</td>
<td>0.2</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td>256</td>
<td>Muck (shallow phase)</td>
<td>384</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>363,520</td>
<td></td>
</tr>
</tbody>
</table>

There is some relationship between the soil types and the topographic features of the county. The Webster soils are all level to depressed in topography. The Clarion loam is gently rolling in topography in typical areas. The Clarion sandy loam also is gently rolling in topography. The steep phase Clarion loam, as the name indicates, is steep in topography. The Dickinson fine sandy loam is rolling in topography. The Pierce loam occurs on knolls or knobs in the rougher sections. The terrace soils show little in the way of topographic features. The Sioux, O’Neill, Benoit and Waukesha soils are developed on the higher terraces and the Fargo clay is found in depressed positions. The bottomland soils show no topographic differences of significance. They are all subject to overflow and must be protected if they are to be cultivated. Drainage is essential for the bottomland soils as well as for the Webster soils on the uplands and the Fargo soils on the terraces.

### THE FERTILITY IN CALHOUN COUNTY SOILS

Samples were taken from each of the soil types in the county except the O’Neill loam, the Sioux sandy loam and the Wabash silty clay loam. The areas of muck and shallow phase muck were not sampled because of their great variability and because the results of the analyses would be of little significance. The soil types mentioned were not sampled because of their small extent and unimportance. The more extensive soils were sampled in triplicate, while only one sample of the minor types was taken.

The samplings were all made with care that the results be entirely satisfactory and that there be no abnormal conditions to affect the data. The samples’
were taken at three depths, 0 to 62/3 inches, 62/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively. Analyses were made on all samples for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were employed for the phosphorus, nitrogen and carbon determinations and the Truog qualitative test was used for the limestone requirement determinations. The figures given in the tables are the averages of all the results secured on all the samples, and they represent, therefore, the averages of two or six determinations.

### The Surface Soils

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

<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>107</td>
<td>Webster silty clay loam</td>
<td>1,275</td>
<td>5,880</td>
<td>82,650</td>
<td>514</td>
<td>4,000</td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>1,149</td>
<td>4,040</td>
<td>44,041</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,091</td>
<td>5,280</td>
<td>58,685</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>1,047</td>
<td>3,840</td>
<td>44,613</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>173</td>
<td>Pierce loam</td>
<td>1,006</td>
<td>3,240</td>
<td>47,777</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>253</td>
<td>Clarion sandy loam</td>
<td>1,091</td>
<td>2,800</td>
<td>31,524</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>175</td>
<td>Dickinson fine sandy loam</td>
<td>983</td>
<td>2,050</td>
<td>25,442</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>1,158</td>
<td>3,400</td>
<td>37,905</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>254</td>
<td>Benoit loam</td>
<td>1,037</td>
<td>5,600</td>
<td>55,568</td>
<td></td>
<td>1,535</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,818</td>
<td>6,000</td>
<td>74,147</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>255</td>
<td>Fargo clay</td>
<td>2,020</td>
<td>8,720</td>
<td>91,373</td>
<td></td>
<td>3,063</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>1,549</td>
<td>6,640</td>
<td>68,143</td>
<td>768</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>1,320</td>
<td>4,360</td>
<td>48,867</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Cass fine sandy loam</td>
<td>1,373</td>
<td>2,280</td>
<td>21,905</td>
<td>12,400</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1,185</td>
<td>3,720</td>
<td>42,568</td>
<td></td>
<td>4,000</td>
</tr>
</tbody>
</table>

The phosphorus content of the soils is variable, ranging from 983 pounds per acre in the Dickinson fine sandy loam to 2,020 pounds per acre in the Fargo clay. There is no apparent relationship between the phosphorus supply and the soil groups, although the terrace and bottomland soils are a little better supplied than the upland soils, as might be expected, since there has been less crop growth on the terraces and bottomland soils and hence less plant food has been removed. There is some relationship between the phosphorus content and the soil series according to these results. Thus the Webster soils are richer than the other upland drift soils, and the Dickinson soil is poorer than the Clarion types. The Pierce loam is lower in phosphorus than the Clarion loam. On the terraces the Waukesha loam is higher than the Sioux and Benoit loams, and the Fargo clay is richer than the other types. On the bottomlands there is not much difference among the various types, but the Lamoure soil is richer than the Wabash and Cass types. The characteristics which distinguish the various soil series apparently have some relation to the phosphorus supply. Types level in topography
like the Webster are richer than rolling soils, like the Clarion. Types black in color like the Webster are richer than the Clarion, Dickinson and Pierce soils; those black like the Fargo are higher in phosphorus than the Sioux, O'Neill, Benoit and Waukesha; those soils darker in color are richer than the lighter colored types. Types which are sandy or gravelly in the subsoils are poorer in phosphorus than those with heavy clay subsoils. Thus the Webster and Clarion soils are richer than the Dickinson and Pierce soils which have sandy or gravelly subsoils. Thus also the Fargo and Waukesha soils are higher than the Sioux and O'Neill types, and the Lamoure and Wabash types on the bottoms are higher than the Cass soils which have a sandy subsoil.

There is some evidence of the effect of texture of the soil on the phosphorus supply, but in most cases only one type of a series is mapped and hence conclusions are hardly possible. The Webster silty clay loam is richer than the Webster loam, and the Clarion loam is higher than the sandy loam. The Wabash silt loam is not so high as the loam which is contrary to the usual results. In general it has been found that soils finer in texture are richer than coarse textured types, and thus silty clay loams are richer than silt loams which are better supplied than loams, and these, in turn, are richer than sandy textured types.

The phosphorus supply of the soils of the county is certainly not high and phosphorus fertilizers will be needed in the near future even if they are not necessary now. If the supply is to be kept up, additions of phosphorus materials will be required regularly. There is some evidence now to show the value of the application or rock phosphate or superphosphate to the soils of this county.

The nitrogen content of the soils varies widely, ranging from 2,080 pounds per acre in the Dickinson fine sandy loam up to 8,720 pounds per acre in the Fargo clay. Again it appears that there is little relation between the nitrogen content of the soils and the soil group, except that the terrace and bottomland soils are slightly higher on the average due undoubtedly to the greater decomposition going on in the upland soils and the greater crop growth there, with the consequently greater removal of plant food.

Some relationships to series appear. Thus the Webster soils are the richest of the upland soils, and the Clarion types are better supplied than the Dickinson or Pierce soils. The Fargo and Waukesha soils on the terraces are richer than the Sioux and Benoit soils. The Lamoure and Wabash soils on the bottomlands are higher than the Cass soil. It is evident again that the color of the soil, the location with respect to topography and the subsoil characteristics affect the nitrogen supply. The black, flat to depressed Webster soils with heavy subsoils are richer than the lighter colored, rolling Clarion, Dickinson and Pierce soils, with lighter textured subsoils. The Clarion soils are richer than the Dickinson and Pierce soils as the latter have sandy to gravelly subsoils while the Clarion soils are heavier. The darker color, heavier subsoil condition and flat topography of the Fargo and Waukesha soils on the terraces give them a higher nitrogen content than the Sioux and Benoit soils. The Lamoure and Wabash types on the bottoms are richer than the Cass soil as the latter has a sandy or gravelly subsoil.

There is some effect of texture on the nitrogen content, but as noted earlier there are few soils of the same series mapped in this county and hence no especial
evidence of the influence of texture is shown. The Webster silty clay loam is higher than the loam, and the Clarion loam is richer than the sandy loam. The Wabash loam is a little higher than the silt loam which is contrary to the usual results. Usually finer textured soils like silty clay loams and silt loams are richer than coarser textured types like loams, and the latter are richer in nitrogen than sandy types.

The nitrogen content of the soils of Calhoun County is not extremely low but neither is it very high, and nitrogen must not be overlooked when systems of permanent fertility are planned. Materials supplying nitrogen must be used regularly on these soils, and in some cases additions would be of large value now. Farm manure, leguminous green manures and crop residues will supply some nitrogen to the soil, and by the proper use of these materials, especially legumes, the supply may be increased as well as maintained.

The organic carbon content of the soils ranges from 21,905 pounds per acre in the Cass fine sandy loam up to 91,373 pounds per acre in the Fargo clay. Little evidence of any relationship between the carbon content and the soil groups is shown. The terrace and bottomland soils are a little better supplied due to the greater accumulation of organic matter in these soils and the less intensive cultivation and growth of crops.

There is some relationship between the soil series and the organic carbon content. Thus the Webster soils are the richest of the upland types. The Clarion types are higher than the Dickinson and Pierce soils. The Fargo clay is the richest of the terrace soils and the Waukesha is better supplied than the Sioux and Benoit types. The Lamoure and Wabash soils on the bottoms are richer than the Cass soil. Again it appears that those types which are blacker in color, more level to depressed in topography and have heavy textured subsoils are richer than the lighter colored soils, with coarse textured subsoils and lying on the more rolling areas. Those characteristics which serve to determine the soil series certainly have an effect on the content of organic carbon.

Little evidence of the influence of texture on the carbon content is obtained. The Webster silty clay loam is richer than the loam. The Clarion loam is richer than the sandy loam. The Wabash silt loam is a little lower than the loam which is not in accord with the usual results. In general fine textured soils are richer in organic carbon than are coarse textured types, and silty clay loams and silt loams are richer than loams which, in turn, are better supplied than sandy types.

The rate of decomposition of the organic matter in soils is indicated by the relationship between the organic carbon and the nitrogen content. In some of the soils in this county this relationship is not at the optimum, as for example in the Clarion loam, the Webster loam, the Clarion sandy loam, the Dickinson fine sandy loam and a number of the terrace and bottomland soils. In such cases the application of farm manure, if only in small amounts, would prove of large value in stimulating the production of available plant food.

There is no striking deficiency in organic matter content in any of the soils, but in some cases the amount present is not so high as it should be and in all the soils it is important that additions of organic matter be made regularly to keep up the supply. No system of soil management will be permanent that does not provide for the regular addition of organic matter to the soils. The lighter-colored, coarser-textured soils will be benefited especially by the ad-
dition of farm manure, leguminous green manures and crop residues, but these materials are needed on all soils for continued productivity.

The Webster silt loam, the Benoit loam, the Fargo clay, the Lamoure silt loam and the Cass fine sandy loam show no acidity in the surface soil but rather have a content of inorganic carbon. This is characteristic of the Fargo and Lamoure, but the other types in some areas may not contain any inorganic carbon. The Webster loam and the steep phase Clarion loam on the uplands and the Wabash loam on the bottoms have no inorganic carbon content, but they show no limestone requirement. They are neutral in reaction in the surface soil. Other samples of these types might show a lime requirement. Some of the types show a lime content in the subsoil such as the steep phase Clarion loam, but in general the reaction of the surface soil indicates the need for limestone to remedy acidity or the occurrence of lime naturally in the soil. All the other types in the county are acid in reaction and in need of lime if the best crop yields are to be secured. The Clarion soils, the Dickinson soil, the Webster loam, the Sioux and Waukesha soils and the Wabash types are in need of lime. Even if lime is found in the subsoil, as is often the case with the Clarion soils, the Webster loam and the Sioux types, there is need for lime if the surface soil is acid. All the soils of the county, except the Fargo and Lamoure should be tested to determine lime needs, especially if a legume such as sweet clover or alfalfa is to be grown.

The lime requirements shown in the table are only an indication of the actual lime needs of the soils. There is a wide variation in lime requirements of soils even of the same type, and tests should always be made to determine the proper amount to apply to any individual area, if the best results are to be obtained.

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 per acre and 6 million pounds of subsoil per acre.

**TABLE V. PLANT FOOD IN CALHOUN COUNTY, IOWA, SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>Webster silt loam</td>
<td>1,858</td>
<td>6,267</td>
<td>86,616</td>
<td>2,829</td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>2,037</td>
<td>5,813</td>
<td>64,339</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>2,128</td>
<td>6,800</td>
<td>79,246</td>
<td></td>
<td>63,181</td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>2,988</td>
<td>3,760</td>
<td>108,352</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>173</td>
<td>Pierce loam</td>
<td>2,208</td>
<td>4,400</td>
<td>48,758</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>253</td>
<td>Clarion sandy loam</td>
<td>1,938</td>
<td>2,960</td>
<td>39,706</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>175</td>
<td>Dickinson fine sandy loam</td>
<td>1,724</td>
<td>2,960</td>
<td>34,832</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>1,938</td>
<td>4,160</td>
<td>53,612</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>254</td>
<td>Benoit loam</td>
<td>2,128</td>
<td>5,600</td>
<td>62,315</td>
<td>4,223</td>
<td>2,000</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>2,586</td>
<td>7,920</td>
<td>108,043</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>255</td>
<td>Fargo clay</td>
<td>2,370</td>
<td>4,960</td>
<td>89,500</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silt loam</td>
<td>2,182</td>
<td>6,560</td>
<td>81,314</td>
<td>768</td>
<td>3,000</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2,074</td>
<td>5,040</td>
<td>62,830</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>130</td>
<td>Cass fine sandy loam</td>
<td>2,908</td>
<td>4,240</td>
<td>66,538</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,262</td>
<td>5,520</td>
<td>91,708</td>
<td></td>
<td>3,000</td>
</tr>
</tbody>
</table>
### Table VI. Plant Food in Calhoun County, Iowa, Soils

Pounds per acre of 6 million pounds of subsoil (20"-40")

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Total Organic Carbon</th>
<th>Total Inorganic Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Webster silty clay loam</td>
<td>2,895</td>
<td>3,960</td>
<td>52,407</td>
<td>58,739</td>
<td>2,000</td>
</tr>
<tr>
<td>Clarion loam</td>
<td>2,590</td>
<td>4,240</td>
<td>45,459</td>
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<td></td>
</tr>
<tr>
<td>Webster loam</td>
<td>2,139</td>
<td>3,480</td>
<td>37,796</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarion loam (steep phase)</td>
<td>3,231</td>
<td>3,360</td>
<td>183,745</td>
<td>139,304</td>
<td></td>
</tr>
<tr>
<td>Pierce loam (no sample)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarion sandy loam</td>
<td>2,706</td>
<td>2,520</td>
<td>24,870</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>Dickinson fine sandy loam</td>
<td>2,424</td>
<td>4,440</td>
<td>17,817</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sioux loam</td>
<td>3,030</td>
<td>3,360</td>
<td>39,268</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>Benoit loam</td>
<td>2,625</td>
<td>2,520</td>
<td>38,237</td>
<td>106,321</td>
<td>2,000</td>
</tr>
<tr>
<td>Waukesha loam</td>
<td>2,907</td>
<td>6,840</td>
<td>103,489</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fargo clay</td>
<td>2,505</td>
<td>2,400</td>
<td>47,940</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamoure silty clay loam</td>
<td>2,745</td>
<td>3,720</td>
<td>66,905</td>
<td>1,152</td>
<td></td>
</tr>
<tr>
<td>Wabaah loam</td>
<td>2,667</td>
<td>4,560</td>
<td>67,557</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cass fine sandy loam</td>
<td>4,041</td>
<td>4,080</td>
<td>83,691</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wabaah silt loam</td>
<td>3,273</td>
<td>4,680</td>
<td>57,430</td>
<td></td>
<td>2,000</td>
</tr>
</tbody>
</table>

Unless there is a striking deficiency in some plant food or a large supply in the lower soil layers, the plant food content of the subsurface soils and subsoils has little influence on the fertility of the soil. In the subsurface soils and subsoils of this county, there is no great supply of plant food nor any large deficit, and hence it is not necessary to consider the analyses of the lower soil layers in detail.

It will be sufficient to note that the conclusions drawn from the analyses of the surface soils, regarding the needs of the soils, are very largely confirmed by the analyses of the lower soil layers. In fact these analyses emphasize the previous conclusions. The soils need phosphorus now or will need it in the near future if the supply is to be kept up. Nitrogen and organic matter, while not deficient now, must be supplied regularly to prevent any deficit in the future. Some of the soils are acid in reaction in the surface soil and need additions of limestone. Even if there is some lime in the lower soil layers this does not change the need for lime in the surface soil as lime rarely moves upward in the soil and if the surface soil is acid lime must be applied for the best growth of legume crops. Farmers should test their soils for reaction or lime needs and make proper application of lime if they wish to obtain the maximum crop yields.

### Greenhouse Experiments

Two greenhouse experiments were carried out on soils from Calhoun County, the Webster silty clay loam and the Clarion loam, the two most important soil types in the area. These tests were conducted to determine the value of the application of various fertilizing materials to these soils. The results, while not conclusive, indicate what may be expected in the field from the same treatments.

In these experiments the soils are treated with manure, limestone, superphosphate and muriate of potash. The amounts of the various materials added are the same as are used in the field. The manure is applied at the rate of 8 tons
per acre, the limestone in sufficient amounts to neutralize the acidity of the soil, the superphosphate at the rate of 200 pounds per acre and the muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown in all the tests, the clover being seeded when the wheat had been up about a month.

The Results on the Webster Silty Clay Loam

The results of the experiment on the Webster silty clay loam are given in table VII. Manure alone increased the clover yield enormously but had no effect on the wheat. Limestone was not applied in this test as the soil was not acid in reaction. Superphosphate alone had a greater effect than manure on the clover and showed a beneficial effect on the wheat. The two materials together had no greater influence on the wheat but brought about a much greater influence on the clover than either material did alone. Muriate of potash with superphosphate and manure had no effect on the wheat but definitely increased the yield of clover.

TABLE VII. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, CALHOUN 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>6.0</td>
<td>25.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>5.8</td>
<td>65.8</td>
</tr>
<tr>
<td>3</td>
<td>Manure + superphosphate</td>
<td>5.8</td>
<td>99.2</td>
</tr>
<tr>
<td>4</td>
<td>Superphosphate</td>
<td>6.7</td>
<td>74.4</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate + muriate of potash</td>
<td>6.3</td>
<td>106.8</td>
</tr>
</tbody>
</table>

The Results on the Clarion Loam

The results obtained in the experiment on the Clarion loam are shown in table VIII.

TABLE VIII. GREENHOUSE EXPERIMENT, CLARION LOAM, CALHOUN 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>3.1</td>
<td>12.1</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>4.5</td>
<td>32.6</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>5.2</td>
<td>48.8</td>
</tr>
<tr>
<td>4</td>
<td>Superphosphate</td>
<td>5.5</td>
<td>36.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>4.4</td>
<td>64.0</td>
</tr>
<tr>
<td>6</td>
<td>Limestone + superphosphate</td>
<td>6.4</td>
<td>56.8</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate</td>
<td>5.8</td>
<td>81.0</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>5.6</td>
<td>83.3</td>
</tr>
</tbody>
</table>

Manure increased the yield of wheat and more than doubled the yield of clover. Limestone with manure gave a further increase in the wheat and brought about a large gain in the clover. Superphosphate had a greater effect than manure on the wheat and clover but had less effect than manure and limestone on the clover. Manure and superphosphate had no greater influence on the wheat than either material alone but gave a large increase in the clover. Limestone with superphosphate had much greater effects than either material alone but less effect on the clover than manure and superphosphate. Manure and limestone and superphosphate had no greater effect on the wheat than lime-
stone and superphosphate without manure, but the three materials together had a very much greater influence on the clover than any of the combinations of two materials. Muriate of potash had no effect on either the wheat or the clover.

FIELD EXPERIMENTS

No field experiments have been carried out in Calhoun County, but the results of tests which are under way in other counties on the same soil types as those which occur extensively in this county, will be given in this report to indicate the value of various fertilizer treatments. The data obtained on the Clarion loam on the Truesdale Field, Series I and Series II in Buena Vista County on the Ruthven Field in Palo Alto County, on the Webb Field in Clay County and on the Superior Field in Dickinson County; on the Webster silty clay loam on the Storm Lake Field in Buena Vista County and on the Newell Field in the same county, on the Webster loam on the Lundgren Field in Webster County; and on the Lamoure silty clay loam on the Everly Field, Series II, in Clay County are included. The results obtained on these fields may be considered to apply directly to the conditions in Calhoun County.

These field experiments are all laid out on land which is representative of the soil type and they are permanently located by the installation of corner stakes. All precautions are taken in applying the fertilizers and in harvesting the crops to insure securing accurate results. The tests are planned to test the value of various fertilizer treatments under the livestock or the grain systems of farming. The fields include either 13 plots or 9 plots 155 feet 7 inches long by 23 feet wide, or one-tenth of an acre in size. In the former, manure and limestone are the basic treatments, while in the latter system, crop residues and limestone are the treatments which are made to all the plots. The other fertilizing materials tested include 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 4-year rotation. The crop residue treatment consists of plowing under the cornstalks which have been cut with a disc or stalk cutter after being winter pastured. Sometimes the second crop of clover is plowed down but usually it is used for hay, seed or pasture and only the residues are plowed down. Limestone is added in amounts sufficient to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in 4 years. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in the rotation. Superphosphate is applied at the rate of 120 pounds of the 20 percent material per acre, three times in the 4-year rotation. Until 1923, this material was applied at the rate of 200 pounds of the 16 percent phosphate per acre annually. From 1923 to 1929, 150 pounds of the 16 percent phosphate were employed 3 years out of 4 in the 4-year rotation. Until 1923 the old standard 2-8-2 complete commercial fertilizer was employed, the application being at the rate of 300 pounds per acre annually.

From 1923 to 1929, a 2-12-2 standard complete brand was used, a 200 pound application being made per acre 3 years out of 4 to supply the same amount of phosphorus as contained in the superphosphate. Beginning in 1929 a 2-12-6
or a 2-16-2 or 4-16-4 complete fertilizer has been used, the application of a sufficient amount being made to supply the same quantity of phosphorus as that added in the superphosphate. On the Clarion loam and Webster loam, the 2-12-6 fertilizer is used, and on the Webster silty clay loam and Lamoure silty clay loam the 2-16-2 complete brand is employed. Muriate of potash is applied at the rate of 25 pounds per acre 3 years out of 4 in the 4-year rotation.

The Truesdale Field

The results secured in the field experiment on the Truesdale Field, Series I, in Buena Vista County are given in table IX. The manure increased all the crops except the clover in 1921 and the barley in 1929, the largest increase appearing on the corn in 1922 and in 1928. The sweet clover in 1926 also showed a large increase. Lime increased the yields in all cases except the corn in 1928 and 1930 and the oats in 1931. It showed the best results with the clover as would be expected. Rock phosphate with manure and lime gave increases in most cases, the

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn bu. per A.</th>
<th>1919 corn bu. per A. (1)</th>
<th>1920 oats bu. per A.</th>
<th>1921 clover tons per A.</th>
<th>1922 corn bu. per A.</th>
<th>1923 oats bu. per A.</th>
<th>1924 corn bu. per A. (2)</th>
<th>1925 oats bu. per A.</th>
<th>1926 sweet clover tons per A.</th>
<th>1927 corn bu. per A.</th>
<th>1928 corn bu. per A. (3)</th>
<th>1929 barley bu. per A.</th>
<th>1930 corn bu. per A. (4)</th>
<th>1931 oats bu. per A. (4)</th>
<th>1932 sweet clover tons per A. (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>38.9</td>
<td>56.5</td>
<td>57.2</td>
<td>1.40</td>
<td>48.4</td>
<td>48.6</td>
<td>44.2</td>
<td>13.0</td>
<td>48.3</td>
<td>1.12</td>
<td>59.3</td>
<td>37.3</td>
<td>39.3</td>
<td>42.3</td>
<td>32.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>44.3</td>
<td>57.1</td>
<td>57.9</td>
<td>1.20</td>
<td>61.6</td>
<td>57.7</td>
<td>24.3</td>
<td>50.7</td>
<td>1.45</td>
<td>62.9</td>
<td>54.1</td>
<td>37.9</td>
<td>43.7</td>
<td>43.8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>46.4</td>
<td>58.1</td>
<td>59.2</td>
<td>1.60</td>
<td>64.0</td>
<td>61.2</td>
<td>32.7</td>
<td>63.2</td>
<td>1.64</td>
<td>68.7</td>
<td>59.3</td>
<td>37.9</td>
<td>42.7</td>
<td>37.4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>54.4</td>
<td>58.7</td>
<td>64.7</td>
<td>2.45</td>
<td>63.2</td>
<td>34.1</td>
<td>64.6</td>
<td>1.77</td>
<td>74.8</td>
<td>60.8</td>
<td>42.4</td>
<td>38.2</td>
<td>48.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure + limestone + superphosphate</td>
<td>46.6</td>
<td>58.7</td>
<td>64.9</td>
<td>3.30</td>
<td>61.6</td>
<td>61.2</td>
<td>32.8</td>
<td>73.1</td>
<td>1.60</td>
<td>69.3</td>
<td>55.2</td>
<td>49.9</td>
<td>36.9</td>
<td>47.0</td>
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<tr>
<td>6</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>46.9</td>
<td>58.7</td>
<td>64.7</td>
<td>3.10</td>
<td>63.7</td>
<td>68.0</td>
<td>37.5</td>
<td>71.0</td>
<td>1.79</td>
<td>70.9</td>
<td>56.3</td>
<td>59.0</td>
<td>34.4</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>38.4</td>
<td>58.1</td>
<td>64.6</td>
<td>2.90</td>
<td>51.0</td>
<td>54.8</td>
<td>30.3</td>
<td>50.4</td>
<td>1.13</td>
<td>51.9</td>
<td>40.3</td>
<td>37.0</td>
<td>40.7</td>
<td>34.3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>49.1</td>
<td>61.9</td>
<td>67.2</td>
<td>2.20</td>
<td>49.7</td>
<td>55.5</td>
<td>27.1</td>
<td>44.3</td>
<td>1.52</td>
<td>54.5</td>
<td>37.1</td>
<td>37.0</td>
<td>39.6</td>
<td>36.3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + limestone</td>
<td>51.2</td>
<td>66.6</td>
<td>66.0</td>
<td>2.20</td>
<td>50.6</td>
<td>54.5</td>
<td>31.0</td>
<td>51.7</td>
<td>1.66</td>
<td>59.9</td>
<td>49.3</td>
<td>37.9</td>
<td>27.3</td>
<td>35.4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + limestone + rock phosphate</td>
<td>58.9</td>
<td>68.8</td>
<td>68.1</td>
<td>3.10</td>
<td>61.6</td>
<td>60.0</td>
<td>31.4</td>
<td>57.6</td>
<td>1.50</td>
<td>64.7</td>
<td>42.4</td>
<td>42.4</td>
<td>24.4</td>
<td>36.7</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Crop residues + limestone + superphosphate</td>
<td>57.6</td>
<td>67.2</td>
<td>76.6</td>
<td>2.90</td>
<td>64.1</td>
<td>64.5</td>
<td>24.5</td>
<td>71.0</td>
<td>1.44</td>
<td>69.3</td>
<td>49.6</td>
<td>43.9</td>
<td>25.1</td>
<td>39.4</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + limestone + complete commercial fertilizer</td>
<td>62.9</td>
<td>66.1</td>
<td>77.6</td>
<td>3.00</td>
<td>60.4</td>
<td>77.0</td>
<td>34.4</td>
<td>71.6</td>
<td>1.29</td>
<td>64.3</td>
<td>50.4</td>
<td>42.4</td>
<td>24.1</td>
<td>40.8</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>47.5</td>
<td>64.0</td>
<td>65.5</td>
<td>2.10</td>
<td>49.0</td>
<td>48.7</td>
<td>29.6</td>
<td>54.4</td>
<td>0.92</td>
<td>55.5</td>
<td>36.3</td>
<td>38.6</td>
<td>34.3</td>
<td>36.3</td>
<td></td>
</tr>
</tbody>
</table>

(1) Plots 8-13 had more moisture; slopes into heavier soil.
(2) Plots 1 and 2 injured by squirrels. Corn green when husked due to killing frost.
(3) Hot, dry season; fertilized plots showed most damage.
(4) Hot, dry weather in June damaged oats.
(5) Stand very uneven. Field pastured. No results.

* The Truesdale Field, Series I, was established in the fall of 1917 on the farm of J. N. Horlacher, north of Storm Lake, in Buena Vista County. It is located in the SW corner of the NW ¼ of the SE ¼ of Section 3, T. 91 N, R. 37 W in Washington Township.
largest effect appearing on the clover. The effect on the oats and corn was smaller.
No increases were secured on the corn in 1922 and 1930 and the oats in 1923. Super­
phosphate gave very similar increases to rock phosphate in some seasons. With
the clover in 1921, however, there was a much larger effect from superphosphate,
while on the same crop in 1926, there was a smaller influence. The oats in 1925
were increased to a greater extent by superphosphate than by rock phosphate,
and the barley in 1929 showed a greater influence from superphosphate. In
most of the other seasons the variations between the effects of the two phosphates
were insignificant. The complete commercial fertilizer showed gains that were
similar to those brought about by the phosphates, giving slightly smaller effects
than superphosphate in some cases and somewhat greater effects in other in­
stances.

The crop residues showed small effects on the yields of succeeding crops ex­
cept in one or two instances. Lime with the residues brought about increases
in crop yields in most cases, the effect being evidenced most on the sweet clover
in 1926 and on some of the oats crops. Rock phosphate with lime and residues
increased the yields of all crops except the clover in 1926 and the corn in 1930.
In some seasons the increases were large while in others small. The clover in
1921 showed a large increase. The oats in 1923 and in 1925 were increased con­
siderably. The corn in 1927 showed an appreciable gain. Superphosphate had
larger effects than rock phosphate in some instances, particularly on the oats
in 1920 and 1925, with very large differences appearing in the latter year. In
several other cases, however, rock phosphate seemed to give quite as large effects
as superphosphate, and rock phosphate gave a slightly larger effect than super­
phosphate on clover. The differences, however, usually were not large enough
to be significant. Only on the oats in 1923 and the corn in 1924 were the differ­
ences of very large importance. The complete commercial fertilizer showed
somewhat larger effects than superphosphate in several seasons, but in many cases
the differences were hardly large enough to be significant.

Table X gives the results secured in the experiment on the Clarion loam,
Truesdale Field, Series II in Buena Vista County. Again the application of
manure increased the yields of the various crops, showing very large effects in
practically all cases. The corn and oats crops were very largely benefited by
the use of manure, and a large increase in the yield of clover was secured in
1923 and of alfalfa in 1929. Lime usually brought about further gains in crop
yields. In one or two instances, the lime had no effect, but in general, as on the
alfalfa, it was very effective.

Rock phosphate, superphosphate and complete commercial fertilizer increased
the yields of crops in practically all cases when applied with manure and lime.
In one or two seasons, rock phosphate did not appear to be of value, but super­
phosphate and complete commercial fertilizer always brought about consider­
able increases in yields, the effects being particularly noted on the clover in 1923
and on the alfalfa in 1929, 1930 and 1931. Superphosphate generally brought
about slightly greater effects than rock phosphate, but in many cases the differ­
ences were not significant. The complete commercial fertilizer had slightly
greater effects than superphosphate in some seasons, but in general the differ­
**TABLE X. FIELD EXPERIMENT, CLARION LOAM, BUENA VISTA COUNTY TRUESDALE FIELD,* SERIES II**

| Plot No. | Treatment | 1918 oats | 1918 clover tons per A. (1) | 1919 oats | 1919 clover tons per A. (2) | 1920 oats | 1920 clover tons per A. (3) | 1921 oats | 1921 clover tons per A. (4) | 1922 oats | 1922 clover tons per A. | 1923 oats | 1923 clover tons per A. | 1924 oats | 1924 clover tons per A. | 1925 oats | 1925 clover tons per A. | 1926 oats | 1926 clover tons per A. | 1927 oats | 1927 clover tons per A. | 1928 oats | 1928 clover tons per A. | 1929 alfalfa tons per A. (6) | 1930 alfalfa tons per A. (6) | 1931 alfalfa tons per A. (7) | 1932 alfalfa tons per A. (7) |
|---------|-----------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|
| 1       | Check     | 69.9      |                           |           |                           | 47.5      |                            | 32.8      |                            | 18.5      |                            | 1.72      |                            | 38.0      |                            | 40.0      |                            | 29.9      |                            | 50.1      |                            | 13.1      |                            | 2.09      |                            | 2.75      |                            | 1.56      |                            | 3.52      |                            |
| 2       | Manure    | 94.2      |                           |           |                           | 57.0      |                            | 39.7      |                            | 24.6      |                            | 1.90      |                            | 52.7      |                            | 50.4      |                            | 38.1      |                            | 55.3      |                            | 33.3      |                            | 2.33      |                            | 2.65      |                            | 1.58      |                            | 3.97      |                            |
| 3       | Manure+limestone+rock phosphate | 91.2 |                           |           |                           | 59.0      |                            | 41.8      |                            | 27.2      |                            | 1.86      |                            | 46.9      |                            | 51.8      |                            | 37.0      |                            | 54.5      |                            | 45.4      |                            | 2.87      |                            | 2.75      |                            | 1.70      |                            | 4.55      |                            |
| 4       | Manure+limestone+complete commercial fertilizer | 88.2 |                           |           |                           | 61.2      |                            | 38.1      |                            | 32.4      |                            | 2.26      |                            | 44.4      |                            | 51.7      |                            | 37.3      |                            | 57.3      |                            | 39.3      |                            | 3.03      |                            | 3.06      |                            | 1.83      |                            | 4.37      |                            |
| 5       | Manure+limestone+superphosphate | 91.2 |                           |           |                           | 62.1      |                            | 40.2      |                            | 31.0      |                            | 2.24      |                            | 24.4      |                            | 54.8      |                            | 43.3      |                            | 57.7      |                            | 45.4      |                            | 3.28      |                            | 3.52      |                            | 2.05      |                            | 4.90      |                            |
| 6       | Manure+limestone+complete commercial fertilizer | 88.2 |                           |           |                           | 64.0      |                            | 44.5      |                            | 31.9      |                            | 2.42      |                            | 45.0      |                            | 58.6      |                            | 43.6      |                            | 58.0      |                            | 46.9      |                            | 3.24      |                            | 3.26      |                            | 2.12      |                            | 5.28      |                            |
| 7       | Check     | 85.1      |                           |           |                           | 57.1      |                            | 36.3      |                            | 23.6      |                            | 1.93      |                            | 42.9      |                            | 51.6      |                            | 34.3      |                            | 55.2      |                            | 34.8      |                            | 1.86      |                            | 2.61      |                            | 1.43      |                            | 4.02      |                            |
| 8       | Crop residues | 89.7 |                           |           |                           | 58.5      |                            | 32.9      |                            | 31.2      |                            | 1.98      |                            | 40.7      |                            | 59.2      |                            | 35.4      |                            | 55.1      |                            | 39.3      |                            | 2.29      |                            | 2.64      |                            | 1.39      |                            | 4.19      |                            |
| 9       | Crop residues+limestone | 97.3 |                           |           |                           | 59.2      |                            | 40.1      |                            | 29.8      |                            | 2.03      |                            | 41.8      |                            | 52.2      |                            | 32.7      |                            | 52.9      |                            | 42.4      |                            | 2.51      |                            | 2.87      |                            | 1.58      |                            | 4.56      |                            |
| 10      | Crop residues+limestone+rock phosphate | 91.2 |                           |           |                           | 60.0      |                            | 35.6      |                            | 34.4      |                            | 2.39      |                            | 46.0      |                            | 51.1      |                            | 38.7      |                            | 56.3      |                            | 37.9      |                            | 3.14      |                            | 3.06      |                            | 1.66      |                            | 4.56      |                            |
| 11      | Crop residues+limestone+superphosphate | 92.7 |                           |           |                           | 60.4      |                            | 33.6      |                            | 36.8      |                            | 2.11      |                            | 40.7      |                            | 60.4      |                            | 47.4      |                            | 54.4      |                            | 40.9      |                            | 3.05      |                            | 3.23      |                            | 1.67      |                            | 4.90      |                            |
| 12      | Crop residues+limestone+complete commercial fertilizer | 95.8 |                           |           |                           | 61.9      |                            | 35.5      |                            | 37.3      |                            | 2.39      |                            | 39.3      |                            | 55.2      |                            | 40.3      |                            | 53.6      |                            | 42.4      |                            | 3.28      |                            | 3.12      |                            | 1.65      |                            | 4.82      |                            |
| 13      | Check     | 85.1      |                           |           |                           | 60.1      |                            | 34.9      |                            | 28.4      |                            | 2.03      |                            | 39.5      |                            | 49.8      |                            | 29.9      |                            | 50.8      |                            | 31.8      |                            | 1.85      |                            | 2.58      |                            | 1.31      |                            | 4.58      |                            |

(1) Plots 1, 2, 3 and 4 disked and seeded to oats. Clover winterkilled.
(2) Poor stand of corn.
(3) Oats green when cut; light and chaffy.
(4) Plot 5 injured by squirrels.
(5) Dry season — low yields.
(6) Total of 2 cuttings.
(7) Total of 3 cuttings.

* The Truesdale Field, Series II, was established in the fall of 1917 on the J. N. Hortacher farm, north of Storm Lake, in Buena Vista County. It is located in the SE corner of the NW ¼ of the SW ¼ of Section 3, T. 91 N, R. 37 W in Washington Township.

ences between the effects of the two materials were too small to permit drawing definite conclusions.

The crop residues had a slight effect on the crop yields in several instances. The application of lime with the crop residues generally brought about increases in yields. The effects were not large, however, except in one or two cases, especially on the alfalfa, and in some instances no gains were secured on the oats and corn.

Rock phosphate, superphosphate and complete commercial fertilizer increased practically all crop yields. Superphosphate seemed to be slightly superior to rock phosphate in some seasons, while in other cases rock phosphate gave slightly greater effects. A larger influence from the latter material appeared on the clover in 1923, on the corn in 1924 and on the alfalfa in 1929. Superphosphate, however, gave much larger effects on the corn in 1925, on the oats in 1926 and on the alfalfa in 1930. It showed small gains in other seasons. The complete commercial fertilizer had about the same effect as superphosphate in most sea-
sons, showing less influence, however, than the latter material in 1925, 1926, 1930 and 1931 and having slightly larger effects in some other seasons.

The Ruthven Field

The results secured in the experiment on the Clarion loam on the Ruthven Field in Palo Alto County are given in table XI. The application of manure increased the crop yields in all but one season, showing the largest effect on the oats in 1926 and on the barley in 1928. Lime with manure increased the crop yields in all seasons, showing very large effects on the sweet clover in 1924 and also bringing about pronounced gains on the corn in 1925 and 1929. There was also a definite increase on the oats in 1923, 1926 and 1930.

Rock phosphate with manure and lime increased crop yields in most seasons. The largest effects appeared on the corn in 1925, 1927, 1929, and 1931 and on the oats in 1930. The yields in 1923 and 1926 were evidently abnormal. Superphosphate with manure and lime showed a somewhat larger effect than rock phosphate in some seasons. It was much superior on the sweet clover in 1924, and it had a larger effect on the oats in 1926 and 1930, but in several seasons rock phosphate gave quite as large an influence.

Muriate of potash with manure, lime and superphosphate brought about a very definite increase over superphosphate alone on the oats in 1923 and the sweet clover in 1924. Corn in 1925 and in 1927 was also increased by the addition of muriate of potash. In some seasons, however, no beneficial effects from potash appeared.

The complete commercial fertilizer with manure and lime showed somewhat larger effects than superphosphate in some seasons. The largest difference appeared on the sweet clover in 1924. Gains were also noted on the oats in 1923 and on the corn in 1925, 1927 and 1931. In the other seasons the differences between the effects of the two materials were very slight.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 corn per A</th>
<th>1923 corn per A</th>
<th>1924 sweet clover per A</th>
<th>1925 corn per A</th>
<th>1926 oats per A</th>
<th>1927 oats per A</th>
<th>1928 barley per A</th>
<th>1929 corn per A</th>
<th>1930 oats per A</th>
<th>1931 oats per A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>47.3</td>
<td>48.7</td>
<td>1.22</td>
<td>42.7</td>
<td>34.0</td>
<td>46.8</td>
<td>34.8</td>
<td>50.3</td>
<td>61.9</td>
<td>56.7</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>53.1</td>
<td>53.3</td>
<td>1.28</td>
<td>39.0</td>
<td>46.8</td>
<td>52.0</td>
<td>40.1</td>
<td>51.0</td>
<td>63.9</td>
<td>59.0</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>55.6</td>
<td>61.2</td>
<td>2.43</td>
<td>50.1</td>
<td>53.4</td>
<td>53.9</td>
<td>43.1</td>
<td>55.5</td>
<td>65.9</td>
<td>60.8</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>57.5</td>
<td>40.8</td>
<td>2.07</td>
<td>58.5</td>
<td>40.6</td>
<td>57.3</td>
<td>47.7</td>
<td>58.1</td>
<td>77.1</td>
<td>64.0</td>
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<td>41.1</td>
<td>43.1</td>
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<td>48.4</td>
<td>60.5</td>
<td>49.2</td>
</tr>
<tr>
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<td>Manure + limestone + superphosphate</td>
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<td>48.7</td>
<td>2.97</td>
<td>58.0</td>
<td>77.9</td>
<td>52.9</td>
<td>46.1</td>
<td>49.6</td>
<td>82.0</td>
<td>61.1</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>55.0</td>
<td>60.1</td>
<td>4.06</td>
<td>64.0</td>
<td>57.3</td>
<td>53.9</td>
<td>43.1</td>
<td>44.4</td>
<td>81.7</td>
<td>61.8</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>51.1</td>
<td>56.7</td>
<td>3.88</td>
<td>61.1</td>
<td>68.1</td>
<td>62.4</td>
<td>47.7</td>
<td>43.8</td>
<td>78.8</td>
<td>64.8</td>
</tr>
<tr>
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<td>38.0</td>
<td>32.8</td>
<td>4.12</td>
<td>43.7</td>
<td>41.1</td>
<td>38.3</td>
<td>31.8</td>
<td>33.8</td>
<td>50.5</td>
<td>51.9</td>
</tr>
</tbody>
</table>

(1) Plots 4, 5, 6, 7, 8 and 9 were planted a week early and freezes did considerable damage.
(2) Plots 1, 2, 3, 4 and 5 were spring plowed which killed 1928 sweet clover. Plots 6, 7, 8 and 9 were fall plowed in 1928; volunteer sweet clover damaged corn due to dry season.

*The Ruthven Field, Series I, was established in the fall of 1921 on the farm of F. A. McMullin, southeast of Ruthven, in Palo Alto County. It is located in the NW ¼ of the SE ¼ of Section 33, T. 96 N, R. 34 W in Highland Township.
The Webb Field

The results secured on the Clarion loam on the Webb Field, Series I, in Clay County are given in table XII. The application of manure increased the crop yields on this field in all seasons except 1931, the largest benefits appearing on the clover in 1925 and on the corn in 1926 and 1927. Lime with the manure increased the crop yields in practically all seasons. Lime, however, showed no large beneficial effects.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Treatment</th>
<th>1923 corn bu. per A.</th>
<th>1924 oats bu. per A.</th>
<th>1925 clover tons per A.</th>
<th>1926 corn bu. per A.</th>
<th>1927 corn bu. per A.</th>
<th>1928 oats bu. per A.</th>
<th>1929 clover and timothy tons per A.</th>
<th>1930 corn bu. per A.</th>
<th>1931 corn bu. per A. (1)</th>
<th>1932 oats bu. per A.</th>
</tr>
</thead>
<tbody>
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<td>71.1</td>
<td>1.10</td>
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<td>65.9</td>
<td>1.61</td>
<td>45.3</td>
<td>30.2</td>
<td>63.5</td>
</tr>
<tr>
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<td>Manure</td>
<td>60.4</td>
<td>77.6</td>
<td>1.26</td>
<td>33.6</td>
<td>45.1</td>
<td>68.1</td>
<td>1.73</td>
<td>45.4</td>
<td>29.0</td>
<td>60.7</td>
</tr>
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<td>Manure + limestone</td>
<td>60.8</td>
<td>78.7</td>
<td>1.38</td>
<td>35.8</td>
<td>44.4</td>
<td>68.1</td>
<td>1.73</td>
<td>45.4</td>
<td>28.8</td>
<td>68.1</td>
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<td>61.0</td>
<td>82.3</td>
<td>1.51</td>
<td>34.4</td>
<td>49.3</td>
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<td>29.6</td>
<td>41.5</td>
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<td>1.63</td>
<td>46.1</td>
<td>33.9</td>
<td>57.8</td>
</tr>
<tr>
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<td>Manure + limestone + superphosphate</td>
<td>62.6</td>
<td>84.7</td>
<td>1.54</td>
<td>36.6</td>
<td>53.7</td>
<td>70.4</td>
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<td>51.5</td>
<td>30.5</td>
<td>70.3</td>
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<tr>
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<td>Manure + limestone + superphosphate + muriate of potash</td>
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<td>79.5</td>
<td>1.65</td>
<td>37.8</td>
<td>58.1</td>
<td>81.7</td>
<td>2.54</td>
<td>50.9</td>
<td>30.0</td>
<td>66.9</td>
</tr>
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<td>Manure + limestone + complete commercial fertilizer</td>
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<td>63.5</td>
<td>1.63</td>
<td>42.7</td>
<td>32.8</td>
<td>53.3</td>
</tr>
</tbody>
</table>

(1) Hot, dry season.

*The Webb Field, Series I, was established in the fall of 1922 on the farm of George Grieve, near Webb, in Clay County. It is located in the SW ¼ of the SE ¼ of Section 17, T. 94 N, R. 35 W in Garfield Township.

Rock phosphate with manure and lime showed definite increases on the crops in some seasons, particularly on the clover in 1925 and the clover and timothy in 1929. No beneficial effects were evidenced on the corn in 1926 nor the oats in 1928. Superphosphate with manure and lime showed somewhat larger effects than rock phosphate in all seasons. The differences, however, were generally hardly large enough to be significant. The corn in 1927 and 1930 and the oats in 1928 were increased more by superphosphate than by rock phosphate.

Muriate of potash with manure, lime and superphosphate showed no beneficial effects of large significance. The clover in 1925 and the clover and timothy in 1929 were increased slightly. The oats in 1928 showed a considerable increase. The corn in 1927 was increased slightly.

The complete commercial fertilizer with manure and lime showed somewhat larger effects than superphosphate in most seasons. The clover in 1925 and and clover and timothy in 1929 were increased more by the complete commercial fertilizer. The differences in the other seasons, however, were not very large.

The Superior Field

The results secured on the Clarion loam on the Superior Field in Dickinson County are given in table XIII. The application of manure increased the crop yields in all seasons on this field. The largest effects from manure appeared on the corn in 1922 and 1926, on the oats in 1923 and on the clover in 1924.
TABLE XIII. FIELD EXPERIMENT, CLARION LOAM, DICKINSON COUNTY
SUPERIOR FIELD,* SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 corn</th>
<th>1923 oats</th>
<th>1924 oats</th>
<th>1925 corn</th>
<th>1926 corn</th>
<th>1927 barley</th>
<th>1928 clover</th>
<th>1929 corn</th>
<th>1930 barley</th>
<th>1931 corn</th>
<th>1932 barley</th>
</tr>
</thead>
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<td>32.1</td>
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<td>27.2</td>
<td>0.85</td>
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<td>38.0</td>
<td>39.7</td>
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</tr>
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<tr>
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<td>40.8</td>
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<td>43.7</td>
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<td>41.6</td>
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<td>1.00</td>
<td>32.3</td>
<td>46.1</td>
<td>40.1</td>
<td>36.7</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>43.3</td>
<td>64.7</td>
<td>1.58</td>
<td>49.2</td>
<td>53.0</td>
<td>48.2</td>
<td>1.42</td>
<td>34.9</td>
<td>54.1</td>
<td>40.7</td>
<td>48.4</td>
</tr>
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<td>71.4</td>
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<td>45.8</td>
<td>53.8</td>
<td>49.6</td>
<td>1.24</td>
<td>33.1</td>
<td>54.8</td>
<td>39.9</td>
<td>54.1</td>
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<td>Manure + limestone + complete commercial fertilizer</td>
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<td>1.67</td>
<td>45.5</td>
<td>48.6</td>
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<td>36.2</td>
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<td>0.76</td>
<td>32.8</td>
<td>42.7</td>
<td>40.1</td>
<td>35.5</td>
</tr>
</tbody>
</table>

(1) Clover winterkilled in spots.
(2) Very dry season; corn mostly nubbins but fairly well matured.
(3) Hot, dry season.

*The Superior Field, Series I, was established in the fall of 1921 on the farm of G. W. Small, south of Superior, in Dickinson County. It is located in the SE ¼ of the NW ¼ of Section 23, T. 99 N, R. 35 W in Richland Township.

Lime with manure increased the crop yields in most seasons, showing the largest effects on the clover in 1924 and on the sweet clover in 1928. Definite increases were also secured in other seasons, for example, on the barley in 1927 and 1930.

Rock phosphate with manure and lime brought about very large increases in the clover in 1924 and in the sweet clover in 1928. It showed increases also on the corn in 1925 and 1926 and on the oats in 1923. Superphosphate with manure and lime showed slightly larger effects than rock phosphate on the crops in 1926, 1927, 1928, 1929 and 1931 but had smaller effects than rock phosphate in the earlier years. Some of the differences were not very large.

Muriate of potash applied with manure, lime and superphosphate showed practically no influence except on the oats in 1923. In the other seasons the differences from the yields on the plots not receiving the muriate of potash were too small to be significant. The complete commercial fertilizer with manure and lime showed somewhat larger effects than superphosphate in one or two cases, but in other seasons had a smaller influence. Most of the differences were not significant.

The Storm Lake Field

The results secured on the Webster silty clay loam on the Storm Lake Field in Buena Vista County are given in table XIV. Manure brought about beneficial effects on the various crops grown, showing up particularly well on the clover and alfalfa. Considerable gains were noted also on some of the corn crops and the barley in 1925. The soil was not acid in reaction and hence no lime was applied.

Rock phosphate and superphosphate with manure increased all crop yields, the effect being particularly large with superphosphate on the corn in 1920 and
1926 and on the clover in 1922. Rock phosphate generally showed slightly less effect than superphosphate. The reverse was true, however, on the barley in 1925, the oats in 1918 and 1927 and the alfalfa in 1928 and 1929.

Muriate of potash with manure and superphosphate showed no beneficial effect on the crops in any season over that produced by superphosphate with manure. The complete commercial fertilizer gave slightly larger increases than superphosphate in several seasons. In other cases, the beneficial effects were not so large. In no case was there any considerable difference between the effects of the two materials.

The crop residues had little effect on the yields on this soil. Rock phosphate and superphosphate applied with the residues brought about some definite increases in yields, particularly on the corn in 1920, the barley in 1925 and the alfalfa in 1928 and 1929. In several cases, however, the phosphates did not seem to show any particularly large effect when applied without manure. The complete commercial fertilizer brought about larger effects than superphosphate in several instances but in other cases had less value. Muriate of potash applied with superphosphate and manure increased the crop yields in practically all seasons, showing the greatest effects on the alfalfa in 1928.

### TABLE XIV. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, STORM LAKE FIELD,* SERIES 1

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 oats bu. per A. (1)</th>
<th>1919 corn bu. per A.</th>
<th>1920 corn bu. per A.</th>
<th>1921 oats bu. per A.</th>
<th>1922 clover tons per A. (2)</th>
<th>1923 corn bu. per A. (3)</th>
<th>1924 corn bu. per A.</th>
<th>1925 barley bu. per A.</th>
<th>1926 corn bu. per A.</th>
<th>1927 oats bu. per A.</th>
<th>1928 alfalfa tons per A. (5)</th>
<th>1929 alfalfa tons per A. (5)</th>
<th>1930 alfalfa tons per A. (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>73.0</td>
<td>64.7</td>
<td>48.2</td>
<td>45.1</td>
<td>0.75</td>
<td>51.0</td>
<td>22.7</td>
<td>40.9</td>
<td>50.4</td>
<td>54.5</td>
<td>53.11</td>
<td>3.51</td>
<td>3.51</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>73.0</td>
<td>54.1</td>
<td>57.3</td>
<td>42.2</td>
<td>1.01</td>
<td>60.7</td>
<td>27.5</td>
<td>47.8</td>
<td>50.1</td>
<td>50.5</td>
<td>3.45</td>
<td>4.99</td>
<td>4.99</td>
</tr>
<tr>
<td>3</td>
<td>Manure+superphosphate+muriate of potash</td>
<td>73.0</td>
<td>57.6</td>
<td>58.1</td>
<td>36.3</td>
<td>1.29</td>
<td>65.1</td>
<td>29.2</td>
<td>56.9</td>
<td>53.6</td>
<td>39.4</td>
<td>13.51</td>
<td>5.31</td>
<td>5.31</td>
</tr>
<tr>
<td>4</td>
<td>Manure+rock phosphate</td>
<td>80.6</td>
<td>61.1</td>
<td>64.2</td>
<td>43.8</td>
<td>1.28</td>
<td>66.4</td>
<td>31.0</td>
<td>61.8</td>
<td>48.5</td>
<td>52.4</td>
<td>5.42</td>
<td>5.44</td>
<td>5.44</td>
</tr>
<tr>
<td>5</td>
<td>Manure+superphosphate</td>
<td>74.5</td>
<td>66.4</td>
<td>76.5</td>
<td>51.8</td>
<td>1.42</td>
<td>68.5</td>
<td>31.8</td>
<td>57.6</td>
<td>58.4</td>
<td>51.7</td>
<td>4.12</td>
<td>5.37</td>
<td>5.37</td>
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<tr>
<td>6</td>
<td>Manure+complete commercial fertilizer</td>
<td>82.0</td>
<td>61.1</td>
<td>80.0</td>
<td>43.8</td>
<td>1.43</td>
<td>66.8</td>
<td>33.9</td>
<td>60.7</td>
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<td>52.5</td>
<td>5.56</td>
<td>5.78</td>
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<td>70.0</td>
<td>71.5</td>
<td>66.6</td>
<td>40.9</td>
<td>1.10</td>
<td>55.5</td>
<td>34.0</td>
<td>44.5</td>
<td>45.8</td>
<td>54.3</td>
<td>3.88</td>
<td>4.08</td>
<td>4.08</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues+superphosphate+muriate of potash</td>
<td>76.0</td>
<td>70.1</td>
<td>67.2</td>
<td>41.1</td>
<td>1.25</td>
<td>70.7</td>
<td>35.7</td>
<td>64.4</td>
<td>52.8</td>
<td>51.2</td>
<td>5.08</td>
<td>5.54</td>
<td>5.54</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+rock phosphate</td>
<td>79.0</td>
<td>70.4</td>
<td>76.2</td>
<td>41.6</td>
<td>1.20</td>
<td>63.2</td>
<td>27.4</td>
<td>52.8</td>
<td>50.1</td>
<td>54.5</td>
<td>4.60</td>
<td>4.93</td>
<td>4.93</td>
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<tr>
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<td>Crop residues+superphosphate</td>
<td>73.0</td>
<td>64.0</td>
<td>76.2</td>
<td>45.5</td>
<td>1.23</td>
<td>63.1</td>
<td>31.1</td>
<td>58.2</td>
<td>49.6</td>
<td>47.0</td>
<td>4.81</td>
<td>5.56</td>
<td>5.56</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+complete commercial fertilizer</td>
<td>85.1</td>
<td>67.5</td>
<td>76.2</td>
<td>43.8</td>
<td>1.13</td>
<td>61.3</td>
<td>27.2</td>
<td>58.1</td>
<td>43.5</td>
<td>61.9</td>
<td>4.45</td>
<td>5.07</td>
<td>5.07</td>
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<td>67.5</td>
<td>67.7</td>
<td>39.7</td>
<td>0.80</td>
<td>51.9</td>
<td>23.1</td>
<td>41.6</td>
<td>34.9</td>
<td>49.5</td>
<td>2.52</td>
<td>3.13</td>
<td>3.13</td>
</tr>
</tbody>
</table>

(1) Soil basic; no manure added until 1919. Oats badly lodged.
(2) Superphosphate and muriate of potash (50 pounds per acre) applied to plots 3 and 9 in 1922.
(3) Hogs in corn damaged yield.
(4) Early frost left corn very chaffy and light, and practically none was marketable.
(5) Total of 3 cuttings.
(6) Field subject to flooding; soil not uniform. Series discontinued.

* The Storm Lake Field, Series I, was established in 1917 on the J. T. Edson farm, near Storm Lake, in Buena Vista County. It was located in the NE ¼ of the SE ¼ of Section 12, T. 50 N, R. 37 W in Hayes Township.
The Newell Field

The results secured on the Webster silty clay loam on the Newell Field in Buena Vista County are given in table XV. Applications of manure brought about large increases in all but one season, in 1926, when the yields were abnormal due to hot, dry weather. The effects of manure were evidenced on the corn and oats but particularly on the clover. Lime with manure gave slight increases in crop yields in several cases. The effects were not large, however, and since this soil is only slightly acid, no large influence from lime was expected.

Rock phosphate and superphosphate brought about increases in crop yields in practically all seasons. There were one or two exceptions, but in these cases the differences were small. The effects of the two materials showed up particularly well on the clover in 1925. Superphosphate had large effects on the clover

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn</th>
<th>1919 corn</th>
<th>1920 oats</th>
<th>1921 clover</th>
<th>1922 corn</th>
<th>1923 corn</th>
<th>1924 oats</th>
<th>1925 clover</th>
<th>1926 corn</th>
<th>1927 corn</th>
<th>1928 oats and barley</th>
<th>1929 alfalfa</th>
<th>1930 alfalfa</th>
<th>1931 alfalfa</th>
<th>1932 alfalfa</th>
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</thead>
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<td>69.0</td>
<td>44.8</td>
<td>56.7</td>
<td>53.0</td>
<td>68.7</td>
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<td>1.70</td>
<td>51.2</td>
<td>45.7</td>
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<td>64.1</td>
<td>60.0</td>
<td>70.5</td>
<td>65.6</td>
<td>1.97</td>
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<td>50.5</td>
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<td>2.67</td>
<td>4.02</td>
<td>4.75</td>
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<tr>
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<td>71.4</td>
<td>64.4</td>
<td>63.5</td>
<td>57.0</td>
<td>69.9</td>
<td>68.3</td>
<td>56.8</td>
<td>1.85</td>
<td>23.5</td>
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<td>74.1</td>
<td>61.4</td>
<td>69.7</td>
<td>0.70</td>
<td>74.1</td>
<td>69.3</td>
<td>63.5</td>
<td>2.04</td>
<td>46.4</td>
<td>31.4</td>
<td>4.36</td>
<td>2.04</td>
<td>3.94</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure+limestone +superphosphate</td>
<td>66.9</td>
<td>65.1</td>
<td>76.3</td>
<td>1.13</td>
<td>80.0</td>
<td>63.4</td>
<td>65.5</td>
<td>2.36</td>
<td>36.3</td>
<td>37.4</td>
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<td>2.57</td>
<td>3.67</td>
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<tr>
<td>6</td>
<td>Manure+limestone +complete commercial fertilizer</td>
<td>66.4</td>
<td>70.9</td>
<td>68.9</td>
<td>1.20</td>
<td>74.4</td>
<td>67.7</td>
<td>72.2</td>
<td>2.22</td>
<td>28.3</td>
<td>50.6</td>
<td>5.09</td>
<td>2.96</td>
<td>4.13</td>
<td></td>
<td></td>
</tr>
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<td>62.4</td>
<td>59.4</td>
<td>0.58</td>
<td>66.9</td>
<td>55.0</td>
<td>62.1</td>
<td>3.15</td>
<td>45.9</td>
<td>31.1</td>
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<td>2.01</td>
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<tr>
<td>8</td>
<td>Crop residues</td>
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<td>59.4</td>
<td>0.50</td>
<td>63.6</td>
<td>56.4</td>
<td>66.5</td>
<td>1.10</td>
<td>52.3</td>
<td>33.2</td>
<td>2.05</td>
<td>0.89</td>
<td>1.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+limestone</td>
<td>64.6</td>
<td>59.2</td>
<td>61.4</td>
<td>0.43</td>
<td>64.2</td>
<td>59.5</td>
<td>71.8</td>
<td>1.21</td>
<td>57.6</td>
<td>41.7</td>
<td>2.34</td>
<td>1.03</td>
<td>3.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>63.4</td>
<td>60.8</td>
<td>56.7</td>
<td>0.53</td>
<td>67.3</td>
<td>65.9</td>
<td>66.9</td>
<td>1.88</td>
<td>50.1</td>
<td>40.5</td>
<td>3.16</td>
<td>1.81</td>
<td>2.20</td>
<td></td>
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</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>62.4</td>
<td>68.5</td>
<td>72.0</td>
<td>0.90</td>
<td>67.3</td>
<td>64.1</td>
<td>69.3</td>
<td>2.08</td>
<td>58.6</td>
<td>52.1</td>
<td>4.19</td>
<td>2.31</td>
<td>2.12</td>
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</tr>
<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>61.3</td>
<td>65.3</td>
<td>71.3</td>
<td>0.93</td>
<td>67.0</td>
<td>65.8</td>
<td>...</td>
<td>2.99</td>
<td>47.5</td>
<td>48.5</td>
<td>4.71</td>
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<td>2.28</td>
<td>4.43</td>
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<td>65.3</td>
<td>60.1</td>
<td>0.58</td>
<td>66.2</td>
<td>60.9</td>
<td>1.78</td>
<td>54.9</td>
<td>45.5</td>
<td>2.44</td>
<td>1.17</td>
<td>2.09</td>
<td>3.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) No limestone applied to plots until the fall of 1920.
(2) Plots 1, 2, 12 and 13 cut before field man arrived at field.
(3) Mixture of red clover and biennial white sweet clover.
(4) Corn cut early due to hot, dry season, average moisture content 37.5 percent which accounts for varying yields.
(5) Corn replanted due to damage by alkali, second planting also damaged. Corn immature when frost came; high moisture content accounts for varying yields.
(6) Mixture of oats and barley grown; no attempt to figure yield in bushels per acre.
(7) Low wet area on plots 1, 2 and 3 responsible for high yields, also high alkali content on these plots which seemed to favor the growth of alfalfa. Total of 3 cuttings.
(8) Same conditions on plots 1, 2 and 3 as in 1929. Total of 2 cuttings.

* The Newell Field was established in the fall of 1917 on the farm of George Boyce, near Newell, in Buena Vista County. It is located in the SW corner of the NW 1/4 of the SW 1/4 of Section 20, T. 90 N, R. 35 W in Newell Township.
in 1921 and on the alfalfa in 1929. The influence on the corn in 1922 and on the oats in 1920 was definite. In most cases superphosphate seemed to be somewhat preferable to rock phosphate. In 1918, 1923 and 1926, however, rock phosphate gave better yields than superphosphate. The yields on the plots in 1926, 1927, 1930 and 1931 were very evidently abnormal owing to unfavorable seasonal conditions. The complete commercial fertilizer showed slightly larger effects than superphosphate in one or two cases, but in general superphosphate gave quite as large or even larger increases in crop yields.

The crop residues had small effects on the yields on this soil as would be expected. Lime with the residues gave slight increases in crop yields in several cases. The differences were not large, however, except on the clover in 1925 and the alfalfa in 1929.

Rock phosphate, superphosphate and complete commercial fertilizer showed beneficial effects in some cases on the various crops grown. The clover in 1925 showed a particularly large benefit from the use of the phosphate materials. Similarly, in 1921, the clover was increased to a large extent by both superphosphate and the complete commercial fertilizer, and in 1929 and 1930 the alfalfa showed very large benefits from both the phosphates and the complete commercial fertilizer. Superphosphate and complete fertilizer both increased the oat yield to a large extent in 1920 and had a beneficial effect on the corn in 1919 and 1927. In some of the other seasons, as in 1922 and 1923, the three materials gave practically identical effects, all showing increases over the crop residues and lime alone.

The Lundgren Field

The results secured in the experiment on the Webster loam on the Lundgren Field in Webster County are given in table XVI. Manure increased crop yields in most cases on this soil, the greatest effects appearing on the clover in 1926. Considerable gains were also obtained in many seasons on the corn and oats. Lime applied with manure proved beneficial in most seasons, but the increases from it usually were not large. As this soil is very slightly acid in reaction and the subsoil is usually well supplied with lime, no large effects from lime were expected.

Rock phosphate, superphosphate and the complete commercial fertilizer brought about considerable increases in crop yields in some cases. Thus, on the corn in 1919, 1920, 1924, 1927 and 1930 definite gains were noted. Similarly, there were gains on the oats in 1923, 1925, 1929 and 1931. The clover in 1926, however, showed the greatest benefit from these fertilizers. Superphosphate generally had somewhat greater effects than rock phosphate as in 1919, 1923, 1924, 1925, 1926, 1927 and 1928, but in the other seasons rock phosphate was just as good or even slightly better in effect. The complete commercial fertilizer showed a greater effect than superphosphate in a few cases but in most seasons it had no greater or even a smaller influence than superphosphate.

The crop residues had little effect on the various crops grown until 1922, some gains being noted, especially on the corn in 1919. Lime with the residues increased the yields in most seasons, but no large effects were evidenced. In some cases no effects from the lime appeared.
**TABLE XVI. FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY**  
**LUNDGREN FIELD,* SERIES I**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 oats</th>
<th>1919 bi.</th>
<th>1920 corn</th>
<th>1921 oats</th>
<th>1921 corn</th>
<th>1922 bi.</th>
<th>1924 oats</th>
<th>1925 corn</th>
<th>1925 clover</th>
<th>1927 corn</th>
<th>1928 oats</th>
<th>1928 corn</th>
<th>1930 corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>93.5</td>
<td>59.0</td>
<td>63.8</td>
<td>32.9</td>
<td>57.7</td>
<td>43.1</td>
<td>29.0</td>
<td>46.8</td>
<td>0.44</td>
<td>47.8</td>
<td>48.6</td>
<td>57.8</td>
<td>39.9</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>85.0</td>
<td>58.3</td>
<td>62.4</td>
<td>37.8</td>
<td>55.5</td>
<td>48.8</td>
<td>33.9</td>
<td>47.4</td>
<td>0.71</td>
<td>52.1</td>
<td>49.6</td>
<td>63.5</td>
<td>56.1</td>
</tr>
<tr>
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<td>Manure+limestone</td>
<td>89.2</td>
<td>60.6</td>
<td>65.3</td>
<td>32.9</td>
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<td>0.68</td>
<td>53.7</td>
<td>47.4</td>
<td>58.9</td>
<td>53.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure+rock phosphate</td>
<td>85.0</td>
<td>61.3</td>
<td>69.3</td>
<td>38.7</td>
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<td>0.77</td>
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<td>39.9</td>
<td>70.3</td>
<td>62.1</td>
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<tr>
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<td>Manure+superphosphate</td>
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<td>67.2</td>
<td>35.8</td>
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<td>60.9</td>
<td>46.3</td>
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<tr>
<td>6</td>
<td>Manure+limestone +complete commercial fertilizer</td>
<td>80.7</td>
<td>71.4</td>
<td>62.4</td>
<td>35.6</td>
<td>57.4</td>
<td>62.5</td>
<td>33.5</td>
<td>52.0</td>
<td>0.77</td>
<td>54.3</td>
<td>39.9</td>
<td>65.1</td>
<td>56.6</td>
</tr>
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<td>65.1</td>
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<td>35.8</td>
<td>54.9</td>
<td>58.0</td>
<td>40.0</td>
<td>53.2</td>
<td>1.14</td>
<td>60.9</td>
<td>46.3</td>
<td>64.6</td>
<td>64.5</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues+superphosphate+</td>
<td>82.9</td>
<td>63.3</td>
<td>57.7</td>
<td>39.8</td>
<td>50.1</td>
<td>57.8</td>
<td>42.8</td>
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<td>54.9</td>
<td>58.0</td>
<td>40.0</td>
<td>53.2</td>
<td>1.14</td>
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<td>46.3</td>
<td>64.6</td>
<td>64.5</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>87.1</td>
<td>65.9</td>
<td>68.9</td>
<td>31.8</td>
<td>51.6</td>
<td>52.2</td>
<td>26.5</td>
<td>48.1</td>
<td>0.68</td>
<td>53.9</td>
<td>39.4</td>
<td>70.3</td>
<td>63.5</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>97.7</td>
<td>70.7</td>
<td>68.6</td>
<td>36.4</td>
<td>54.8</td>
<td>62.5</td>
<td>23.4</td>
<td>45.0</td>
<td>0.86</td>
<td>56.5</td>
<td>40.9</td>
<td>79.4</td>
<td>66.2</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>93.5</td>
<td>73.9</td>
<td>65.2</td>
<td>39.9</td>
<td>56.1</td>
<td>62.5</td>
<td>31.8</td>
<td>44.5</td>
<td>0.64</td>
<td>54.8</td>
<td>41.9</td>
<td>73.7</td>
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<td>54.2</td>
<td>57.7</td>
<td>35.0</td>
<td>52.1</td>
<td>48.2</td>
<td>26.0</td>
<td>37.6</td>
<td>0.32</td>
<td>44.1</td>
<td>43.9</td>
<td>61.2</td>
<td>46.0</td>
</tr>
</tbody>
</table>

(1) Limestone not applied to series until fall of 1921.  
(2) Superphosphate and muriate of potash added to plot 8 beginning with 1922 corn crop.  
* The Lundgren Field was established in the fall of 1917 on the Nels Olson farm, near Lundgren, in Webster County. The series is located on the north side of the NW 1/4 of the SW 1/4 of Section 36, T. 88 N, R. 29 W in Elk Horn Township.

Rock phosphate, superphosphate and complete commercial fertilizer with the crop residues and lime brought about some definite increases in crop yields, but in other cases had no effect. The oats in 1918, 1923, 1929 and 1931 were increased. The corn in 1919, 1920, 1922, 1927 and 1930 was increased. The clover in 1926 showed a gain. Superphosphate had a greater effect than rock phosphate in practically all cases, showing up particularly well on the oats in 1918, 1923, 1929 and 1931 and on the clover in 1926. In a few cases rock phosphate had a little greater effect than superphosphate, but the differences were never large. The complete commercial fertilizer had somewhat greater effects than superphosphate in some instances, but in general the results were similar with the two materials. Muriate of potash with superphosphate and crop residues showed no larger effect than superphosphate alone, or brought about only small increases.

**The Everly Field—Series II—Lamoure Silty Clay Loam**

The results secured in the field experiment on the Lamoure silty clay loam in the Everly Field, Series II, in Clay County are shown in table XVII. The
beneficial effects of farm manure on this soil are definitely shown. Large increases in crop yields were secured in practically every season. Beneficial effects were very large in the case of the corn in 1924, the oats in 1922 and 1926, the clover in 1923 and the alfalfa in 1927, 1928, 1929 and 1930.

Rock phosphate or superphosphate with manure increased the yields in most seasons. Beneficial effects were noted particularly on the alfalfa, on the oats in 1922 and 1926, on the clover in 1919 and 1923 and on the corn in 1924. In other seasons when corn was grown, no large effects were shown. Superphosphate showed up much better than rock phosphate on the clover, alfalfa and oats.

The complete commercial fertilizer applied with manure showed smaller effects than superphosphate in all seasons. The addition of muriate of potash with superphosphate did not show any pronounced effects. In fact, in most cases there was no indication of value from the potash.

Crop residues increased the crop yields in several seasons, but the increases were small and hardly significant. Rock phosphate or superphosphate with the

### TABLE XVII. FIELD EXPERIMENT, LAMOURE SILTY CLAY LOAM, CLAY COUNTY EVERLY FIELD,* SERIES II

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 oats bu. per A.</th>
<th>1919 clover tons per A.</th>
<th>1920 clover bu. per A. (1)</th>
<th>1921 oats bu. per A.</th>
<th>1922 clover tons per A.</th>
<th>1923 clover bu. per A.</th>
<th>1924 alfalfa tons per A.</th>
<th>1925 alfalfa tons per A.</th>
<th>1926 oats bu. per A.</th>
<th>1927 alfalfa tons per A. (3)</th>
<th>1928 alfalfa tons per A. (4)</th>
<th>1929 corn bu. per A.</th>
<th>1930 alfalfa tons per A. (5)</th>
<th>1931 corn bu. per A.</th>
<th>1932 corn bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>63.8</td>
<td>74.6</td>
<td>65.8</td>
<td>35.6</td>
<td>0.57</td>
<td>38.1</td>
<td>57.9</td>
<td>47.4</td>
<td>105</td>
<td>2.03</td>
<td>1.63</td>
<td>1.22</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>91.2</td>
<td>1.45</td>
<td>45.2</td>
<td>54.1</td>
<td>0.71</td>
<td>58.2</td>
<td>68.6</td>
<td>62.9</td>
<td>1.43</td>
<td>2.94</td>
<td>3.26</td>
<td>1.64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure+superphosphate+muriate of potash</td>
<td>100.3</td>
<td>1.60</td>
<td>83.2</td>
<td>75.8</td>
<td>1.83</td>
<td>69.4</td>
<td>58.8</td>
<td>76.8</td>
<td>2.82</td>
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<td>4</td>
<td>Manure+rock phosphate</td>
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<td>1.67</td>
<td>83.2</td>
<td>70.0</td>
<td>1.25</td>
<td>61.7</td>
<td>55.1</td>
<td>76.8</td>
<td>1.82</td>
<td>4.54</td>
<td>4.87</td>
<td>2.25</td>
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<td></td>
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<tr>
<td>5</td>
<td>Manure+complete commercial fertilizer</td>
<td>88.2</td>
<td>2.03</td>
<td>80.8</td>
<td>68.1</td>
<td>1.75</td>
<td>67.2</td>
<td>55.8</td>
<td>83.0</td>
<td>3.26</td>
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<td>2.82</td>
<td></td>
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<tr>
<td>6</td>
<td>Manure+complete commercial fertilizer</td>
<td>100.3</td>
<td>1.79</td>
<td>80.8</td>
<td>63.2</td>
<td>1.26</td>
<td>60.8</td>
<td>54.0</td>
<td>71.1</td>
<td>3.00</td>
<td>4.82</td>
<td>5.85</td>
<td>2.88</td>
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<td>1.34</td>
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<tr>
<td>8</td>
<td>Crop residues</td>
<td>69.9</td>
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<td>54.7</td>
<td>52.8</td>
<td>0.87</td>
<td>39.6</td>
<td>45.4</td>
<td>53.4</td>
<td>1.02</td>
<td>2.76</td>
<td>2.24</td>
<td>1.40</td>
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<tr>
<td>9</td>
<td>Crop residues+superphosphate+muriate of potash</td>
<td>73.0</td>
<td>1.56</td>
<td>70.4</td>
<td>61.9</td>
<td>1.47</td>
<td>56.5</td>
<td>44.2</td>
<td>71.6</td>
<td>2.36</td>
<td>4.32</td>
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<td>2.28</td>
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<td></td>
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<tr>
<td>10</td>
<td>Crop residues+rock phosphate</td>
<td>79.0</td>
<td>1.68</td>
<td>73.6</td>
<td>60.4</td>
<td>1.14</td>
<td>61.2</td>
<td>42.2</td>
<td>72.4</td>
<td>1.24</td>
<td>3.55</td>
<td>3.71</td>
<td>2.33</td>
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<tr>
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<td>Crop residues+superphosphate</td>
<td>97.3</td>
<td>1.56</td>
<td>83.4</td>
<td>60.8</td>
<td>1.59</td>
<td>57.7</td>
<td>44.7</td>
<td>77.6</td>
<td>2.28</td>
<td>3.99</td>
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<td>2.51</td>
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<tr>
<td>12</td>
<td>Crop residues+complete commercial fertilizer</td>
<td>103.4</td>
<td>2.03</td>
<td>77.8</td>
<td>64.7</td>
<td>1.73</td>
<td>56.4</td>
<td>57.7</td>
<td>76.5</td>
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<tr>
<td>14</td>
<td>Manure</td>
<td>97.3</td>
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<td>0.83</td>
<td>35.7</td>
<td>53.5</td>
<td>50.4</td>
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<td>2.04</td>
<td>1.75</td>
<td>0.98</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Plots 2 and 8 not harvested.
(2) Superphosphate and potassium added to plots 3 and 9.
(3) Total of 2 cuttings.
(4) Total of 3 cuttings.
(5) Corn replanted: hot, dry season; very poor corn.
(6) Plots 1, 2 discontinued. Plot 14 added.

* The Everly Field, Series II, was established in the fall of 1917 on the farm of John Heuck, east of Everly, in Clay County. The series is located on the north side of the NW ¼ of the NE ¼ of Section 1, T. 96 N, R. 38 W in Lone Tree Township.
residues brought about increases in crop yields in most seasons. In general the gains were large as on the clover in 1923 and on the alfalfa. The oats and corn also showed beneficial effects in some seasons. Superphosphate generally gave better results than rock phosphate on the various crops grown on this field. The differences were particularly noted on the alfalfa in 1923, on the clover in 1922 and 1926 and on the corn in 1920. Superphosphate and muriate of potash with the crop residues brought about increases similar to those occasioned by superphosphate alone. In only one case was there any pronounced difference in favor of muriate of potash with superphosphate. This was with the alfalfa in 1928. The complete commercial fertilizer applied with the residues increased the yields in practically all seasons. Large beneficial effects were noted on the clover in 1919 and 1923 and on the alfalfa. On these crops the effects were greater than with superphosphate. The complete fertilizer also proved more effective on the oats in 1922, on the corn in 1921 and 1925. In the other cases the differences were small but slightly in favor of the phosphates.

**PEAT AND MUCK SOILS**

Peat or muck is partially rotted vegetable matter which consists either of swamp grasses, sedges, rushes and flags or of a sphagnum moss, the former being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes or flat undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits only very incomplete decomposition. Muck is an advanced stage in the decomposition of peat. Peat and muck occur in Iowa mainly in the Wisconsin drift soil area. Calhoun County is located in this area and has several areas of muck, aggregating 4,480 acres or 1.2 percent of the county.

The muck in Calhoun County is generally from 6 to 20 inches in thickness and in no area does it extend to a depth of more than 3 feet. Practically all the muck soils in the county may be reclaimed and made productive by proper methods of treatment and cropping.

**Field Experiments on Peat and Muck Soils**

Field experiments were carried out several years ago on some typical shallow peats. In no case was there any profitable increase in crop yields from the use of various fertilizing materials. Recent tests, however, have shown distinctly profitable increases from the use of muriate of potash or superphosphate on shallow peats or mucks. Sometimes the phosphate is the more effective. At other times the potash gives the better results. Tests of these two fertilizers on the peat and muck soils in Calhoun County are recommended.

**Treatment of Peat and Muck Soils**

Drainage is the most important treatment needed for peat and muck soils in Calhoun County if they are to be made productive. Sufficient tile of ample size should be provided and special drains installed to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall. The

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

Fall plowing is desirable to expose the peat or muck to the action of the frost, rain and snow during the winter and hasten decay. Fall-plowed peats or mucks may be worked earlier in the spring, hence the seedbed may be more thoroughly prepared. Deep plowing is also valuable, especially when the peat or muck is very shallow, and some of the underlying heavy clay may be mixed with the peat or muck.

Peat or muck soils which are not over 16 inches deep should not be rolled as such an operation may compact them too much and check decomposition. Where the peat or muck is deeper than this, careful rolling may be desirable. The practice cannot be generally recommended.

The frequent cultivation of peat or muck soils is very important in opening them up and hastening the decay of the organic matter.

Applications of manure are not advisable on peat or muck soils. Frequently the addition of superphosphate or muriate of potash or both may be advisable, especially where truck crops are grown. Tests of these fertilizers are desirable.

Corn and small grain crops, as a rule, do not do well on newly reclaimed peat and muck soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. A mixture of timothy and alsike clover is one of the best crops to seed on newly reclaimed peats and mucks, using the crop for pasture preferably. Many vegetables such as onions, celery, potatoes, tomatoes, cabbage, beets, turnips and other crops may be grown satisfactorily on peat or muck soils, especially when properly fertilized. After a few years of pasturing or growing fertilized vegetable crops the soils are usually in better condition for growing corn and small grains successfully.

"ALKALI" SOILS

There are areas of so-called "alkali" soils in Calhoun County, and while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the soil the appearance of having been lightly strewn with a fine white powder. The spots occur in swales, ponds or sloughs which have recently been drained. They do not occur in the lower parts of the sloughs but always in a belt around the low spot which frequently consists of peat. Corn produces only a stunted growth on such spots while other crops are less affected.

Treatment of "Alkali" Soils

The first treatment needed for the reclamation of "alkali" soils in Iowa is proper drainage. In draining a pond or slough, lines of tile should be laid around the low area in such a way that the two lines run through the spot where the "alkali" is most likely to appear, and thus will permit more rapid washing
out of the excess salts. The lines of tile may be brought together again below the slough, and if the area is wide, a third line of tile through the center of the slough may be advisable.

If the tile are properly laid when a pond or slough is drained, the occurrence of "alkali" spots may frequently be prevented. When an "alkali" spot is fully developed, the removal of excess "alkali" salts by proper drainage is hastened by the application of heavy dressings of farm manure, the use of straw or any vegetable matter or a crop of sweet clover plowed under. The application of 200 pounds per acre of muriate of potash has been found\(^3\) to be of value on these alkali soils. Tests of the effect of this fertilizer are very desirable.

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

The results of the laboratory, greenhouse and field experiments which have been described earlier in this report indicate the fertilizer treatments which will be most worth while for use on the soils of this county. A few general recommendations may be made at the present time, therefore, for handling the various soils. The suggestions which are made in the following pages are based upon the results of the experiments conducted on the different soil types and also upon the experiences of many farmers. Only such treatments as have proved of value by practical tests will be proposed, and any of the treatments may be put into operation on any farm.

MANURING

The majority of the soils in Calhoun County are rich in organic matter and black in color and not in need of applications of organic materials in large amounts, at least in the immediate future. Some of the soils, however, are not so rich in organic matter, and this is indicated in the lighter color of the surface soil. The Webster soils on the uplands are very dark in color and high in organic matter. This is particularly true of the Webster silty clay loam. The Clarion soils, the Dickinson and the Pierce soils are not so rich, and hence they are not so dark in color. The Dickinson and Pierce soils are poorer than the Clarion types. The Fargo clay on the terraces is very high in organic matter and black in color. The Waukesha loam is higher than the Sioux and Benoit loams, and it is darker in color but not so dark as the Fargo clay. The Lamoure and Wabash soils on the bottoms are richer than the Cass soil. On the lighter colored soils the need of additions of fertilizing materials supplying organic matter is evident now, but even on those soils which are richer in organic matter, organic fertilizing materials must be used regularly if the supply is to be kept up. The Dickinson, Pierce, Sioux, O'Neill, Benoit and Cass soils would respond in a large way now to the use of organic fertilizing materials. But the Clarion and Webster, the Waukesha and the Wabash and Lamoure soils will also be benefited by the use of organic materials, especially farm manure, although only small amounts should be used on these soils.

The use of farm manure is very desirable on the livestock farm to keep up the supply of organic matter in the soil. If all the manure produced is properly preserved and applied to the land, it will go far toward maintaining the supply. Large beneficial effects appear on the crops grown. Tests described earlier in this report have shown the value of farm manure on the Webster silty clay loam, the Clarion loam, the Webster loam and the Lamoure silty clay loam. Many of the other soils in the county would undoubtedly show just as great or even greater effects from the application of farm manure, as some of these soils tested are among the richest types in the county. It is apparent that the addition of manure is of value on all the soils, larger applications being made to the lighter-colored, sandy types while only small applications should be made to the richer, blacker soils. Regular additions should be made to these soils, however, if the supply of organic matter is to be kept up.
On most livestock farms, the amount of farm manure produced is not sufficient to permit applications regularly to all the land on the farm, and on grain farms there is, of course, little or no farm manure produced. In both cases some other source of organic matter must be sought. In such cases it is very desirable to utilize leguminous crops as green manures. The practice of green manuring not only supplies organic matter to the land but also adds nitrogen. When they are well inoculated, legumes take much of their nitrogen from the atmosphere and hence, when they are turned under as a green manure, they act as a nitrogenous fertilizer. On many of the soils in Calhoun County, green manuring is to be recommended, especially on the lighter, sandy types. Green manuring should never be practiced blindly nor carelessly, however, as the effects may be distinctly unfavorable if the green materials are not properly decomposed in the soil.

The thorough utilization of all the crop residues on the farm plays an important part in the maintenance of the organic matter in the soil. On the livestock farm these materials should be used for feed or bedding and returned to the land with the manure. On grain farms, they may be stored and allowed to decompose partially or they may be applied directly to the soil.

**LIMING**

Most of the soils in Calhoun County are acid in reaction at least in the surface soil, and hence in need of lime if the best growth of general farm crops, and especially of legumes, is to be secured. The Webster silty clay loam often shows a small content of lime in the surface soil, but in other cases it is acid in reaction at the surface, although the lower soil layers are well supplied with lime. The Benoit and Fargo soils on the terraces show lime in the surface soil and throughout the lower soil layers. The Lamoure and Cass soils on the bottomlands contain lime in the surface soil, and in the case of the Lamoure throughout the subsoil. With the exception of these types, and also the steep phase of the Clarion loam which has a high amount of lime in the lower soil layers and often in the surface soil, the soils of the county are acid in reaction in the surface soil and in need of lime.

The results of the analysis reported in table IV show the lime requirements of the acid soils of the county. They do not show exactly the amounts of lime which should always be applied to the same types, however, as soils vary widely in lime needs, and even soils of the same type from different areas will vary in lime requirements. The safest plan to follow in order to insure the proper application of lime is to test the particular soil. Farmers may test their own soils, but it will usually prove more satisfactory if they will send a small sample to the Soils Subsection of the Iowa Agricultural Experiment Station and have it tested free of charge. All the soils in the county except the Benoit and Fargo on the terraces and the Lamoure on the bottoms should be tested for lime needs especially before seeding to legumes. Only by testing can the proper amount of lime to apply be determined.

General farm crops do not yield as well on acid soils as they do on soils containing lime, or those slightly basic in reaction. Such crops as sweet clover and alfalfa may not grow at all on acid soils. Most other crops show large
increases when lime is applied to acid soils. The legumes are, of course, benefited the most, but surprisingly large gains in corn and small grain crops are often obtained. Even if only the surface soil is acid the addition of lime may bring about large effects on the growth of legumes. The tests referred to earlier in this report have shown the value of liming Clarion loam, Webster silty clay loam (when it is acid) Webster loam and other soil types. The remaining acid soils in the area would respond to quite as large an extent to the use of lime. Many tests and the experiences of many farmers have shown the value of liming acid soils.

The use of lime is necessary on acid soils, at regular intervals to keep up the supply. One application may last for several years, but the best plan to follow is to test the soil once in the rotation, just preceding the growing of the legume crop. Then the lime may be applied as needed and at a point in the rotation where it will give the best effects.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Calhoun County have shown that the phosphorus content is rather low. It is evident, therefore, that phosphorus fertilizers will be needed on these soils in the very near future, even if they are not of value at present. It seems likely that some phosphorus fertilizer might be used on the soils of the county, with profitable effects, now.

The two fertilizers which are available on the market to supply phosphorus are rock phosphate and superphosphate. Rock phosphate is usually applied at the rate of 1,000 pounds or possibly 500 pounds per acre once in 4 years. The larger amount is usually used. Superphosphate is added at the rate of 120 pounds per acre annually, 3 years out of 4 in the 4-year rotation. Superphosphate contains phosphorus in a form immediately available to plants, while the element in rock phosphate must be changed into an available form before it can be utilized. Hence superphosphate gives immediate effects when it is used, while rock phosphate usually shows its greatest effect the second year after it is applied. The cost of the two fertilizers is different, superphosphate being more costly, but the smaller application means a lower cost for the actual treatment. Hence rock phosphate must bring about much larger effects on crop yields, over a 4-year rotation, if it is to prove as economically desirable as superphosphate.

The tests reported on earlier and the experiences of farmers have shown that one or the other of these phosphates may be applied to the Webster silty clay loam, the Clarion loam, the Webster loam or the Lamoure silty clay loam with profitable effects. The influence on other types, especially some of the poorer ones, would undoubtedly be even greater. Sometimes rock phosphate gives the better results, and in other cases superphosphate proves more desirable. It is impossible, therefore, at the present time, to make any definite recommendations regarding the use of these two materials. Farmers are urged to test both phosphates on their own farms, and thus determine for their particular conditions which material should be used.

Most of the soils in the county are not strikingly deficient in nitrogen, but in some cases the supply is not high and a need for nitrogen may be evident now. In any case, however, nitrogen must not be overlooked when systems of perma-
nent fertility are planned. Nitrogen is lost from soils regularly by removal in the crops and by leaching in the drainage waters. Some fertilizing materials supplying nitrogen must be used on all soils, therefore, at regular intervals if the supply is to be kept up.

The thorough utilization of all the crop residues and of the farm manure produced, aids materially in keeping up the nitrogen content of soils. The turning under of leguminous crops as green manures is the cheapest and best means of supplying nitrogen to the land. On all farms the practice of green manuring is a desirable one, to supplement the use of farm manure and crop residues. Legumes, if well inoculated, take a large part of their nitrogen from the atmosphere, and hence when they are plowed down they add this nitrogen to the soil. Thus the nitrogen supply in the soil may be built up and maintained without the use of expensive commercial nitrogenous fertilizers. For special crops, such fertilizers may give profitable effects, but for general farm crops they cannot be recommended. They should never be used on an extensive scale until they are tested on small areas and their value determined.

Commercial potassium fertilizers may have beneficial effects on the crops grown in some cases, but their general use for the common farm crops cannot be recommended. They have been found to be of definite value on peat and muck soils and on alkali spots. But on normal soils they should not be employed extensively until they have been tested and their value proved. When it has been shown that they give good effects, then they may be applied to large areas with assurance of profit.

Many tests have been carried out comparing complete commercial fertilizers with superphosphate, and some of the results secured in such experiments have been shown in this report. In general it appears that superphosphate will give quite as large crop increases or even greater in some cases, and rock phosphate often proves just as effective. As the complete commercial fertilizers cost much more than the phosphates, they must bring about much larger effects on crops if they are to prove as desirable for use. It seems that they do not prove as profitable for general use as the phosphates. At any rate tests should always be carried out on small areas in comparison with superphosphate before extensive applications are made. There is no objection to the use of complete commercial fertilizers; it is merely a question of profit.

DRAINAGE

The natural drainage system of Calhoun County is poor, but there has been so much work done in extending the system and improving the drainage artificially that most of the land in the county is now adequately drained. On the level to depressed areas of Webster soils, particularly the Webster silty clay loam, the drainage is naturally poor. Some areas in the Clarion loam are also poorly drained. The Fargo clay on the terraces is poorly drained. The Lamoure and Wabash types on the bottoms are also poorly drained. The muck soils are often not adequately drained. The bottomland soils are also subject to overflow and must be protected from flood waters as well as drained if they are to be cultivated.

Wherever drainage conditions are not entirely satisfactory, the installation of tile will be of value. It is impossible to obtain satisfactory crop yields on land
which is too wet. While most areas of land in the county are now well taken
care of, it is possible that there may be individual areas where more adequate
drainage should be provided. In such cases it will be worth while to make the
installation. In many cases the installation of tile may make the difference
between no crop at all and a very satisfactory yield.

ROTATION OF CROPS

The continuous growing of any one crop very quickly reduces the fertility
of the soil and eventually may make it entirely unproductive. A good rotation
always helps to keep up the fertility of the soil and makes it possible to secure
high crop yields.

Various crop rotations may be employed with good results. Almost any ro­
tation may be used, provided it contains a legume and the money crops, all of
which must be suited to the soil, climate and seasonal conditions. The following
are suggested as good rotations in Iowa:

1. Six-Year Rotation

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

This rotation may be reduced to a 5-year rotation by cutting out either the
second or sixth year and to a 4-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 clover and timothy)
Fourth year—Clover (if timothy was seeded with the clover, the last crop will consist princi­
pally of timothy and the rotation will become a 5-year one)

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 for 5 years. The field should then
be used for the 4-year rotation, outlined above.)

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)
Third year—Clover
First year—Corn
Second year—Oats or wheat (with sweet clover)
Third year—Sweet clover (The clover may be used for pasture or green manure. Plowing under the clover makes this a 2-year rotation.)

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

THE PREVENTION OF EROSION

Erosion is the carrying away of the surface soil by the free movement of water over the land. There are two types of erosion, sheet washing and gully ing. Sheet erosion is the washing away of the surface soil. Gully ing is more striking in appearance since gullies or ravines may be formed.

There is some erosion in Calhoun County in the Clarion loam areas. Where the steep phase of this type occurs, considerable erosion has occurred. Some of the other types show the occurrence of erosion. Wherever the destructive action is found, some means must be taken to prevent the formation of gullies and the carrying away of the surface soil by washing.

Various methods are followed to control and prevent erosion in Iowa. These methods differ somewhat depending upon the type of erosion. Erosion due to dead furrows may be controlled by "plowing in," by "staking in" or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven-wire dams or concrete dams. They may be prevented from occurring by thorough drainage or by the use of sod strips. Large gullies may be similarly filled or prevented from occurring. Erosion in bottomlands may be prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion may be controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.4

INDIVIDUAL SOIL TYPES IN CALHOUN COUNTY

There are 17 individual soil types in the county, and these with the steep phase Clarion loam and the areas of muck and shallow phase muck make a total of 20 separate soil areas. They are divided into drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are 6 drift soils in the county and with the steep phase Clarion loam, 7 drift areas. Together they cover 93.5 percent of the county. The soils are mapped in the Webster, Clarion, Pierce and Dickinson series.

Webster Silty Clay Loam (107)

The Webster silty clay loam is the largest soil type in the county and the largest drift soil, covering 39.1 percent of the county. It occurs in extensive areas in all parts of the county. There are few farms which do not include some areas of this soil, and many consist almost entirely of it.

The surface soil of the Webster silty clay loam is a very dark grayish-brown to nearly black silty clay loam, extending to a depth of about 8 inches. From 8 to 28 inches there is a very dark grayish-brown silty clay of a granular structure. In the heavier phases of the type the clay is so highly plastic or waxy that the farmers call it gumbo. In many places the lower part of this layer is highly calcareous, and in some areas the calcareous material extends up through the surface soil. Between 28 and 40 inches there is a very heavy calcareous silty clay, gray in color mottled with yellow and brown. In sloughs and depressions the color is a dark bluish-drab. Below 40 inches the subsoil is a silty clay or silty clay loam somewhat more friable than the layer above. In places below 3 or 4 feet, lime has accumulated in flakes and nodules and rusty-brown stains often occur. In many areas there is an occurrence of alkali salts on the surface of the soil.

Most of the Webster silty clay loam is under cultivation, and general farm crops are grown. Only in such limited areas as are poorly drained is the soil uncultivated. Corn gives very high yields on well drained areas, averaging 50

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

Calhoun County adjoins 5 Iowa counties that have previously been surveyed. In places the soils as mapped in Calhoun County do not have the same names as those mapped in adjoining counties. For example, by a change in definition the Carrington soils mapped in Greene and Carroll counties are combined with the Clarion soils of Calhoun County. The designations of a few minor types have also been changed.
bushels per acre and often giving as high yields as 75 to 80 bushels per acre. Small grains are not grown to any large extent as they are likely to lodge and thus give low yields. The soil is well adapted to the clovers, and high yields are obtained. Sweet clover grows luxuriantly, and alfalfa also has proved to be a profitable crop. Certain truck crops, such as potatoes, tomatoes and cabbage are successfully grown.

The Webster silty clay loam is not naturally well drained, and unless adequate drainage has been provided, this is the first treatment needed. It will then respond to small applications of farm manure to stimulate the production of available plant food. Large additions should not be made as there is danger of increasing the lodging of grain crops. When the soil is acid in reaction at the surface, lime should be applied before legumes are grown. The use of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are desirable. The experiments carried out on this soil have indicated profit from the use of these phosphates, and while definite recommendations cannot be made as to which phosphate should be employed, it is suggested that farmers test both materials on their own farms.

Clarion Loam (138)

The Clarion loam is the second largest drift soil and the second largest individual soil type in the county. It covers 34.7 percent of the total area. It occurs on the broad gently rounded divides, prominent knolls and gentle slopes bordering the creek valleys. It occurs in all parts of the county in extensive areas, the largest development appearing in the southwestern townships, Elm Grove, Jackson, Clark Creek and Calhoun. It is also developed largely in Union and Cedar townships.

The surface soil of the Clarion loam is a dark brown to very grayish-brown crumbly fine-textured loam, to a depth of 8 inches. From 8 to 18 inches the material is slightly heavier and darker than the layer above. From 18 to 22 inches there is a transitional layer. From 22 to 42 inches there is a yellowish-brown clay loam or heavy loam, containing much coarse material. From 42 to 50 inches there is a pale yellowish-gray silty pebbly material containing yellow and yellowish-brown stains. Some lime concretions as specks and flakes occur in this layer. Below 50 inches the subsoil becomes highly calcareous and a little more compact and more stones and gravel occur. On steep hillside, the soil may be thinner, and on the more nearly level areas the soil is deeper. Occasionally the yellowish-
brown subsoil may appear in the plow zone. Elsewhere the dark colored soil continues for 15 to 20 inches.

The Clarion loam is all under cultivation, and general farm crops are grown. Good crop yields are usually obtained. Corn yields 40 bushels per acre on the average, but yields of 60 to 75 bushels per acre are fairly common. Yields of oats range from 25 to 60 bushels per acre. Hay crops yield well.

The Clarion loam will respond very profitably to an application of farm manure. The soil is acid in the surface soil and will be benefited by liming, especially for the growth of legumes. The application of a phosphate fertilizer will undoubtedly prove of value, and tests of rock phosphate and superphosphate will be worth while. The tests reported on earlier in this bulletin indicate the large effects of the use of farm manure, lime and one or the other of the phosphates.

**Webster Loam (55)**

The Webster loam is the third largest drift soil and the third largest type in the county, covering 18.0 percent of the total area. It occurs in numerous small areas in all parts of the county in association with the Webster silty clay loam and the Clarion loam, occupying the higher areas in the Webster silty clay loam uplands, and lying a little lower than the Clarion loam. The largest individual areas of the type occur in the northern townships, especially Butler and Sherman townships.

The surface soil of the Webster loam to a depth of 6 inches, is a very dark grayish-brown loam, soft and slightly crumbly. From 6 to 26 inches there is a darker colored silty clay loam. From 26 to 32 inches there is a dull yellowish-brown silty clay loam, which shows some black streaks from the darker layer above. From 32 to 38 inches there is a porous friable silty material which is mainly gray with faint yellow stains. This layer is calcareous with some lime concretions, small flakes and specks. From 38 to 50 inches the friable silty material contains a little more sand and some shale and limestone pebbles, changing with depth to mixed clay and calcareous gravel. There are some variations in the soil in the different areas. In some cases the areas include slight local elevations and short slopes on which the Clarion loam occurs. The black granular clay subsoil seldom occurs at a depth of less than 12 or 15 inches, but occasionally it does. In many places free lime occurs below the dull yellowish-brown and drab layer which lies at a depth of about 30 inches, but in some places it is much deeper. The surface
soil is usually acid in reaction and the acidity may extend down into the sub-
surface soil, often to a depth of 10 to 15 inches and frequently deeper, but the
subsoil is typically high in lime. Occasionally there may be some lime in the
surface soil.

The Webster loam is all under cultivation, and general farm crops are grown. The yields are much the same as on the Clarion loam. Corn yields average 40
to 45 bushels per acre. Oat yields range from 30 to 60 bushels per acre. Hay
crops do well. Under the most favorable conditions, much higher yields of corn,
oats and hay are obtained. The small grains do much better than on the heavier
Webster silty clay loam and are not likely to lodge.

Most of the type is well drained, but in the shallow sags and small rather flat
spots in fields of the soil, tiling would be of value. The soil is in need of lime
to correct the acidity of the surface soil, especially if legumes are to be grown.
The application of farm manure would prove of large value. The addition
of a phosphate fertilizer would also undoubtedly be worth while, and tests of
rock phosphate and superphosphate are recommended. The experiments dis-
cussed earlier in this report have shown the large value of the use of farm
manure, limestone and either rock phosphate or superphosphate for general farm
crops grown on this soil.

Clarion Loam (steep phase) (151)

The steep phase Clarion loam is a minor soil in the county, covering 1.3
percent of the area. It occurs in a considerable number of narrow areas, on
the steep blufflike slopes facing the valleys of the streams and on the rougher
lands extending up short ravines and tributaries of the main streams. It is de-
veloped most extensively in the southwestern part of the county, along the
Raccoon River, Lake Creek and Purgatory Creek. Many other areas appear
along the minor streams of the county.

The soil is similar to the typical Clarion loam, except that the surface soil is
very thin and the subsoil is often exposed at the surface. The surface soil is a
dark brown or very dark grayish-brown fine-textured loam which may be a few
inches in depth. Sometimes it is absent. The next layer is a slightly heavier
and darker soil which likewise may be rather shallow in depth. The subsoil is
a yellowish-brown clay loam or heavy loam containing much coarse material and
changing in the lower part into a pale yellowish-gray pebbly silty material,
showing yellow and yellowish-brown stains. There are many specks and flakes
of lime, and the content of the lower soil layers in lime is high. In some places this
yellow to yellowish-gray subsoil is exposed at the surface. On the steep slopes bor-
dering the Sioux and Dickinson soils, the type may be rather sandy in places
and seepy spots occur along the upper slopes.

Most of the soil is in permanent pasture and in normal seasons the grasses
do well. Undoubtedly most of the area if not all of it, should be kept in pas-
ture. This is the only way that it can be protected from serious washing or
erosion. Even those areas which are not too steep to farm should be put into
pasture to keep the soil from being washed away. Good pastures may be main-
tained on much of this land by proper reseeding and fertilizing. The use of
lime is not likely to be necessary and clovers do well on the soil due to the general occurrence of lime. The application of a phosphate fertilizer before reseeding may be of considerable help in getting a stand of the clover in the seeding mixture and in keeping a good stand of grasses.

**Pierce Loam (173)**

The Pierce loam is a minor type, covering only 0.2 percent of the county. There are a number of small areas of the soil in various parts of the area, chiefly in Williams, Butler, Lincoln, Twin Lakes and Jackson townships. The largest individual area is found in the latter township. It is found on the crests of rather prominent mounds and narrow ridges, which contain more or less gravel and stones. Occasionally the type occurs on comparatively smooth upland, and the gravel does not appear at the surface but at a depth of 20 to 30 inches.

The surface soil of the Pierce loam is a dark grayish-brown loam underlaid by a very dark grayish-brown loam, at a depth of a few inches. At about 10 inches there is a brown gravelly sandy loam mottled with rusty-brown and gray. Some fine and coarse gravel are present, and many of the gravel are coated with white carbonates. At about 22 inches there is a gray sticky calcareous sand and gravel. There are wide variations in the depth of the surface soil, and in some places the gravelly subsoil is exposed at the surface. In other places there is a thin layer of surface soil before the gravel is reached.

The agricultural value of the soil is determined mainly by the thickness of the loam layer at the surface. All areas of the soil are subject to drouth, but fairly good yields of corn and small grains are often obtained when the seasonal conditions are favorable. Clovers also often do well. In many areas any agricultural value has been destroyed by the excavations for gravel.

If these areas are to be cultivated they need large applications of farm manure and the turning under of legumes as green manures to build up the organic matter of the soil and make it less subject to drouth. The soil would then undoubtedly respond to the application of a phosphate fertilizer, and tests of superphosphate would be desirable.

**Clarion Sandy Loam (253)**

The Clarion sandy loam is a minor type in the county, covering 0.1 percent of the area. It occurs in a number of prominent knolls and small ridges on the uplands south of the Raccoon River in Jackson Township.

The surface soil of the Clarion sandy loam is a dark gray gritty loam to a brown sandy loam, extending to a depth of 12 to 15 inches. Between 15 and 20
inches there is a brownish-yellow or yellow friable silty clay loam containing varying amounts of sand, gravel and pebbles. The subsoil is a yellowish-brown gritty silty clay mottled with gray, rusty-brown and white. The depth to the yellow-brown clay loam does not commonly exceed 25 or 30 inches. Here and there gravel spots occur, and such areas are more drouthy than the heavier soil.

The type is all under cultivation, and general farm crops are grown. The yields, however, are much lower than on the Clarion loam on the adjacent uplands. In many seasons the yields are very low because of drouth. The type needs the addition of liberal amounts of farm manure and the turning under of leguminous crops as green manures if it is to be made more productive and less subject to drouth. The surface soil is acid, and additions of lime may be necessary before legumes can be successfully grown. The application of a phosphate fertilizer would also prove of value, and tests of superphosphate are recommended.

Dickinson Fine Sandy Loam (175)

The Dickinson fine sandy loam is a minor type in the county, covering 0.1 percent of the total area. It occurs in several areas along the crest of the high hills south of the Raccoon River in Jackson Township.

The surface soil of the Dickinson fine sandy loam is a dark brown friable sandy loam or fine sandy loam. Below this point and continuing to a depth of 24 inches there is a light brown fairly compact sandy loam containing a few pebbles. From 24 inches on down, there is a yellow, gray, and brown sand and very fine gravel. In many places gravel beds are reached at a depth ranging from 7 to 8 feet. At the tops of the slopes the soil is a dark grayish-brown friable sandy loam, while at short distances from the crest of the slope, the surface soil becomes darker and finer in texture. Here the depth to the subsoil decreases. In most areas the clay or gravel layer is encountered at depths ranging from 50 to 60 inches. Less than one-fourth of a mile back from the hills the soil merges with the Clarion loam.

The Dickinson fine sandy loam is all in cultivation, and general farm crops are grown. The yields are lower than those secured on the Clarion loam. In seasons of high and well-distributed rainfall, the crops grown give better yields, but the soil is drouthy, and crops are likely to suffer for moisture. Pastures may do well but are not entirely dependable on this soil.

The chief need of this type, if it is to be made more satisfactorily productive, is for the addition of organic matter. The liberal application of farm manure would be of large value, and the turning under of legumes as green manures would add organic matter in which the soil is particularly deficient. These additions would improve the water-holding power of the type and make it less drouthy. The soil is acid, and the application of lime is necessary if legumes are to be grown successfully. The addition of a phosphate fertilizer would undoubtedly help, and tests of superphosphate are very desirable.

TERRACE SOILS

There are 6 terrace soils in the county, classified in the Sioux, O'Neill, Benoit, Waukesha and Fargo series. Together they cover 2 percent of the total area.
Sioux Loam (76)

The Sioux loam is the largest of the terrace soils, covering 1.2 percent of the total area. It is the chief terrace type along the Raccoon River and the tributaries of this stream, Prairie Creek and Lake Creek in Jackson Township. Small areas are found in other sections of the county along the various streams.

The surface soil of the Sioux loam is a dark grayish-brown loam, ranging from a silt loam to a sandy loam, and always containing some fine sand. Below 12 inches and extending to a depth of 20 inches, the soil is a brown or yellowish-brown gritty loamy sand, containing some rounded sand and small boulders. Underlying this layer and continuing to a depth ranging from 10 to 12 feet there are beds of stratified gravel, fine sand, and rounded gravel. Much of the gravel is coated with lime and the entire soil mass is calcareous. The more sandy areas commonly occur on the low swells and other local elevations, and the heavier and darker colored variations are limited to the flat areas and slight depressions. The lighter-colored phases of the soil predominate, and hence the soil is lower in organic matter than the Clarion loam.

Practically all of the type is under cultivation and general farm crops are grown. The yields are commonly rather low as the soil is dryish. Corn yields from 20 to 50 bushels per acre depending upon the seasonal conditions. Other crops give correspondingly low yields.

The chief need of this soil if it is cultivated, is for the incorporation of organic matter. Liberal additions of farm manure should be made, and legumes should be turned under as green manures. The surface soil of the type is acid, and additions of lime are necessary for new seedings of legumes. The application of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

O'Neill Loam (108)

The O'Neill loam is the second largest terrace soil, covering 0.2 percent of the total area. It occurs on the highest bench lands along the Raccoon River, in Jackson Township. The largest area of this soil occurs along the county line, south of the river.
The surface soil of the O'Neill loam is a very dark grayish-brown loose, me­
low friable loam, underlaid by a brown or yellowish-brown fine sandy loam. The surface soil usually ranges from 10 to 13 inches in depth. The soil below a depth of 24 to 27 inches is more sandy, and the main texture is a gritty some­
what sticky sand.

Practically all of the type is under cultivation, and general farm crops are
grown. Crop yields are low, however, as the soil is drouthy. It needs liberal
additions of organic matter in the form of farm manure or leguminous green
manure if it is to be made less drouthy and more productive. It is acid and
in need of lime, especially for the best growth of legumes. The addition of a
phosphate fertilizer would undoubtedly prove of value, and tests of super-
phosphate are recommended.

Benoit Loam (254)

The Benoit loam is a minor type in the county, covering 0.2 percent of the
total area. It occurs on low terraces along Camp Creek in Elm Grove and Gar­
field townships and along Cedar Creek in Williams Township. There are no
large areas of the type.

The surface soil of the Benoit loam is a black or nearly black loam, from 10 to 15
inches in depth. The upper subsoil to a depth of 24 to 26 inches is a gray to drab
silty clay to clay. The lower subsoil is a coarse sand or gravelly sand. In places the
sandy subsoil ranges in thickness from 12 inches to 3 feet with clay below. The gravel
subsoil is highly calcareous and includes many limestone fragments. In some places
the subsoil does not contain sufficient lime to show any effervescence with acid, and in some
areas the surface soil is highly calcareous. On the sharper slopes and highest points, the
surface soil is usually brown or yellowish-brown in color and a gritty loam in texture,
with same gravel and stones. The depth to gravel varies widely, ranging within small
areas from 10 to 40 inches. In some places the gravel layer is only a foot or two thick and is underlaid by the calcareous
clay.

The Benoit loam is mainly cultivated and general farm crops are grown or
the land is in pasture. The yields of crops are generally much lower than on
the adjacent areas of Clarion loam except in the areas in which the Benoit soil
is darker and deeper and less drouthy. In most cases the soil is not sufficiently
supplied with moisture to permit the best growth of crops. The type needs
additions of organic matter to make it less drouthy and better suited for crop
growth. The liberal application of farm manure will help, and the turning
under of legumes as green manures will also prove of value. The surface soil
is usually high in lime, and liming is unnecessary. When it is acid, lime should be applied for legume growth. The application of a phosphate fertilizer would help, and tests of superphosphate are recommended.

Waukesha Loam (60)

The Waukesha loam is a minor type in the county, covering only 0.2 percent of the total area. It occurs in numerous small areas on the high terraces along the main streams of the area. The largest development of the type is found in Jackson Township along the Raccoon River and its tributaries, Camp Creek, Prairie Creek and Lake Creek. Small areas are found in other parts of the county.

The surface soil of the Waukesha loam is a dark grayish-brown mellow friable loam, 10 or 12 inches in depth. The layer from 12 to 20 inches is a dark grayish-brown heavy loam. From 20 inches on down, the subsoil is a yellowish-brown or light yellow friable silty clay loam or heavy loam with many dark streaks of organic matter brought down from above. Below 42 inches the soil is a brownish-yellow or yellowish-brown friable silty clay loam mottled with gray and faint iron stains. Within the type as mapped there are included a number of small areas of poorly drained soils at the foot of slopes or in the sags or depressions in the terraces. In these areas the soil is blacker and heavier than the typical Waukesha, and the subsoils are slightly mottled or gray. Except for these spots the type is well drained.

The Waukesha loam is all in cultivation, and general farm crops are grown successfully. The yields are very much the same as those secured on the Clarion loam, at least in the typical areas of the Waukesha loam. The type will be increased in productivity, however, by liberal additions of farm manure or by the turning under of legumes as green manures. The soil is acid in reaction, and lime must be applied for the best growth of legumes. The use of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are urged.

Sioux Sandy Loam (14)

The Sioux sandy loam is a minor type in the county, covering 0.1 percent of the total area. It occurs on a few ridges on the terraces lying higher than the Sioux loam, with which it is associated. It is mainly found in Jackson Township along the Raccoon River, Prairie Creek and Lake Creek.

The surface soil of the Sioux sandy loam is a dark grayish-brown sandy loam, extending to a depth of 12 or more inches. Below 12 inches and extending to a depth of about 20 inches, the soil is a brown or yellowish-brown gritty loamy
sand, containing some sand and small boulders. Underlying this layer and continuing to a depth ranging from 10 to 12 feet there are beds of stratified gravel, fine sand and rounded gravel. Much of the gravel is coated with lime, and the entire soil mass is calcareous. The surface soil is generally acid in reaction, but the subsoil is high in lime, and occasionally the lime extends up into the surface layer.

The type is all under cultivation, and general farm crops are grown, but the yields are somewhat lower than on the Sioux loam, because of the drouthy nature of the soil. The type needs especially to be supplied with organic matter, using farm manure in liberal amounts and turning under legumes as green manures. The addition of lime is necessary if legumes are to be grown, and the application of a phosphate fertilizer would certainly prove of value.

Fargo Clay (255)

The Fargo clay is a minor type in the county, covering 0.1 percent of the total area. It occurs on the flat areas on the terraces along the Raccoon River in association with the Wabash silty clay loam. There are a number of small areas of the type, but no large developments occur.

The surface soil of the Fargo clay is a nearly black clay or silty clay loam which is sticky when wet but becomes coarse and crumbly when dry. It extends to a depth of about 6 inches. Below this point the soil is a dark drab or bluish-drab clay, which continues unchanged for many feet, except for a slightly lighter color at the lower depths. Lime occurs abundantly in the subsoil and usually up into the surface soil.

The Fargo clay is very poorly drained, and tiling is necessary before it can be successfully cultivated. It is mostly kept in permanent pastures, and bluegrass does well. When cultivated it must be handled carefully in order to be kept in the best physical condition, as it is likely to form clods. It would be benefited by small additions of farm manure, especially when newly drained. It would also be increased in fertility by the application of a phosphate fertilizer, and tests of rock phosphate and superphosphate are recommended.

SWAMP AND BOTTOMLAND SOILS

There are 5 bottomland soils and these with the areas of muck and shallow phase muck make a total of 7 soil areas. Together they cover 4.5 percent of the total area. The types mapped are included in the Lamoure, Wabash and Cass series.

Lamoure Silty Clay Loam (111)

The Lamoure silty clay loam is the largest of the bottomland soils, covering 1.7 percent of the total area. It is extensively developed along practically all the minor streams of the county and also on the bottomlands of some of the major streams. Most of the areas are long and narrow, and in no case is there any wide area of this bottomland.

The surface soil of the Lamoure silty clay loam is a very dark grayish-brown to almost black mellow silty clay loam, extending to a depth of 10 or 12 inches. Below this it is a black or very dark grayish-brown silty clay mottled with white calcareous material and some yellow specks. From 20 inches to 3 feet or deeper
there is a dark grayish-brown or black silty clay mottled with white, yellowish-brown, gray and yellow. The lime content of the subsoil is high, and lime often occurs up through the entire soil section. Occasionally the surface soil may be free of lime and acid. There are included with the areas of the Lamoure silty clay loam, as mapped, small areas of other types, such as the Lamoure silt loam, the Wabash silty clay loam and the Wabash silty clay. These areas were too small to separate on the map. The occurrence of lime in the subsoil is often the only means of separating the Lamoure and the Wabash silty clay loams, and the variation in lime occurrence makes the separation difficult.

The Lamoure silty clay loam is naturally very poorly drained, but the enlargement of ditches and the straightening of the channels has improved the drainage materially. The land is all subject to overflow, however, and hence it is utilized chiefly for pasture. Bluegrass does well on the type. Much of the land in the soil should certainly be kept in pasture. If it is to be cultivated it must be protected from overflow and well drained. It will then be benefited by a small application of farm manure to start the decomposition processes and the production of available plant food. Large additions should not be made. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of rock phosphate and superphosphate are urged.

Muck (21)

Muck is the second bottomland soil in area, covering 1.1 percent of the total area. It occurs in numerous areas, most of which are small in size. The largest areas are found in Twin Lakes, Sherman and Butler townships. The largest individual tract forms a part of Gun Barrel slough, and another is the old marsh 2 miles northwest of Knoke. Few of the other areas include as much as 20 acres, and many are low spots within areas of Webster soils.

The surface soil of the areas of muck is a black finely divided organic material, underlaid by a less completely decomposed peaty material, which rests upon the subsoil of clay or mixed clay and sand. The depth of the deposits varies widely, averaging about 3 or 4 feet, in the small areas, up to as high as 10 feet in the more extensive areas. In all areas the clay subsoil is highly calcareous, and the lime content is usually high up through the surface soil. In most areas the light textured surface soil changes at 15 to 20 inches to a darker colored soft plastic muck.

The largest areas of the soil are used for pasture, and good pastures are maintained. The soil needs thorough drainage if it is to be used for cultivated crops. Earlier in this report a discussion has been given of the handling of
such areas. The growing of truck crops may prove very profitable, and fertili-
ization with phosphates and potash will pay when such crops are grown.

**Wabash Loam (49)**

The Wabash loam is minor in extent in the county, covering 1.1 percent of the total area. It occurs on the bottomlands along some of the creeks and smaller streams of the county. It is found mainly along Cedar Creek, Lizard Creek, Camp Creek, Prairie Creek, Lake Creek and Purgatory Creek. There are no large individual areas of the soil.

The surface soil of the Wabash loam is a dark brown to dark grayish-brown to black loam, extending to a depth of 18 to 24 inches. The subsurface soil is heavier than the surface A layer, approaching a silty clay loam. This layer is a brown in color and contains some sand. The subsoil is a grayish-brown to gray silty clay loam to clay loam or clay, marked with black, rusty-brown and yellow. The texture of the soil varies somewhat in different areas, depending upon the adjacent upland soils, but the main variation from the surface soil is found in the occurrence of sand in the subsoil. This happens in many areas but only in spots in the areas. Where there is sufficient sand in the subsoil and the area is of sufficient size, the Cass soil is mapped.

The Wabash loam occurs on flat bottoms, but drainage is naturally fair. The type is subject to overflow, however, and hence the land is utilized mainly for pasture. Bluegrass and other pasture grasses do well. If it is to be cultivated it must be drained as well as protected from overflow. It needs lime if legumes are to be grown. It would respond to a phosphate fertilizer, and tests of rock phosphate and superphosphate would be worth while.

**Cass Fine Sandy Loam (130)**

The Cass fine sandy loam is a minor type in the county, covering 0.2 percent of the total area. It occupies the bottomlands immediately bordering the channel of the Raccoon River, which are in general a few feet lower than the level of the Wabash soils, especially the areas on the inner side of the numerous horseshoe bends. They include sand bars in process of formation and the more silty deposits at somewhat higher levels, which are commonly sandy loams or fine sandy loams with a large amount of silt.

The surface soil of the Cass fine sandy loam is a dark grayish-brown fine sandy loam extending to a depth of about 8 inches. The subsurface soil is very similar in texture and just slightly lighter in color, to a depth of 15 inches. From this point to a depth of 28 or 30 inches there is a grayish-brown loam or sandy loam which becomes lighter in color at the lower depths. The subsoil is a gray or
grayish-brown fine sandy loam or loamy fine sand, highly calcareous in many places. In some areas the lighter sandy subsoil is not encountered within the 40-inch section. In some of the low spots there is a layer of stiff dark colored clay overlying the surface soil. There are many other variations in the character of the surface soil and in the subsoil, owing to the frequent inundations.

The soil was originally forested with soft maple, ash and elm with willow and cottonwood along the river banks. Nearly all of the trees have been removed and the land is now in bluegrass pasture which does very well. Most of it should undoubtedly remain in pasture. If cultivated it will need to be protected from overflow. It would then be improved by the treatment with farm manure and leguminous green manures, such as are recommended for all drouthy soils. The use of a phosphate fertilizer might prove of value, and tests of superphosphate are desirable.

**Wabash Silty Clay Loam (48)**

The Wabash silty clay loam is a minor type in the area, covering 0.2 percent of the total area. It occurs in small areas along Hardin Creek and the lower course of Prairie Creek. Small areas are also found along the Raccoon River and in other places along some of the minor streams. It occupies the flatter, lower bottomlands, and the land is subject to overflow.

The surface soil of the Wabash silty clay loam is a very dark grayish-brown or almost black silty clay loam, extending to a depth of 12 to 15 inches. Here the color becomes a little lighter and the texture not quite so heavy as the surface soil. Below 30 inches the subsoil is a dark gray compact plastic heavy clay loam or clay, with numerous brown, rusty brown and black streaks.

All the land in the type is utilized for pasture. It needs drainage and protection from overflow if it is to be cultivated. It would then respond to a light application of farm manure. Large additions should not be made. It is acid in reaction and should be limed before growing legumes. It would be benefited by the use of a phosphate fertilizer, and rock phosphate and superphosphate should be tested.
Wabash Silt Loam (26)

The Wabash silt loam is a minor type in the county, covering 0.1 percent of the total area. It occurs on the first bottoms of the Raccoon River in a number of areas, varying considerably in size.

The surface soil of the Wabash silt loam is a dark brown to dark grayish-brown silt loam, containing some sand. It ranges in depth from 18 to 24 inches. Below the surface soil the texture changes to a silty clay loam and the color to a lighter brown. The lower part of the subsoil is gray streaked with black, rusty-brown and yellow, and the texture is a silty clay loam to silty clay. There are some variations in the surface soil, usually in the amount of sand which is present. Some variations also occur in the subsoil character.

The Wabash silt loam is a little higher than the other Wabash soils and hence is not subject to overflow as regularly and is utilized more generally for the production of general farm crops. Yields in favorable seasons are much the same as on the Clarion soils on the uplands. There is danger of overflow, and the soil should be protected if it is to be most profitably productive in all seasons. The use of farm manure would increase the production of crops, and the addition of lime is necessary for the growth of legumes. The application of a phosphate fertilizer would help, and tests of rock phosphate and superphosphate are recommended.

Muck (shallow phase) (256)

There is a very small area of shallow phase muck in the county, covering 0.1 percent of the total area. These areas are found in association with the areas of muck and are distinguished chiefly by the shallow nature of the surface layer of well-decomposed muck. When well drained the areas of this soil are in pasture and productive. It may be possible to grow vegetable crops successfully on some areas, and when this is done the use of fertilizers as previously suggested would be desirable. The use of superphosphate and muriate of potash would be worth while for such crops.
APPENDIX

THE SOIL SURVEY OF IOWA

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

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

Map of Iowa showing the counties surveyed.
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 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. Little is known as yet, however, 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. Applications of a fertilizer containing one of the elements present in such large quantities in the soil may, however, 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 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 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.
TABLE I. PLANT FOOD IN CROPS AND VALUE

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant food, pounds</th>
<th>Value of plant food</th>
<th>Total value of plant food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen (N)</td>
<td>Phosphorus (P)</td>
<td>Potassium (K)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nitrogen (N)</td>
<td>Phosphorus (P)</td>
<td>Potassium (K)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn, crop</td>
<td>111</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td></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>32.5</td>
<td>6</td>
<td>18.5</td>
<td></td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Rye, crop</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
<td></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>

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 available 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 are 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, swamp soils is a good illustration of the action of excessive moisture on 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 the 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 in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the 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 rotation 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 phosphates. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphates 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 through a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and 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 Subsection, Iowa Agricultural Experiment Station.

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 through 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 like 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 "niggerheads." 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 entirely 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 from the 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 stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift 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
THE PRINCIPAL SOIL AREAS OF IOWA

Map showing the principal soil areas in Iowa.

Accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, although some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is 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. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or eumulose.
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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**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

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* 25mm. equals 1 in. † Bureau of Soils Handbook.
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 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 inspections and by consultation with those in charge of the work at the Bureau of Chemistry and 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.