Soil Survey of Iowa, Report No. 69—Pocahantas County Soils

P. E. Brown
Iowa State College

A. M. O'Neal
Iowa State College

H. R. Meldrum
Iowa State College

Follow this and additional works at: http://lib.dr.iastate.edu/soilsurveys

Part of the Agriculture Commons, Agronomy and Crop Sciences Commons, and the Soil Science Commons

Recommended Citation
http://lib.dr.iastate.edu/soilsurveys/83

This Report is brought to you for free and open access by the Extension and Experiment Station Publications at Iowa State University Digital Repository. It has been accepted for inclusion in Soil Survey Reports by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
SOIL SURVEY OF IOWA
POCAHONTAS COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

Farm Crops and Soils Section
Soils Subsection

Soil Survey Report No. 69
June, 1933
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

Soil Survey Reports*

<table>
<thead>
<tr>
<th></th>
<th>County</th>
<th></th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bremer County</td>
<td>37</td>
<td>Dickinson County</td>
</tr>
<tr>
<td>2</td>
<td>Pottawattamie County</td>
<td>38</td>
<td>Hardin County</td>
</tr>
<tr>
<td>3</td>
<td>Muscatine County</td>
<td>39</td>
<td>Dallas County</td>
</tr>
<tr>
<td>4</td>
<td>Webster County</td>
<td>40</td>
<td>Woodbury County</td>
</tr>
<tr>
<td>5</td>
<td>Lee County</td>
<td>41</td>
<td>Page County</td>
</tr>
<tr>
<td>6</td>
<td>Sioux County</td>
<td>42</td>
<td>Jasper County</td>
</tr>
<tr>
<td>7</td>
<td>Van Buren County</td>
<td>43</td>
<td>O'Brien County</td>
</tr>
<tr>
<td>8</td>
<td>Clinton County</td>
<td>44</td>
<td>Greene County</td>
</tr>
<tr>
<td>9</td>
<td>Scott County</td>
<td>45</td>
<td>Des Moines County</td>
</tr>
<tr>
<td>10</td>
<td>Ringgold County</td>
<td>46</td>
<td>Benton County</td>
</tr>
<tr>
<td>11</td>
<td>Mitchell County</td>
<td>47</td>
<td>Grundy County</td>
</tr>
<tr>
<td>12</td>
<td>Clay County</td>
<td>48</td>
<td>Floyd County</td>
</tr>
<tr>
<td>13</td>
<td>Montgomery County</td>
<td>49</td>
<td>Worth County</td>
</tr>
<tr>
<td>14</td>
<td>Black Hawk County</td>
<td>50</td>
<td>Jefferson County</td>
</tr>
<tr>
<td>15</td>
<td>Henry County</td>
<td>51</td>
<td>Clarke County</td>
</tr>
<tr>
<td>16</td>
<td>Buena Vista County</td>
<td>52</td>
<td>Winnebiko County</td>
</tr>
<tr>
<td>17</td>
<td>Linn County</td>
<td>53</td>
<td>Appanoose County</td>
</tr>
<tr>
<td>18</td>
<td>Wapello County</td>
<td>54</td>
<td>Plymouth County</td>
</tr>
<tr>
<td>19</td>
<td>Wayne County</td>
<td>55</td>
<td>Harrison County</td>
</tr>
<tr>
<td>20</td>
<td>Hamilton County</td>
<td>56</td>
<td>Delaware County</td>
</tr>
<tr>
<td>21</td>
<td>Louisa County</td>
<td>57</td>
<td>Jones County</td>
</tr>
<tr>
<td>22</td>
<td>Palo Alto County</td>
<td>58</td>
<td>Fremont County</td>
</tr>
<tr>
<td>23</td>
<td>Winnebago County</td>
<td>59</td>
<td>Cherokee County</td>
</tr>
<tr>
<td>24</td>
<td>Polk County</td>
<td>60</td>
<td>Carroll County</td>
</tr>
<tr>
<td>25</td>
<td>Marshall County</td>
<td>61</td>
<td>Howard County</td>
</tr>
<tr>
<td>26</td>
<td>Madison County</td>
<td>62</td>
<td>Warren County</td>
</tr>
<tr>
<td>27</td>
<td>Adair County</td>
<td>63</td>
<td>Chickasaw County</td>
</tr>
<tr>
<td>28</td>
<td>Cedar County</td>
<td>64</td>
<td>Kossuth County</td>
</tr>
<tr>
<td>29</td>
<td>Mahaska County</td>
<td>65</td>
<td>Clayton County</td>
</tr>
<tr>
<td>30</td>
<td>Fayette County</td>
<td>66</td>
<td>Lyon County</td>
</tr>
<tr>
<td>31</td>
<td>Wright County</td>
<td>67</td>
<td>Buchanan County</td>
</tr>
<tr>
<td>32</td>
<td>Johnson County</td>
<td>68</td>
<td>Union County</td>
</tr>
<tr>
<td>33</td>
<td>Mills County</td>
<td>69</td>
<td>Pocahontas County</td>
</tr>
<tr>
<td>34</td>
<td>Boone County</td>
<td>70</td>
<td>Butler County</td>
</tr>
<tr>
<td>35</td>
<td>Dubuque County</td>
<td>71</td>
<td>Sac County</td>
</tr>
<tr>
<td>36</td>
<td>Emmet County</td>
<td>72</td>
<td>Calhoun County</td>
</tr>
</tbody>
</table>

*For list of additional publications on soils see inside back cover.
SOIL SURVEY OF IOWA

Report No. 69—POCAHONTAS COUNTY SOILS

By P. E. Brown, A. M. O'Neal and H. R. Meldrum

IOWA AGRICULTURAL EXPERIMENT STATION
R. M. Hughes, Acting Director
Ames, Iowa
CONTENTS

Type of Agriculture in Pocahontas County .................. 3
Geology of Pocahontas County .............................. 8
    Physiography and Drainage ............................ 9
Soils of Pocahontas County ................................. 11
    Fertility in Pocahontas County Soils ............... 12
    Greenhouse Experiments ............................. 17
    Field Experiments ................................... 19
    Peat Soils ............................................ 33
    Alkali Soils ......................................... 34
Needs of Pocahontas County Soils as Indicated by Labora-
tory, Greenhouse and Field Tests ....................... 35
    Manuring ............................................. 35
    Liming ............................................... 36
    Use of Commercial Fertilizers ...................... 37
    Drainage ............................................. 38
    Rotation of Crops ................................... 39
    Prevention of Erosion ............................... 40
Individual Soil Types in Pocahontas County .............. 41
    Drift Soils .......................................... 41
    Terrace Soils ....................................... 45
    Swamp and Bottomland Soils ......................... 49
    Muck and Peat ....................................... 50
Appendix: The Soil Survey of Iowa ........................ 53
POCAHONTAS COUNTY SOILS

BY P. E. BROWN, A. M. O'NEAL AND H. R. MELDRUM

Pocahontas County is located in the northwestern part of Iowa, in the third tier of counties south of the Minnesota state line and in the fourth tier east of the Missouri River. It lies entirely in the Wisconsin drift soil area, and the soils of the county, are, therefore, all of drift origin.

The total area of the county is 576 square miles or 368,640 acres. Of this area, 357,752 acres, 97.0 percent, are in farm land. The total number of farms is 2,053, and their average size is 174 acres. Owners operate 33.6 percent of the total farm land and renters the remaining 66.4 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1931 show the utilization of the farm land in the county.

- Acreage in general farm crops: 285,588
- Acreage in farm buildings, public highways and feedlots: 29,780
- Acreage in pasture: 48,678
- Acreage in wasteland not utilized for any purpose: 2,232
- Acreage in farm woodlots used for timber only: 289
- Acreage in crop land lying idle: 841
- Acreage in crops not otherwise listed: 106

THE TYPE OF AGRICULTURE IN POCAHONTAS COUNTY

The type of agriculture practiced in Pocahontas County at present is mainly general farming. Corn, oats, barley and other general farm crops are produced and cattle and hogs are raised and fed. Some dairying is also practiced. The farm income is derived mainly from the sale of corn, hogs and cattle and is supplemented in many cases by the sale of special crops, dairy products and poultry. The greater part of the corn produced is used as feed on the farms, but much is sold out of the county. Most of the oats and other minor crops grown are fed, and only small amounts are sold.

There is a rather large acreage in wasteland, not utilized for any purpose, and some method of treatment should be adopted to reclaim such areas. General recommendations for the handling of these soils cannot be given, as the causes of infertility are variable, and treatments of value in one area may have little effect in another. Special treatments which prove of value under individual soil conditions will be suggested later 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 general farm crops in Pocahontas County in the order of their importance are corn, oats, alfalfa, hay (other than alfalfa), barley, potatoes, rye, wheat, flaxseed and soybeans. The average yield and value of these crops in 1931 are given in table I.
### TABLE I  ACREAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN POCAHONTAS 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>157,469</td>
<td>44.02</td>
<td>29.60</td>
<td>4,661,082</td>
<td>$ 0.35</td>
<td>$1,631,379</td>
</tr>
<tr>
<td>Oats</td>
<td>107,712</td>
<td>30.11</td>
<td>34.10</td>
<td>3,672,713</td>
<td>0.20</td>
<td>734,543</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>270</td>
<td>0.08</td>
<td>25.00</td>
<td>6,754</td>
<td>0.43</td>
<td>2,904</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>120</td>
<td>0.03</td>
<td>18.70</td>
<td>2,241</td>
<td>0.44</td>
<td>986</td>
</tr>
<tr>
<td>Barley</td>
<td>2,063</td>
<td>0.58</td>
<td>26.70</td>
<td>55,016</td>
<td>0.35</td>
<td>19,256</td>
</tr>
<tr>
<td>Rye</td>
<td>601</td>
<td>0.17</td>
<td>18.50</td>
<td>11,130</td>
<td>0.39</td>
<td>4,341</td>
</tr>
<tr>
<td>Clover hay***</td>
<td>166</td>
<td>0.04</td>
<td>1.05</td>
<td>174</td>
<td>8.31</td>
<td>1,446</td>
</tr>
<tr>
<td>Clover and timothy hay (mixed)***</td>
<td>1,758</td>
<td>0.49</td>
<td>0.63</td>
<td>1,108</td>
<td>8.31</td>
<td>9,207</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>9,089</td>
<td>2.54</td>
<td>1.68</td>
<td>15,270</td>
<td>8.31</td>
<td>126,894</td>
</tr>
<tr>
<td>All other tame hay</td>
<td>743</td>
<td>0.21</td>
<td>0.67</td>
<td>498</td>
<td>8.31</td>
<td>4,138</td>
</tr>
<tr>
<td>Wild hay</td>
<td>2,052</td>
<td>0.57</td>
<td>0.55</td>
<td>1,129</td>
<td>7.00</td>
<td>7,903</td>
</tr>
<tr>
<td>Soybeans sown with other crops</td>
<td>32</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td>696</td>
</tr>
<tr>
<td>Soybeans sown alone</td>
<td>327</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans harvested for beans</td>
<td>84</td>
<td>0.02</td>
<td>13.80</td>
<td>1,160</td>
<td>0.60</td>
<td>696</td>
</tr>
<tr>
<td>Potatoes</td>
<td>218</td>
<td>0.06</td>
<td>57.90</td>
<td>12,428</td>
<td>0.60</td>
<td>7,456</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>257</td>
<td>0.07</td>
<td>8.00</td>
<td>2,099</td>
<td>1.20</td>
<td>2,483</td>
</tr>
<tr>
<td>Sweet clover seed</td>
<td>132</td>
<td>0.03</td>
<td>1.60</td>
<td>215</td>
<td>3.00</td>
<td>585</td>
</tr>
<tr>
<td>Sweet clover****</td>
<td>463</td>
<td>0.11</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 and all tame hay, including alfalfa. Average state farm price for remainder of crops.

***Sweet clover not included.

****All varieties for all purposes.

Corn is the most important crop both in acreage and value. In 1931 it was grown on 44.02 percent of the farm land and yielded 29.6 bushels per acre. On individual farms where good systems of soil management are being followed, the yields are often as high as 65 to 70 bushels per acre.

The oats crop is second in acreage and value. In 1931 oats were grown on 30.11 percent of the total farm land and average yields of 34.1 bushels per acre were secured. In many cases much higher yields are secured, often amounting to 60 to 65 bushels per acre.

Alfalfa is the third crop in acreage and value. In 1931 it was grown on 2.54 percent of the total farm land, and average yields of 1.68 tons per acre were secured. The value of the alfalfa crop is considerable. It may be grown very successfully, provided lime is applied when the soil is acid, good seed which has been well inoculated is employed and seasonal conditions are not abnormal.

The hay crops include, in addition to alfalfa, clover, timothy, clover and timothy mixed and wild hay. In 1931 clover and timothy mixed hay was grown on 0.58 percent of the total farm land with yields of 0.82 ton per acre on the average. Wild hay was produced on 0.57 percent of the land in 1931 and yielded 0.55 ton per acre. Clover alone and timothy alone were grown on limited areas with yields of 1.05 and 0.63 tons per acre, respectively, in 1931. All the hay grown is utilized on the farms, but the amount produced is usually insufficient to meet the needs of the county. Considerable amounts are generally shipped in each season.
Barley is an important crop. It was grown on 0.58 percent of the total farm land in 1931, with average yields of 26.7 bushels per acre. It is used almost entirely for hog feed.

Potatoes are grown on most farms, chiefly for home consumption. In 1931 the average yield was 57.0 bushels per acre. The surplus produced on individual farms is sold on the local markets.

Rye is grown on a limited area, with yields of 18.5 bushels per acre secured on the average. It is used as hog feed. Both winter wheat and spring wheat are produced on small areas, and the grain is sold.

Flax is grown on small areas, and yields of 8.0 bushels per acre of flaxseed are produced. Some pop corn and buckwheat are also grown. Soybeans are grown with corn that is to be used for silage in some sections. They are sometimes grown alone, and occasionally the crop is harvested for beans.

Apple orchards are found on some farms, and when the trees are properly handled they produce good fruit. Some raspberries, gooseberries and strawberries are grown for home use. Gardens are maintained on practically all farms, and a variety of vegetables are grown for home consumption.

THE LIVESTOCK INDUSTRY IN POCAHONTAS COUNTY

The livestock industries in Pocahontas 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.

Hogs are raised on practically all farms and are one of the chief sources of income. Duroc Jersey, Poland China, Chester White, Spotted Poland China and Tamworth are the leading breeds. Ordinarily from 10 to 15 sows are kept on the farm and 60 to 75 pigs are farrowed. In the northern part of the county a number of feeders are shipped in from Omaha and Sioux City, in the fall, fed for 6 months and resold. The hogs are usually sold through cooperative shipping associations.

The raising and feeding of beef cattle is a very important industry. The Hereford and Shorthorn breeds are the most common and there are a few Angus. In addition to the cattle raised, many farmers ship in one or two carloads of feeders from the western range. Some buy as many as five or six carloads each year. The animals are fed throughout the winter and sold after 60 to 90 days. A few farmers raise purebred cattle for sale.

Dairying is a sideline in most cases. Farmers generally keep from one to three milk cows, and about 50 farmers have herds ranging from 10 to 15. Near the larger towns a few farms are devoted to dairying. The dairy cows are mostly of the Holstein, Jersey and Guernsey breeds. The cream is sold to creameries or cream stations, after being separated on the farms.

A few horses and mules are raised on the farms to keep up the supply of work stock. Very few animals are sold. Only a few farmers raise sheep. Occasionally a carload of western sheep is brought in for feeding.

The poultry industry is carried on only as a sideline, but it has become much more important in the last few years and now contributes a considerable income on many farms. The chickens and eggs are usually sold to produce houses, or they may be sold or traded by farmers at the grocery stores.
THE FERTILITY SITUATION IN POCAHONTAS COUNTY

Yields of general farm crops in Pocahontas County are usually satisfactory on the well-drained upland areas, but increases may often be secured by the adoption of proper methods of soil management.

Considerable attention has been paid to drainage; many creeks and important drainageways have been ditched and straightened and lateral ditches dug. Tile has been laid on most farms and, in general, therefore, the soils are now well drained. In any case where the drainage is still inadequate, ditching or tiling is necessary. Soils in the Webster, Bremer, Lamoure and Wabash series are likely to need drainage, and peat and muck areas must always be thoroughly drained before they can be reclaimed and brought under cultivation.

Many of the soils are acid in reaction, at least in the surface soil, and are therefore in need of lime. The Clarion loam and the Webster loam on the uplands, the terrace types of the Sioux, O'Neill, Bremer, Waukesha and Judson series and the Wabash soils in the bottomlands are likely to be acid and will respond to liming for the best growth of general farm crops and especially legumes such as sweet clover and alfalfa. Some of the soils contain lime in the lower soil layers. This is true of the Clarion loam, the Webster loam and the Sioux loam. But these soils should be tested to determine the lime needs of the surface soil, and lime should be applied if the best crops are to be secured, regardless of the lime content of the subsoil. It is important that the soils listed be tested for lime needs and that lime be applied as necessary for the best crop yields and for the fertility of the soil. The value of liming the acid soils in the county is great.

The phosphorus content of the soils is not high and in fact in most cases it is rather low. It seems likely, therefore, that phosphorus fertilizers will be needed on these soils in the near future, even if they are not absolutely necessary now. But in many cases there is evidence from experiments and the experience of farmers that either superphosphate or rock phosphate may be applied now with profit. In some cases rock phosphate proves superior, while in other instances superphosphate gives better results. Farmers are urged to test both materials under their own individual conditions and thus determine which may be used with the greater profit.

The soils of Pocahontas County are generally well supplied with organic matter and some of the types are very high in this constituent. In any cases where the soil is not dark in color, it is apparent that there is a deficiency of organic matter and some should be applied. But on all the soils, it is very important that the content be kept up by regular additions if the soils are not to become deficient. Under continued cultivation soils lose organic matter rapidly through decomposition.

Farm manure, if properly preserved and applied to the land, will aid materially in increasing and keeping up the content of organic matter. The application of normal amounts of farm manure increases crop yields considerably on many of the soils in this county.

The turning under of leguminous crops as green manures is a means of supplying organic matter and nitrogen to the land, and the practice of green manur-
ing is essential on grain farms where little or no farm manure is produced. It may also be of value on some livestock farms to supplement the farm manure. Crop residues also aid in keeping up the organic matter in soils, and all residues should be thoroughly utilized and not wasted or destroyed.

On the sandy soils such as the Pierce, the Sioux, the O'Neill and the Cass types it is particularly necessary that materials supplying organic matter be added. Additions will also prove of value, however, on the Clarion, Waukesha, Judson and other soils in the area. Small additions of manure are effective on even the dark colored, heavy textured soils, as a stimulation in available plant food production is brought about. But large amounts should not be applied to such soils. The largest benefits, of course, from manure are shown on the poorer, sandier soils.

Other fertilizing materials, such as complete commercial fertilizers, muriate of potash and commercial nitrogen fertilizers may be used with profit in some cases, but their general use cannot be recommended. Usually superphosphate gives as good or better results at a lower cost than a complete fertilizer. Potash fertilizers are of value on peat soils and "alkali" spots, but they should not be used on normal soils until tests have been carried out on small areas and the material has proved of definite value under the particular conditions. Commercial nitrogen fertilizers should also be tested on small areas before being applied extensively. Ordinarily, leguminous crops used as green manures will supply nitrogen to the land just as satisfactorily and much more cheaply.

Erosion occurs to a very limited extent in the county and is therefore of little importance. Some washing away of the surface soil occurs with the Clarion loam, but the other types are not affected to any appreciable extent.
THE GEOLOGY OF POCAHONTAS COUNTY

The geological history of Pocahontas County is not significant in connection with the study of the soils of the county as the rocks underlying the soil have been so deeply buried by the glacial deposits that they have little or no influence on the characteristics of the soils.

During the glacial age, at least two great glaciers swept over the county and upon their retreat vast deposits of glacial debris or drift were left on the surface of the land. The earlier glacier, known as the Kansan, moved over the entire area, leveling old hills and filling up former valleys. It buried the native rock and the areas of pre-Kansan sand and gravel which occurred in some sections. The drift material or till is an accumulation of materials gathered up by the glacier in its forward march over the land, hence it is extremely variable in composition and contains sand, gravel and boulders. The original Kansan till was typically a very stiff and impervious blue clay, containing many pebbles and boulders of varying shape and size. Upon weathering the material becomes a reddish-brown or yellow. The depth of the deposit is quite variable and ranges from 10 to over 300 feet, due undoubtedly to the varying erosive action which took place during the centuries which elapsed after the deposition before the Wisconsin glaciation occurred. None of the soil types are derived from the Kansan till, but there may have been some effect on the subsoil conditions of some of the types.

At a much later date, a second glacier, known as the Wisconsin, moved over the county from the northwest, leaving behind a deposit which varied widely in thickness. The lower layers of this drift material sometimes consist of what is known as the Wisconsin gravels. They were deposited mainly in old valleys and drainage channels when the glacier retreated. They may now appear at considerable distances from the present drainageways, in isolated mounds on the sides of hills or in low ridges on level plains. In general, the drift covering is so deep that the gravel is not encountered in the three-foot section of the soils. The Pierce types are the only soils which contain sufficient of these gravels to constitute a soil difference.

The depth of the Wisconsin drift material is now extremely variable, ranging from a few feet to 15 or more feet in depth. In some areas it may be as much as 80 feet deep. It consists of 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. Since it was laid down, the surface of the deposit has been modified considerably by the accumulation of organic matter and by leaching. The color has become darker and is now a very dark brown to black. Much organic matter has accumulated in the soil, owing to the heavy subsoil and the high moisture content which kept down decomposition processes. The lower layers are usually the typical grayish or yellowish calcareous clay with some gravel and boulders. Where drainage has been established, there has been a leaching out of the lime content, and in many cases now the surface soils on the uplands are acid in reaction and in need of lime. In general the lower soil layers are still well supplied.

The upland types mapped in the county are derived entirely from the Wisconsin drift material, and they are classified in the Webster, Clarion and Pierce
series. The Webster soils are found on the more level, poorly drained areas and are black in color or almost black with gray to grayish-white subsoils. The Clarion types are developed on the more rolling uplands and are dark-brown in color with yellowish or grayish-yellow subsoils. The Pierce soils are developed on knobs or high points and are characterized by a high gravel content and a shallow, dark colored surface soil. The subsoil is usually almost entirely made up of gravel.

There are areas of terrace or second bottomlands which were probably formed when large amounts of water from the melting glacier passed through the drainage channels. Coarse materials were deposited by the glacial waters and formed terraces. Thus the Sioux and O'Neill soils were developed with gravelly subsoils, the former showing a high content of lime in the subsoil while the O'Neill types have no lime content. The Bremer, Waukesha and Judson soils are also found on terraces, and the Rogers silt loam occurs in old lake beds, occurring in depressed areas. The recent alluvial deposits along the streams are classified in the Lamoure, Wabash and Cass series, and areas of peat and muck are found throughout the uplands in low swampy places or former swamps where water stood for long periods of time.

PHYSIOGRAPHY AND DRAINAGE

In topography, Pocahontas County is mainly a nearly level plain almost without slope or drainage. Near the center of the county, east and west of the city of Pocahontas and extending northeastward, this is the characteristic topography. In other parts of the county streams cut through the upland flats, and there are low ridges and isolated knobs. In the southeast corner, the level plain changes abruptly to an area of strong relief, and the greater part of Lizard and Lake townships is rolling or moderately hilly. Narrow areas similarly rough in topography occur along the West Des Moines River and Beaver Creek in the extreme northeastern corner of the county and bordering Little Cedar and Cedar creeks in the western half of the area.

The streams are winding with shallow valleys, and there are few tributaries extending through the flat areas between the streams. The natural drainage of

![Fig. 3. A typical area in Pocahontas County.](image-url)
the county is quite inadequate as is indicated on the accompanying drainage map (fig. 4). The West Des Moines River cuts across the northeastern corner of the county and with Beaver Creek and Pilot Creek, drains the north central and northeastern sections, but only rather poorly. Lizard Creek, North Branch Lizard Creek and South Branch Lizard Creek provide drainage for limited areas adjacent to the stream courses through the central and southern parts of the county. Cedar Creek and Little Cedar Creek drain sections of the western and southwestern parts of the area. Considerable artificial drainage has been provided and most of the old lakes, marshes and poorly drained uplands have been drained. There are still areas, however, where drainage is not yet entirely adequate.

There are rather extensive terraces developed along the West Des Moines River, and narrow first bottoms are found along all the creeks and smaller streams. The total area in first and second bottomlands is small, however, in proportion to the area of the county.

Fig. 4. Map showing the natural drainage system of Pocahontas County.
THE SOILS OF POCAHONTAS COUNTY

The soils of Pocahontas 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 at the surface. 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 II. AREAS OF DIFFERENT GROUPS OF SOILS IN POCAHONTAS COUNTY**

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>331,200</td>
<td>89.9</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>9,408</td>
<td>2.5</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>28,032</td>
<td>7.6</td>
</tr>
<tr>
<td>Total</td>
<td>268,640</td>
<td></td>
</tr>
</tbody>
</table>

Almost nine-tenths of the total area, 89.9 percent, is covered by the drift soils. Terrace soils cover only 2.5 percent of the county. Swamp and bottomland soils are more extensive, covering 7.6 percent of the area.

There are 15 soil types in the county, and these with the steep phase Clarion loam and the area of muck and peat make a total of 17 separate soil areas. There are five drift soils including the steep phase Clarion loam, seven terrace types and five areas of swamp and bottomland soils, including the muck and peat. 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 Clarion loam, with the steep phase which is limited in occurrence, is much the largest individual type. It covers 43.2 percent of the county. The Webster silty clay loam is the second largest type, covering 28.0 percent of the total area. The Webster loam is third in extent, covering 18.4 percent of the area. The Pierce sandy loam is the fourth largest drift soil, but it is small in total area, covering only 0.3 percent of the county.

The Sioux loam is the largest terrace type, covering 1.2 percent of the county. The remaining terrace soils of the O'Neill, Rogers, Bremer, Waukesha and Judson series are extremely limited in area, covering less than one-half percent of the total area in each case. The Lamoure silty clay loam is the largest swamp and bottomland soil and the fourth largest type in the county, covering 5.1 percent of the total area. The muck and peat cover 1.4 percent of the total area, and the other bottomland soils of the Lamoure, Wabash and Cass series are minor in area, each covering less than 1 percent of the county.

Somewhat definite relationships are shown between the topographic features of the county and the soil types occurring in the various areas. The Clarion
TABLE III. AREAS OF DIFFERENT SOIL TYPES IN POCAHONTAS 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>138</td>
<td>Clarion loam</td>
<td>157,248</td>
<td>43.2</td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>1,792</td>
<td>4.7</td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,216</td>
<td>3.3</td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>67,840</td>
<td>18.4</td>
</tr>
<tr>
<td>191</td>
<td>Pierce sandy loam</td>
<td>1,216</td>
<td>0.3</td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>4,416</td>
<td>1.2</td>
</tr>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>1,536</td>
<td>0.4</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>1,216</td>
<td>0.3</td>
</tr>
<tr>
<td>108</td>
<td>O’Neill loam</td>
<td>896</td>
<td>0.2</td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>832</td>
<td>0.2</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>384</td>
<td>0.1</td>
</tr>
<tr>
<td>251</td>
<td>Judson fine sandy loam</td>
<td>128</td>
<td>0.1</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>18,944</td>
<td>5.1</td>
</tr>
<tr>
<td>21</td>
<td>Muck and peat</td>
<td>5,056</td>
<td>1.4</td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>2,496</td>
<td>0.7</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>1,024</td>
<td>0.3</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>512</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>368,640</td>
<td></td>
</tr>
</tbody>
</table>

The Clarion loam is gently rolling in topography in typical areas. The steep phase, as the name indicates, is steeply rolling. The Webster soils are all level to very slightly undulating in topography and some are flat to depressed in position. The Pierce sandy loam occurs on knolls or knobs in the rougher sections of the area. The terrace and bottomland soils show little in the way of topographic features. The Sioux, O’Neill, Waukesha and Judson soils are developed on higher terraces while the Rogers silt loam occupies an old lake bed and the Bremer loam a level to depressed, low-lying terrace. The bottomland soils are subject to overflow and must be protected if they are to be cultivated. Drainage is essential for most of the bottomland types as well as for the Rogers and Bremer soils on the terraces and the Webster types on the uplands.

THE FERTILITY IN POCAHONTAS COUNTY SOILS

Samples were taken from each of the soil types in the county. The areas of muck and peat were not sampled because of their great variability and because the results of the analysis would have little significance. The more extensive soil types 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 satisfactory and no abnormal conditions enter to affect the data. The samples were drawn at three depths, 0 to 6 inches, 6 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, total 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 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.

The content of phosphorus in the soils is somewhat variable, ranging from 915 pounds per acre in the steep phase Clarion loam up to 2,208 pounds per acre in the Rogers silt loam. No relationship appears between the phosphorus supply and the soil groups, although the terrace and bottomland soils, on the average, are a little better supplied than the drift upland soils, which might be expected since there has been a smaller crop growth on the alluvial soils on the terraces and bottomlands and undoubtedly fewer crops have been grown.

Some relationship between the phosphorus content and the soil series is shown. Thus, the Webster soils on the drift uplands are higher than the Clarion soils, and the steep phase Clarion loam is very low in phosphorus. On the terraces the Rogers silt loam is much higher than the other types. The Sioux and Judson are higher than the O'Neill, Bremer and Waukesha although the differences in some cases are hardly significant. On the bottoms the Lamoure types are much richer in phosphorus than the Wabash and Cass soils. There is some evidence of the effect of the texture of the soil upon the phosphorus supply, but in most cases only one type of a series is mapped and hence no conclusions are possible. With the Webster types and the O'Neill soils on the uplands and terraces, respectively, the textural effects did not appear. On the bottoms the Lamoure loam was higher than the silty clay loam which is contrary to the usual results and probably indicates that the sample of the silty clay loam was abnormal for some reason. It is generally true that fine-textured types are richer in plant food and fertility than are coarse-textured soils. Silty clay loams are generally richer than silt loams and these in turn are richer than loams or sandy loams.

The characteristics which distinguish various soil types have apparently some relation to the phosphorus supply. Types level to flat in topography, black in

### TABLE IV. PLANT FOOD IN POCAHONTAS COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>1,104</td>
<td>1,880</td>
<td>56,588</td>
<td></td>
<td></td>
</tr>
<tr>
<td>137</td>
<td>Clarion loam (steep phase)</td>
<td>915</td>
<td>1,500</td>
<td>56,132</td>
<td>38,531</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>1,131</td>
<td>6,360</td>
<td>70,650</td>
<td>2,706</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,144</td>
<td>7,200</td>
<td>83,091</td>
<td></td>
<td></td>
</tr>
<tr>
<td>191</td>
<td>Pierce sandy loam</td>
<td>1,252</td>
<td>4,040</td>
<td>41,620</td>
<td>1,521</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>1,481</td>
<td>4,480</td>
<td>54,553</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>1,444</td>
<td>3,440</td>
<td>37,414</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>2,208</td>
<td>14,360</td>
<td>212,062</td>
<td>29,332</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>1,144</td>
<td>4,680</td>
<td>52,331</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>1,198</td>
<td>4,280</td>
<td>38,859</td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>1,091</td>
<td>3,280</td>
<td>38,614</td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>251</td>
<td>Judson fine sandy loam</td>
<td>1,293</td>
<td>3,320</td>
<td>32,760</td>
<td></td>
<td>6,000</td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>1,293</td>
<td>5,480</td>
<td>65,139</td>
<td>8,190</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>1,497</td>
<td>12,240</td>
<td>129,909</td>
<td>29,532</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>1,091</td>
<td>3,920</td>
<td>48,213</td>
<td></td>
<td>2,000</td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>1,051</td>
<td>3,520</td>
<td>45,874</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
color and with heavy subsoils like the Webster are richer in phosphorus than types rolling in topography, lighter in color and with coarser subsoils like the Clarion and Pierce types. The Rogers soils are higher than the other terrace types and heavier in surface soil and subsoil texture. The Bremer and Judson soils are richer than the Waukesha and O'Neill types. On the bottomlands the Lamoure and Wabash soils are richer than the Cass and they have heavier subsoils.

In general, it appears that the phosphorus supply is not high in any of the soils in Pocahontas County and phosphorus fertilizers will need to be applied in the near future even if they are not necessary now, if the supply is to be kept up. There is evidence now of the economic value of the application of rock phosphate or superphosphate to meet the deficiency in available phosphorus.

The nitrogen content of the soils varies considerably, ranging from 1,300 pounds per acre in the Clarion loam steep phase, up to 14,360 pounds per acre in the Rogers silt loam. As was noted in the case of phosphorus, there is no relationship evidenced between the nitrogen supply and the various soil groups, except that the upland soils are slightly lower on the average due undoubtedly to the greater decomposition processes going on in these soils and the greater removal by the growth of more and bigger crops.

Some relationship to the soil series is shown. Thus, the Webster soils are richer than the Clarion and Pierce types, the Rogers is the richest of the terrace soils, and the Lamoure soils are the highest in nitrogen among the bottomland soils. It is evident again that the color of the soil, the topographic position, and the subsoil characteristics have an effect on the nitrogen supply. The black, flat to depressed Webster soils with heavy subsoils are richer than the lighter colored, rolling Clarion types or Pierce soils with coarser textured subsoils. The darker colored terrace soils are higher in nitrogen, and those with gravelly subsoils are the lowest. The blacker, heavier bottomland types are the highest in nitrogen.

Texture affects the nitrogen content in some cases, but with the soils in this county there is little evidence of its influence. The O'Neill loam is richer than the O'Neill fine sandy loam, but the Lamoure loam is richer than the silty clay loam and the same holds true for the Webster soils. This is contrary to the usual
POCAHONTAS COUNTY SOILS

results, as the finer textured soils like silty clay loams are usually richer than the silt loams which, in turn, are better supplied than the loams, and the sandy types are the lowest in nitrogen.

The nitrogen content of the soils of Pocahontas County is not low but neither is it very high and nitrogen must not be overlooked when systems of permanent fertility are worked out. Materials supplying nitrogen must be used regularly on these soils. By the proper use of farm manure, leguminous green manures and crop residues the nitrogen supply may be kept up and even increased.

Wide variations occur in the content of organic carbon in the soils in this county, the amount present ranging from 33,760 pounds per acre in the Judson fine sandy loam up to 212,062 in the Rogers silt loam. Again as noted in the case of nitrogen and phosphorus, there is little relationship between organic carbon content and the soil groups. The terrace and bottomland soils are a little higher on the average than the upland types, but there is not much difference.

Some relationship between the organic carbon content and the soil series is shown. Thus, the Webster soils on the uplands are richer than the Clarion or Pierce soils. The Rogers silt loam is the highest of the terrace types, and the Lamoure soils are the richest among the bottomland types. Those types which are blacker in color, level to depressed in topography and have heavy subsoils are higher in organic carbon just as they were in nitrogen and phosphorus. Those characteristics which serve to determine soil series certainly affect the organic carbon or organic matter content.

There is little evidence from these data of the effects of texture, as there are only a few cases where there are different types in the same series. The O'Neill loam is richer than the fine sandy loam, but the Webster loam is higher than the silty clay loam, and the Lamoure loam is richer than the Lamoure silty clay loam. These latter results are contrary to what is usually the case. The Lamoure loam is apparently somewhat abnormal according to all the analyses probably due to an abnormal sample being secured. In general, fine textured soils are richer in organic matter than coarse textured ones, and silty clay loams are richer than loams or silt loams which, in turn, are higher than sandy types.

Some indications of the rate of decomposition of the organic matter in the soils is given by the relationship shown between the nitrogen and organic carbon. In some of the soils this relationship is not at the optimum, as, for example, in the Webster types, the O'Neill soils, the Bremer and Waukesha types and the Lamoure soils. In these cases the application of farm manure, if only in small amounts, would prove of large value in stimulating the production of available plant food.

The supply of organic matter is not low in any of the soils, but in some cases the amount present is not as 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 satisfactory which does not provide for the regular addition of organic matter to these soils.

The steep phase Clarion loam, the Webster silty clay loam, the Pierce sandy loam, the Rogers silt loam and the Lamoure types show some inorganic carbon in the surface soil and hence no lime requirement. The Clarion loam and Cass loam show no content of inorganic carbon, but they have no lime requirement.
or are neutral in reaction in the surface soil. Some of the types such as the Clarion loam, Webster loam, Sioux loam and Cass loam show lime in the subsoil as will be noted later. In spite of this supply of lime in the lower soil layers, if these soils show acidity in the surface soil they should be limed in order to secure the best yields of crops and especially legumes. All the other types in the county which are acid in reaction should be tested and lime applied as necessary. This applies to the O’Neill, Bremer, Waukesha, Judson and Wabash soils. The soils of the Clarion, Webster, Sioux and Cass series should also be tested as they are occasionally acid in the surface soil.

The lime requirements shown in the table are only an indication of the 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 of lime to apply to any individual area, if the best results are to be secured.

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.

The plant food content of the lower soil layers has little influence on the fertility of the soil unless there is a deficiency of some element, or a very large amount of a constituent is present. In the soils of Pocahontas County there is no large amount of any plant food in the lower soil layers nor is there any striking deficiency.

The analyses show that the soils need phosphorus fertilizers now or will need them 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 a deficit in the future. Some of the types are acid in reaction in the surface soil and need lime now. While there is lime in the lower soil layers in some cases, this does

### Table V. Plant Food in Pocahontas County, Iowa, Soils

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>1,426</td>
<td>5,760</td>
<td>66,769</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>2,838</td>
<td>4,620</td>
<td>36,709</td>
<td>90,699</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>Webster silty clay loam</td>
<td>2,123</td>
<td>8,560</td>
<td>103,895</td>
<td>12,238</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,534</td>
<td>8,240</td>
<td>100,135</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>191</td>
<td>Pierce sandy loam</td>
<td>1,562</td>
<td>2,240</td>
<td>25,731</td>
<td>57,060</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>2,236</td>
<td>2,240</td>
<td>30,378</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>O’Neill fine sandy loam</td>
<td>1,778</td>
<td>4,240</td>
<td>47,395</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>O’Neill loam</td>
<td>2,123</td>
<td>5,120</td>
<td>61,660</td>
<td>122,438</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>1,426</td>
<td>3,360</td>
<td>51,322</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>2,046</td>
<td>5,840</td>
<td>64,920</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>251</td>
<td>Judson fine sandy loam</td>
<td>2,542</td>
<td>2,900</td>
<td>51,867</td>
<td>5,000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>1,454</td>
<td>11,580</td>
<td>55,184</td>
<td>7,809</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>2,046</td>
<td>13,840</td>
<td>165,544</td>
<td>7,238</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Wahsh silty clay</td>
<td>2,074</td>
<td>5,080</td>
<td>76,683</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>1,016</td>
<td>3,920</td>
<td>29,122</td>
<td>302</td>
<td></td>
</tr>
</tbody>
</table>
TABLE VI. PLANT FOOD IN POCOHONTAS COUNTY, IOWA, SOILS
Pounds per acre of 6 million pounds of subsoil (20"-40")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>138</td>
<td>Clarion loam</td>
<td>2,586</td>
<td>4,080</td>
<td>44,938</td>
<td>38,426</td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>Clarion loam (steep phase)</td>
<td>2,586</td>
<td>2,160</td>
<td>19,500</td>
<td>150,664</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>Webster silty clay loam</td>
<td>2,957</td>
<td>1,880</td>
<td>55,829</td>
<td>25,417</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Webster loam</td>
<td>1,616</td>
<td>6,480</td>
<td>85,214</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>191</td>
<td>Pierce sandy loam</td>
<td>1,616</td>
<td>360</td>
<td>110,800</td>
<td>87,016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DRIFT SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Sioux loam</td>
<td>2,055</td>
<td>360</td>
<td>22,117</td>
<td>134,549</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>O'Neill fine sandy loam</td>
<td>2,139</td>
<td>2,040</td>
<td>22,170</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Rogers silt loam</td>
<td>4,443</td>
<td>27,440</td>
<td>288,017</td>
<td>206,933</td>
<td></td>
</tr>
<tr>
<td>108</td>
<td>O'Neill loam</td>
<td>2,302</td>
<td>3,600</td>
<td>47,449</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Bremer loam</td>
<td>1,333</td>
<td>4,200</td>
<td>66,429</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Waukesha loam</td>
<td>2,544</td>
<td>5,160</td>
<td>40,741</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>251</td>
<td>Judson fine sandy loam</td>
<td>2,745</td>
<td>3,360</td>
<td>58,248</td>
<td>4,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TERRACE SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>111</td>
<td>Lamoure silty clay loam</td>
<td>2,181</td>
<td>3,120</td>
<td>66,812</td>
<td>3,708</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>Lamoure loam</td>
<td>2,366</td>
<td>11,520</td>
<td>155,715</td>
<td>14,286</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Wahash silt clay</td>
<td>2,220</td>
<td>4,080</td>
<td>66,756</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Cass loam</td>
<td>2,058</td>
<td>2,180</td>
<td>31,833</td>
<td>11,280</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SWAMP AND BOTTOMLAND SOILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 should be applied to provide for the best growth of legume crops.**

**GREENHOUSE EXPERIMENTS**

Two greenhouse experiments were carried out on soils from Pocahontas County, the Clarion loam and the Webster silty clay loam, two of the most important soil types. These tests were carried out to determine the value of the application of various fertilizing materials to these soils. The results secured in the experiment on the Webster loam from Kossuth County are also given as this soil occurs in Pocahontas County and the results secured certainly will indicate the effects of the same treatments on the soil in the field in Pocahontas County.

In these tests 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 about 1 month after the wheat was up.

**The Results on the Clarion Loam**

The results of the experiment on the Clarion loam are given in Table VII. The manure alone increased the yields of the wheat and clover, showing a very large effect on the clover. Limestone with manure had little effect, undoubtedly due to the fact that this soil had only a slight acidity. Superphosphate alone had less effect than manure alone on the wheat but showed a greater effect on the clover. Manure plus superphosphate showed some effect on the wheat, but more than doubled the clover yield. Limestone and superphosphate showed a slight gain over superphosphate alone. The manure-limestone-superphosphate
### TABLE VII. GREENHOUSE EXPERIMENT, CLARION LOAM, POCAHONTAS 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>8.9</td>
<td>9.5</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>11.8</td>
<td>26.5</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>11.4</td>
<td>26.8</td>
</tr>
<tr>
<td>4</td>
<td>Superphosphate</td>
<td>9.9</td>
<td>30.3</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>10.4</td>
<td>65.8</td>
</tr>
<tr>
<td>6</td>
<td>Limestone + superphosphate</td>
<td>10.4</td>
<td>38.3</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate</td>
<td>11.7</td>
<td>65.8</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>11.6</td>
<td>63.8</td>
</tr>
</tbody>
</table>

Manure increased the yields of wheat and clover on this soil, showing a very pronounced effect on the clover. Limestone with manure had no effect on either crop. Superphosphate alone increased the clover crop, but had less effect than manure alone. Manure and superphosphate together increased the yields of both crops but had little greater effect than manure alone. Limestone with superphosphate had a little greater effect on the wheat than superphosphate alone but about the same effect on the clover. Manure, limestone and superphosphate had a little greater effect on the wheat than was brought about by manure and superphosphate, but it had no greater influence on the clover. Muriate of potash with manure, lime and phosphate apparently had no effect on either crop.

### The Results on the Webster Silty Clay Loam

The results obtained in the test on the Webster silty clay loam are shown in table VIII.

### TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER SILITY CLAY LOAM, POCAHONTAS 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>13.2</td>
<td>57.3</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>15.2</td>
<td>70.8</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>15.0</td>
<td>64.5</td>
</tr>
<tr>
<td>4</td>
<td>Superphosphate</td>
<td>12.0</td>
<td>63.5</td>
</tr>
<tr>
<td>5</td>
<td>Manure + superphosphate</td>
<td>15.7</td>
<td>70.8</td>
</tr>
<tr>
<td>6</td>
<td>Limestone + superphosphate</td>
<td>15.6</td>
<td>63.5</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate</td>
<td>18.3</td>
<td>62.8</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + superphosphate + muriate of potash</td>
<td>15.6</td>
<td>63.5</td>
</tr>
</tbody>
</table>

Manure increased the yields of wheat and clover on this soil, showing a very pronounced effect on the clover. Limestone with manure had no effect on either crop. Superphosphate alone increased the clover crop, but had less effect than manure alone. Manure and superphosphate together increased the yields of both crops but had little greater effect than manure alone. Limestone with superphosphate had a little greater effect on the wheat than superphosphate alone but about the same effect on the clover. Manure, limestone and superphosphate had a little greater effect on the wheat than was brought about by manure and superphosphate, but it had no greater influence on the clover. Muriate of potash with manure, lime and phosphate apparently had no effect on either crop.

### The Results on the Webster Loam from Kossuth County

The results secured on the Webster loam from Kossuth County are given in table IX. The application of superphosphate alone increased the yield of the wheat to an appreciable extent but brought about an enormous increase in the yield of clover. Lime with superphosphate had no beneficial effect on the wheat but definitely increased the clover. Manure applied alone gave a larger increase on the wheat than did superphosphate but had a slightly smaller effect on the clover. Superphosphate with manure showed very little effect on the wheat.
TABLE IX. GREENHOUSE EXPERIMENT, WEBSTER LOAM, KOSUTH 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>17.1</td>
<td>21.7</td>
</tr>
<tr>
<td>2</td>
<td>Superphosphate</td>
<td>20.1</td>
<td>71.1</td>
</tr>
<tr>
<td>3</td>
<td>Limestone+superphosphate</td>
<td>19.7</td>
<td>75.6</td>
</tr>
<tr>
<td>4</td>
<td>Manure</td>
<td>22.2</td>
<td>65.6</td>
</tr>
<tr>
<td>5</td>
<td>Manure+superphosphate</td>
<td>22.4</td>
<td>55.4</td>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone+superphosphate</td>
<td>24.3</td>
<td>79.8</td>
</tr>
<tr>
<td>7</td>
<td>Manure+limestone+superphosphate+muriate of potash</td>
<td>23.4</td>
<td>114.1</td>
</tr>
</tbody>
</table>

and none on the clover. Lime with manure and superphosphate increased the yield of the wheat and greatly increased the yield of the clover. Muriate of potash with manure, limestone and superphosphate showed no beneficial effect on the wheat but enormously increased the yield of the clover.

FIELD EXPERIMENTS

No field experiments have been carried out in Pocahontas 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; on the O'Neill loam on the Everly Field, Series I, in Clay 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 the 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 ensure the securing of accurate results. The tests are planned to test the value

Fig. 6. Cattle on Webster silty clay loam in Pocahontas County.
of various fertilizer treatments on these soils under the livestock or the grain system of farming. The fields include either 13 plots or 9 plots each, 155 feet 7 inches long by 28 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, on the Webster silty clay loam and Lamoure silty clay loam the 2-16-2 complete brand is employed and on the O'Neill loam the 4-16-4 brand is added. 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 X. The manure brought about an increase in 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. The rock phosphate with the manure and lime gave increases in most cases, the largest effect appearing on the clover. The effect on the oats and corn was smaller, and in the case of the corn in 1922 and 1930 and the oats in 1923, no increases were secured. The superphosphate gave very similar increases to the rock phosphate in some seasons. With the clover in 1921, however, there was a much larger effect from the superphosphate, while on the same crop in 1926, there was a smaller influence. The oats in 1925 were increased to a greater extent by the superphosphate than by the rock phosphate.
TABLE X. FIELD EXPERIMENT, CLARION LOAM, BUENA VISTA COUNTY
TRUESDALE FIELD, SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1921 corn lb. per A.</th>
<th>1922 corn lb. per A.</th>
<th>1923 oats lb. per A.</th>
<th>1924 corn lb. per A.</th>
<th>1925 oats lb. per A.</th>
<th>1926 corn lb. per A.</th>
<th>1927 corn lb. per A.</th>
<th>1928 corn lb. per A.</th>
<th>1929 barley lb. per A.</th>
<th>1930 corn lb. per A.</th>
<th>1931 oats lb. per A.</th>
<th>1932 corn lb. per A.</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>48.6</td>
<td>44.2</td>
<td>13.0</td>
<td>48.3</td>
<td>11.2</td>
<td>59.3</td>
<td>37.3</td>
<td>39.3</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>24.2</td>
<td>57.0</td>
<td>1.45</td>
<td>62.9</td>
<td>54.1</td>
<td>37.9</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>61.3</td>
<td>32.7</td>
<td>63.2</td>
<td>1.64</td>
<td>68.7</td>
<td>53.9</td>
<td>37.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone</td>
<td>+rock phosphate</td>
<td>54.4</td>
<td>58.7</td>
<td>64.7</td>
<td>2.45</td>
<td>63.2</td>
<td>60.0</td>
<td>34.1</td>
<td>64.6</td>
<td>1.77</td>
<td>74.8</td>
<td>60.8</td>
</tr>
<tr>
<td>5</td>
<td>Manure+limestone</td>
<td>+superphosphate</td>
<td>49.6</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>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone</td>
<td>+complete commercial fertilizer</td>
<td>49.6</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>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>38.4</td>
<td>58.1</td>
<td>56.4</td>
<td>2.00</td>
<td>51.6</td>
<td>54.8</td>
<td>30.2</td>
<td>50.4</td>
<td>1.13</td>
<td>51.9</td>
<td>49.3</td>
<td>37.0</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>49.1</td>
<td>61.9</td>
<td>67.7</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>57.1</td>
<td>37.0</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>1.68</td>
<td>59.9</td>
<td>49.3</td>
<td>37.9</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>66.0</td>
<td>34.1</td>
<td>57.6</td>
<td>1.50</td>
<td>64.7</td>
<td>49.3</td>
<td>42.4</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>57.6</td>
<td>67.2</td>
<td>76.8</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>
</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>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>47.5</td>
<td>64.0</td>
<td>56.5</td>
<td>2.10</td>
<td>49.0</td>
<td>48.7</td>
<td>29.8</td>
<td>54.4</td>
<td>0.92</td>
<td>55.5</td>
<td>56.3</td>
<td>38.6</td>
</tr>
</tbody>
</table>

(1) Plots 8 to 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 weather in June damaged oats.
(4) Field pastured. Sweet clover stand very uneven. Not worth fencing. 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 Section 3, T. P. R. 37 W. in Washington Township.

and the barley in 1929 showed a greater influence from the 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 the superphosphate in some cases and somewhat greater effects in other instances.

The crop residues showed small effects on the yields of succeeding crops except 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 in practically all cases. Only with the clover in 1926 and the corn in 1930 was no increase evidenced. In some seasons the increases were large, while in other cases they were small. The clover in 1921 showed a large increase. The oats in 1923 and in 1925 were increased considerably. The corn in 1927 showed an appreciable gain. The superphosphate had larger effects than the 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, the rock phosphate seemed to give quite as large effects as the superphosphate, and in the case of the clover crop, the rock phosphate gave a slightly larger effect than the superphosphate. The differences, however, were usually not large enough to be significant. Only on the oats in 1923 and the corn in 1924 were the differences of very large importance.

The complete commercial fertilizer showed somewhat larger effects than the superphosphate in several seasons, but in many cases the differences were hardly large enough to be significant.

Table XI 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 and 1932. Lime brought about further gains in crop yields in most cases. In one or two instances, lime had no effect, but in general, as on the alfalfa, it was effective.

**TABLE XI. FIELD EXPERIMENT, CLARION LOAM, BUENA VISTA COUNTY TRUESDALE FIELD,* SERIES II**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1921 oats t. per A.</th>
<th>1921 clover tons per A. (1)</th>
<th>1920 corn bu. per A. (2)</th>
<th>1920 corn. tons per A.</th>
<th>1921 corn bu. per A. (3)</th>
<th>1921 corn. tons per A.</th>
<th>1923 clover tons per A.</th>
<th>1924 corn bu. per A. (4)</th>
<th>1925 corn bu. per A.</th>
<th>1926 oats bu. per A. (5)</th>
<th>1927 barley bu. per A.</th>
<th>1928 alfalfa tons per A. (6)</th>
<th>1929 alfalfa tons per A. (6)</th>
<th>1930 alfalfa tons per A. (6)</th>
<th>1931 alfalfa tons per A. (6)</th>
<th>1932 alfalfa tons per A. (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>69.9</td>
<td>47.5</td>
<td>53.2</td>
<td>18.5</td>
<td>51.7</td>
<td>38.0</td>
<td>40.0</td>
<td>29.9</td>
<td>50.1</td>
<td>31.8</td>
<td>20.9</td>
<td>2.09</td>
<td>2.75</td>
<td>1.56</td>
<td>3.52</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>94.2</td>
<td>57.0</td>
<td>39.7</td>
<td>24.6</td>
<td>1.90</td>
<td>52.7</td>
<td>50.4</td>
<td>38.1</td>
<td>55.3</td>
<td>33.3</td>
<td>23.3</td>
<td>2.65</td>
<td>1.58</td>
<td>3.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>91.2</td>
<td>59.0</td>
<td>41.8</td>
<td>37.1</td>
<td>1.86</td>
<td>46.9</td>
<td>51.8</td>
<td>37.0</td>
<td>54.5</td>
<td>46.4</td>
<td>2.87</td>
<td>2.73</td>
<td>1.70</td>
<td>4.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rock phosphate</td>
<td>88.2</td>
<td>61.2</td>
<td>38.1</td>
<td>32.4</td>
<td>2.26</td>
<td>44.4</td>
<td>51.7</td>
<td>37.3</td>
<td>57.3</td>
<td>39.3</td>
<td>3.03</td>
<td>3.06</td>
<td>1.83</td>
<td>4.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure+limestone+superphosphate</td>
<td>91.2</td>
<td>1.89</td>
<td>62.1</td>
<td>40.2</td>
<td>3.10</td>
<td>2.24</td>
<td>24.4</td>
<td>54.8</td>
<td>43.3</td>
<td>57.7</td>
<td>45.4</td>
<td>3.28</td>
<td>3.52</td>
<td>2.05</td>
<td>4.90</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>88.2</td>
<td>5.00</td>
<td>64.0</td>
<td>44.5</td>
<td>31.9</td>
<td>2.42</td>
<td>45.0</td>
<td>58.6</td>
<td>43.6</td>
<td>58.0</td>
<td>46.9</td>
<td>3.24</td>
<td>3.26</td>
<td>2.12</td>
<td>5.28</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>85.1</td>
<td>1.59</td>
<td>57.1</td>
<td>36.3</td>
<td>23.6</td>
<td>1.93</td>
<td>43.9</td>
<td>51.6</td>
<td>54.3</td>
<td>55.2</td>
<td>34.8</td>
<td>1.86</td>
<td>2.61</td>
<td>1.43</td>
<td>4.92</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>89.7</td>
<td>1.98</td>
<td>38.5</td>
<td>32.9</td>
<td>31.2</td>
<td>1.98</td>
<td>40.7</td>
<td>59.2</td>
<td>55.4</td>
<td>55.1</td>
<td>39.3</td>
<td>2.99</td>
<td>2.64</td>
<td>1.39</td>
<td>4.19</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+limestone</td>
<td>97.3</td>
<td>2.07</td>
<td>59.2</td>
<td>40.1</td>
<td>29.8</td>
<td>2.03</td>
<td>41.8</td>
<td>52.2</td>
<td>32.7</td>
<td>59.2</td>
<td>42.4</td>
<td>2.51</td>
<td>2.87</td>
<td>1.85</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>91.2</td>
<td>2.19</td>
<td>60.0</td>
<td>35.6</td>
<td>34.4</td>
<td>2.39</td>
<td>46.0</td>
<td>51.1</td>
<td>38.7</td>
<td>56.3</td>
<td>37.9</td>
<td>3.14</td>
<td>3.06</td>
<td>1.66</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>92.7</td>
<td>2.22</td>
<td>60.4</td>
<td>33.6</td>
<td>36.8</td>
<td>2.11</td>
<td>40.7</td>
<td>60.4</td>
<td>47.4</td>
<td>54.4</td>
<td>49.0</td>
<td>3.05</td>
<td>3.23</td>
<td>1.67</td>
<td>4.90</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>95.8</td>
<td>2.37</td>
<td>61.9</td>
<td>35.5</td>
<td>37.3</td>
<td>2.39</td>
<td>39.3</td>
<td>55.2</td>
<td>40.3</td>
<td>53.6</td>
<td>42.4</td>
<td>3.28</td>
<td>3.12</td>
<td>1.65</td>
<td>4.82</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>85.1</td>
<td>1.91</td>
<td>60.9</td>
<td>34.9</td>
<td>28.4</td>
<td>2.03</td>
<td>39.5</td>
<td>54.9</td>
<td>49.8</td>
<td>59.9</td>
<td>50.8</td>
<td>31.8</td>
<td>1.85</td>
<td>2.58</td>
<td>1.31</td>
<td>4.58</td>
</tr>
</tbody>
</table>

(1) Plots 1, 2, 3 and 4 disced 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. Horlacher 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 5, T. 91 N., R. 37 W. in Washington Township.
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 superphosphate and complete commercial fertilizer always brought about considerable increases in yields, the effects being particularly noted on the clover in 1923 and on the alfalfa in 1929, 1930, 1931 and 1932. Superphosphate generally brought about slightly greater effects than the rock phosphate, but in many cases the differences were not significant. The complete commercial fertilizers had slightly greater effects than superphosphate in some seasons, but in general the differences between the effects of the two materials were too small to permit definite conclusions.

The crop residues had a slight effect on the crop yields in several instances. The application of lime with crop residues increased the yields in most cases. 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 the crop yields in practically all cases. 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. The superphosphate, however, gave much larger effects on the corn in 1925, on the oats in 1926 and on the alfalfa in 1930 and 1932. It showed small gains in other seasons. The complete commercial fertilizer had about the same effect as superphosphate in most seasons, 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 XII. The application of manure increased the crop yields in all but one season, showing the largest effect on the oats in 1926 and 1932 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 produced as large increases.

Muriate of potash with manure, lime and superphosphate brought about a very definite increase over superphosphate alone in the case of the oats in 1923 and 1932 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 the potash appeared.
TABLE XII. FIELD EXPERIMENT, CLARION LOAM, PALO ALTO COUNTY
RUTHVEN FIELD,* SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 corn, bu. per A.</th>
<th>1924 oats, per A.</th>
<th>1925 sweet clover,</th>
<th>1926 corn, bu. per A.</th>
<th>1927 corn,</th>
<th>1928 corn, bu. per A.</th>
<th>1929 corn, bu. per A.</th>
<th>1930 oats, per A.</th>
<th>1931 corn, bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>47.3</td>
<td>48.7</td>
<td>42.7</td>
<td>34.0</td>
<td>34.8</td>
<td>50.3</td>
<td>61.9</td>
<td>56.7</td>
<td>56.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>53.1</td>
<td>53.3</td>
<td>42.0</td>
<td>52.0</td>
<td>51.0</td>
<td>59.0</td>
<td>64.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>55.6</td>
<td>61.2</td>
<td>50.3</td>
<td>43.1</td>
<td>55.5</td>
<td>61.1</td>
<td>61.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>57.5</td>
<td>40.8</td>
<td>58.3</td>
<td>40.6</td>
<td>57.9</td>
<td>43.7</td>
<td>58.1</td>
<td>77.1</td>
<td>64.0</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>47.6</td>
<td>22.3</td>
<td>41.4</td>
<td>45.1</td>
<td>43.1</td>
<td>48.4</td>
<td>84.0</td>
<td>60.6</td>
<td>42.6</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>57.3</td>
<td>48.7</td>
<td>57.9</td>
<td>40.6</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 + manure of potash</td>
<td>55.0</td>
<td>60.1</td>
<td>4.06</td>
<td>64.0</td>
<td>43.1</td>
<td>44.4</td>
<td>81.7</td>
<td>61.8</td>
<td>77.7</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>73.8</td>
<td>84.8</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>38.0</td>
<td>1.42</td>
<td>43.7</td>
<td>41.1</td>
<td>33.0</td>
<td>35.8</td>
<td>50.5</td>
<td>51.9</td>
<td>50.5</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 4, 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 E. A. McMillin, southeast of Ruthven, in Palo Alto County. It is located in the NW 1/4 of the SE 1/4 of Section 33, T. 96 N, R. 34 W in Highland Township.

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 1925, 1927 and 1931. In the other seasons the differences between the effects of the two materials were very slight.

The Webb Field

The results secured on the Clarion loam on the Webb Field, Series I, in Clay County, are given in table XIII. The application of manure increased the crop yields on this field in all seasons except 1931 and 1932, the largest benefits ap-

TABLE XIII. FIELD EXPERIMENT, CLARION LOAM, CLAY COUNTY
WEBB FIELD,* SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1923 corn, bu. per A.</th>
<th>1924 oats, per A.</th>
<th>1925 sweet clover,</th>
<th>1926 corn, bu. per A.</th>
<th>1927 corn,</th>
<th>1928 corn, bu. per A.</th>
<th>1929 corn, bu. per A.</th>
<th>1930 oats, per A.</th>
<th>1931 corn, bu. per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>56.9</td>
<td>71.1</td>
<td>1.10</td>
<td>58.0</td>
<td>38.4</td>
<td>65.9</td>
<td>1.61</td>
<td>45.3</td>
<td>30.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>60.4</td>
<td>77.6</td>
<td>1.96</td>
<td>135.6</td>
<td>65.1</td>
<td>1.66</td>
<td>46.3</td>
<td>29.0</td>
<td>60.7</td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>60.8</td>
<td>78.9</td>
<td>1.53</td>
<td>155.8</td>
<td>84.4</td>
<td>1.43</td>
<td>45.4</td>
<td>25.8</td>
<td>68.1</td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<td>61.0</td>
<td>82.3</td>
<td>1.51</td>
<td>284.4</td>
<td>102.8</td>
<td>2.55</td>
<td>46.7</td>
<td>30.8</td>
<td>65.8</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>54.4</td>
<td>70.3</td>
<td>1.17</td>
<td>286.4</td>
<td>105.6</td>
<td>1.68</td>
<td>46.1</td>
<td>25.3</td>
<td>57.8</td>
</tr>
<tr>
<td>6</td>
<td>Manure + limestone + superphosphate</td>
<td>62.8</td>
<td>84.7</td>
<td>1.54</td>
<td>366.6</td>
<td>153.7</td>
<td>1.45</td>
<td>51.5</td>
<td>30.5</td>
<td>70.3</td>
</tr>
<tr>
<td>7</td>
<td>Manure + limestone + superphosphate + manure of potash</td>
<td>60.0</td>
<td>76.5</td>
<td>1.68</td>
<td>37.3</td>
<td>50.1</td>
<td>81.7</td>
<td>2.58</td>
<td>50.9</td>
<td>30.0</td>
</tr>
<tr>
<td>8</td>
<td>Manure + limestone + complete commercial fertilizer</td>
<td>61.2</td>
<td>87.4</td>
<td>1.72</td>
<td>36.0</td>
<td>85.7</td>
<td>79.5</td>
<td>2.59</td>
<td>50.6</td>
<td>30.8</td>
</tr>
<tr>
<td>9</td>
<td>Check</td>
<td>56.6</td>
<td>69.1</td>
<td>1.18</td>
<td>286.4</td>
<td>45.6</td>
<td>65.5</td>
<td>1.63</td>
<td>42.7</td>
<td>32.8</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 1/4 of the SE 1/4 of Section 17, T. 94 N, R. 35 W in Garfield Township.
pearing on the clover in 1925 and on the corn in 1926 and 1927. Lime with manure increased the crop yields in practically all seasons. No large beneficial effects from the use of lime were evidenced, however.

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 or the oats in 1928 or 1932. Superphosphate with manure and lime showed somewhat larger effects than rock phosphate in all seasons. The differences, however, were generally large enough to be significant. The corn in 1927 and 1930 and the oats in 1928 and 1932 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 the clover and timothy in 1929 were increased more by the complete commercial fertilizer. The differences in the other seasons were not very large, however.

The Superior Field

The results secured on the Clarion loam on the Superior Field in Dickinson County are given in table XIV. The application of manure increased the crop yields in all seasons on this field. The largest effects from the manure appeared on the corn in 1922 and 1926, on the oats in 1923, on the clover in 1924 and on the barley in 1932. Lime with manure increased the crop yields in most seasons, showing the largest increases 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.

![Table XIV. Field Experiment, Clarion Loam, Dickinson County, Superior Field, Series I](image-url)
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, on the oats in 1923 and on the barley in 1932. Superphosphate with manure and lime showed slightly larger effects than rock phosphate on the crops in 1926, 1927, 1928, 1929, 1931 and 1932 but had smaller effects than rock phosphate in the earlier years. Some of the differences were not large.

Muriate of potash applied with manure, lime and superphosphate showed practically no influence except on the oats in 1923 and the barley in 1932. In the other seasons the differences from the yields on the plots not receiving the muriate 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. The differences in most cases 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 XV. The manure brought about beneficial effects on the various crops grown, showing up particularly well on the clover and on the alfalfa. Considerable gains were noted also on some of the

| TABLE XV. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, STORM LAKE FIELD,* SERIES I |
|---|---|---|---|---|---|---|---|---|---|
| Plt. No. | Treatment | 1918 oats lb. per A. | 1921 corn o. | 1922 corn o. | 1923 oats o. | 1924 oats o. | 1925 barley o. | 1926 barley o. |
| 1 | Check | 73.0 | 54.7 | 48.2 | 45.1 | 0.75 | 51.0 | 22.7 | 40.9 |
| 2 | Manure | 73.0 | 54.1 | 57.3 | 42.2 | 1.01 | 60.7 | 27.5 | 47.8 |
| 3 | Manure-superphosphate-muriate of potash | 73.0 | 57.6 | 58.1 | 36.3 | 1.29 | 65.1 | 29.2 | 56.9 |
| 4 | Manure-rock phosphate | 80.6 | 61.1 | 43.2 | 43.8 | 1.26 | 66.4 | 31.0 | 61.8 |
| 5 | Manure-superphosphate | 74.5 | 66.4 | 75.5 | 51.8 | 1.42 | 68.5 | 31.8 | 57.6 |
| 6 | Manure-complete commercial fertilizer | 82.0 | 61.1 | 80.0 | 43.8 | 1.43 | 66.8 | 31.8 | 57.6 |
| 7 | Check | 70.0 | 71.5 | 66.9 | 40.9 | 1.10 | 58.7 | 34.8 | 44.0 |
| 8 | Crop residues | 85.1 | 75.7 | 76.8 | 49.1 | 1.08 | 63.3 | 37.3 | 44.6 |
| 9 | Crop residues-superphosphate-muriate of potash | 76.0 | 70.1 | 67.2 | 41.1 | 1.25 | 70.7 | 35.7 | 56.4 |
| 10 | Crop residues-rock phosphate | 79.0 | 70.4 | 76.2 | 41.6 | 1.20 | 63.3 | 27.4 | 52.8 |
| 11 | Crop residues-superphosphate | 73.0 | 64.0 | 76.2 | 45.5 | 1.23 | 63.1 | 31.1 | 58.2 |
| 12 | Crop residues-complete commercial fertilizer | 85.1 | 67.5 | 76.2 | 43.8 | 1.13 | 61.3 | 27.2 | 58.1 |
| 13 | Check | 79.0 | 67.5 | 76.7 | 39.7 | 0.86 | 51.9 | 23.1 | 41.6 |

(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. 90 N, R. 37 W in Hayes Township.
corn crops and on the barley in 1925. The soil was not acid in reaction and hence no lime was applied.

The use of rock phosphate and superphosphate with manure brought about increases in crop yields in all cases, 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 secured with superphosphate and 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 definite increases in yields in some cases, 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 residues increased the crop yields in practically all seasons, showing the greatest effects on the alfalfa in 1928.

**The Newell Field**

The results secured on the Webster silty clay loam on the Newell Field in Buena Vista County are given in table XVI. 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 and alfalfa. 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 and the acidity is confined to the surface soil, 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 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. There were, however, one or two exceptions. In 1918, 1923 and in 1926, rock phosphate gave better yields than superphosphate. The yields on the plots in 1926, 1927, 1930, 1931 and 1932 were 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 fully 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
### TABLE XVI. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, NEWELL FIELD,* SERIES I

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn bu. per A.</th>
<th>1919 corn bu. per A.</th>
<th>1920 oats bu. per A.</th>
<th>1921 clover tons per A.</th>
<th>1922 corn bu. per A.</th>
<th>1923 corn bu. per A.</th>
<th>1924 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 and barley bu. per A.</th>
<th>1929 alfalfa tons per A.</th>
<th>1930 alfalfa tons per A.</th>
<th>1931 alfalfa tons per A.</th>
<th>1932 alfalfa tons per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>69.0</td>
<td>44.8</td>
<td>50.7</td>
<td>0.58</td>
<td>68.7</td>
<td>59.2</td>
<td>1.70</td>
<td>51.2</td>
<td>45.7</td>
<td>4.71</td>
<td>2.52</td>
<td>3.87</td>
<td>4.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>70.9</td>
<td>49.1</td>
<td>64.1</td>
<td>1.20</td>
<td>67.4</td>
<td>71.2</td>
<td>2.28</td>
<td>28.3</td>
<td>50.6</td>
<td>5.09</td>
<td>2.49</td>
<td>2.96</td>
<td>4.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure + limestone</td>
<td>71.4</td>
<td>54.4</td>
<td>63.5</td>
<td>1.70</td>
<td>69.9</td>
<td>68.3</td>
<td>5.98</td>
<td>35.5</td>
<td>50.5</td>
<td>4.84</td>
<td>2.57</td>
<td>3.67</td>
<td>4.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + limestone + rock phosphate</td>
<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>6.55</td>
<td>40.4</td>
<td>50.2</td>
<td>4.36</td>
<td>2.04</td>
<td>3.32</td>
<td>3.94</td>
<td></td>
<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>
<td>4.02</td>
<td>3.05</td>
<td>4.07</td>
<td></td>
<td></td>
</tr>
<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>67.2</td>
<td>2.28</td>
<td>28.3</td>
<td>50.6</td>
<td>5.09</td>
<td>2.49</td>
<td>2.96</td>
<td>4.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>69.9</td>
<td>62.4</td>
<td>59.4</td>
<td>0.58</td>
<td>66.9</td>
<td>55.0</td>
<td>2.13</td>
<td>35.5</td>
<td>45.9</td>
<td>3.11</td>
<td>2.34</td>
<td>2.01</td>
<td>2.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>62.9</td>
<td>56.1</td>
<td>68.4</td>
<td>0.90</td>
<td>63.6</td>
<td>56.4</td>
<td>6.65</td>
<td>5.10</td>
<td>52.3</td>
<td>33.2</td>
<td>2.05</td>
<td>1.78</td>
<td>3.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + limestone</td>
<td>64.5</td>
<td>59.2</td>
<td>61.4</td>
<td>0.43</td>
<td>64.2</td>
<td>59.5</td>
<td>7.18</td>
<td>51.7</td>
<td>56.4</td>
<td>4.17</td>
<td>2.34</td>
<td>2.03</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>6.69</td>
<td>51.8</td>
<td>50.1</td>
<td>4.05</td>
<td>3.16</td>
<td>2.20</td>
<td>4.34</td>
<td></td>
<td></td>
</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>6.93</td>
<td>5.86</td>
<td>52.1</td>
<td>4.19</td>
<td>2.31</td>
<td>2.12</td>
<td>4.74</td>
<td></td>
<td></td>
</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>2.29</td>
<td>47.5</td>
<td>48.5</td>
<td>4.71</td>
<td>2.15</td>
<td>2.28</td>
<td>4.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>59.4</td>
<td>65.3</td>
<td>60.1</td>
<td>0.58</td>
<td>62.6</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.

cases. The differences were not large, however, except on the clover in 1925 and the alfalfa in 1929, 1930, 1931 and 1932.

Rock phosphate, superphosphate and complete commercial fertilizer showed beneficial effects in some cases on the various crops grown but in other instances no effects were evidenced. 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, 1930 and 1932 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 XVII. 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. In most cases, however, the increases from the lime 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 the lime were expected.

Rock phosphate, superphosphate and the complete commercial fertilizer brought about some rather large increases in crop yields. 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

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 oats lb. per A.</th>
<th>1919 corn lb. per A.</th>
<th>1920 corn lb. per A.</th>
<th>1921 oats lb. per A.</th>
<th>1922 corn lb. per A.</th>
<th>1923 oats lb. per A.</th>
<th>1924 corn lb. per A.</th>
<th>1925 oats lb. per A.</th>
<th>1926 corn lb. per A.</th>
<th>1927 corn lb. per A.</th>
<th>1928 corn lb. per A.</th>
<th>1929 oats lb. per A.</th>
<th>1930 corn lb. per A.</th>
<th>1931 oats lb. per A.</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>29.6</td>
<td>40.8</td>
<td>44.8</td>
<td>47.8</td>
<td>48.6</td>
<td>57.8</td>
<td>49.1</td>
<td>36.9</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>51.7</td>
<td>52.1</td>
<td>49.6</td>
<td>63.5</td>
<td>56.1</td>
<td>35.8</td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>86.1</td>
<td>59.2</td>
<td>65.3</td>
<td>39.0</td>
<td>56.0</td>
<td>46.5</td>
<td>38.6</td>
<td>55.7</td>
<td>63.7</td>
<td>47.4</td>
<td>58.9</td>
<td>53.9</td>
<td>30.3</td>
<td>61.8</td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rock phosphate</td>
<td>86.5</td>
<td>61.0</td>
<td>69.3</td>
<td>38.7</td>
<td>57.1</td>
<td>52.3</td>
<td>31.1</td>
<td>49.9</td>
<td>57.7</td>
<td>39.9</td>
<td>70.3</td>
<td>62.1</td>
<td>44.2</td>
<td>60.2</td>
</tr>
<tr>
<td>5</td>
<td>Manure+superphosphate</td>
<td>90.8</td>
<td>65.4</td>
<td>72.2</td>
<td>35.8</td>
<td>54.9</td>
<td>38.0</td>
<td>40.0</td>
<td>53.2</td>
<td>1.14</td>
<td>60.9</td>
<td>46.6</td>
<td>64.5</td>
<td>39.1</td>
<td>59.8</td>
</tr>
<tr>
<td>6</td>
<td>+commer­</td>
<td>91.7</td>
<td>65.7</td>
<td>38.6</td>
<td>54.9</td>
<td>38.0</td>
<td>40.0</td>
<td>53.2</td>
<td>1.14</td>
<td>60.9</td>
<td>46.6</td>
<td>64.5</td>
<td>39.1</td>
<td>59.8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>88.0</td>
<td>54.0</td>
<td>50.7</td>
<td>36.6</td>
<td>46.6</td>
<td>44.2</td>
<td>30.0</td>
<td>44.6</td>
<td>66.9</td>
<td>44.4</td>
<td>46.3</td>
<td>66.9</td>
<td>50.9</td>
<td>36.9</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues+superphosphate+muriate of potash</td>
<td>82.9</td>
<td>63.3</td>
<td>57.7</td>
<td>38.5</td>
<td>50.1</td>
<td>57.8</td>
<td>28.8</td>
<td>47.3</td>
<td>55.0</td>
<td>1.18</td>
<td>60.5</td>
<td>39.5</td>
<td>69.2</td>
<td>65.8</td>
</tr>
<tr>
<td>9</td>
<td>+limestone</td>
<td>85.0</td>
<td>63.5</td>
<td>57.7</td>
<td>39.6</td>
<td>47.7</td>
<td>52.2</td>
<td>26.8</td>
<td>45.4</td>
<td>50.0</td>
<td>49.1</td>
<td>40.1</td>
<td>61.2</td>
<td>56.9</td>
<td>32.3</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>1.08</td>
<td>65.3</td>
<td>39.4</td>
<td>70.3</td>
<td>63.5</td>
<td>36.3</td>
</tr>
<tr>
<td>11</td>
<td>+superphosphate</td>
<td>97.7</td>
<td>69.4</td>
<td>68.6</td>
<td>36.4</td>
<td>54.8</td>
<td>62.2</td>
<td>23.4</td>
<td>45.0</td>
<td>0.86</td>
<td>56.5</td>
<td>49.9</td>
<td>79.4</td>
<td>66.2</td>
<td>44.2</td>
</tr>
<tr>
<td>12</td>
<td>+commer­</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>
<td>68.1</td>
<td>43.1</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>80.7</td>
<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>61.8</td>
<td>46.0</td>
<td>32.9</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 SW 1/4 of the SW 1/4 of Section 36, T. 88 N, R. 29 W, in Elk Horn Township.
superphosphate in a few cases, but in most seasons it had no greater or even a smaller influence than superphosphate.

Although crop residues had little effect on the various crops grown until 1922, some gains were 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.

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 the 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 produced only very small increases.

The Everly Field, Series I, O'Neill Loam

The results obtained in the experiment on the O'Neill loam on the Everly Field, Series I, in Clay County are shown in table XVIII. Manure increased the crop yield on this soil in practically every season. Some very large gains were noted, as, for example, on the clover in 1921, on the corn in 1922, on the oats in 1924, and on the alfalfa in 1932. In other seasons small but definite increases were obtained. Lime with manure increased the crop yields in practically all seasons. The greatest effects appeared on the clover in 1921 and on the oats in 1924. There were increases also on some of the corn crops.

Rock phosphate with manure and lime increased crop yields in several seasons. In general, no large effects were noted, however, except on the clover in 1921 and in 1925. Superphosphate with manure and lime showed a larger beneficial effect on crop yields in several seasons. The beneficial influence appeared particularly on the clover in 1921 and 1925, on the oats in 1924, and on the alfalfa in 1931 and 1932. In other seasons the differences between the effects of the two phosphates were not very pronounced. The complete commercial fertilizer with the manure and lime had about the same influence on the crop yields as did the phosphates. In one or two cases slightly greater effects were obtained, while in other instances the yields were somewhat smaller. In no case, however, was there any large difference.

The crop residues showed little effect on the crops grown in most seasons. Lime with the residues brought about increases in the yields in practically all cases. In some seasons very large effects were noted, as on the clover in 1921 and on the oats in 1924.

Rock phosphate with the residues and lime increased crop yields in practically all cases. In several seasons the increases were not very large, but in one or two cases considerable gains were noted, as on the clover in 1921 and the corn in 1922. Superphosphate with crop residues and lime had about the same effect on crop yields as did rock phosphate in most seasons. In some cases super-
<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1918 corn bu. per A.</th>
<th>1919 corn bu. per A.</th>
<th>1920 oat bu. per A. (1)</th>
<th>1921 clover tons per A. (2)</th>
<th>1922 corn bu. per A. (3)</th>
<th>1923 corn bu. per A. (4)</th>
<th>1924 oat bu. per A. (5)</th>
<th>1925 clover tons per A. (6)</th>
<th>1926 corn bu. per A. (7)</th>
<th>1927 corn bu. per A. (8)</th>
<th>1928 alfalfa tons per A. (9)</th>
<th>1929 alfalfa tons per A. (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>47.7</td>
<td>37.1</td>
<td>23.3</td>
<td>1.80</td>
<td>41.3</td>
<td>27.2</td>
<td>47.9</td>
<td>0.40</td>
<td>51.5</td>
<td>25.8</td>
<td>45.0</td>
<td>43.2</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>56.2</td>
<td>34.1</td>
<td>27.5</td>
<td>2.35</td>
<td>51.5</td>
<td>37.0</td>
<td>58.8</td>
<td>0.48</td>
<td>50.3</td>
<td>26.3</td>
<td>44.6</td>
<td>48.8</td>
</tr>
<tr>
<td>3</td>
<td>Manure+limestone</td>
<td>56.4</td>
<td>38.0</td>
<td>28.9</td>
<td>2.60</td>
<td>53.1</td>
<td>42.3</td>
<td>66.7</td>
<td>0.47</td>
<td>55.4</td>
<td>28.3</td>
<td>44.4</td>
<td>49.9</td>
</tr>
<tr>
<td>4</td>
<td>Manure+limestone+rock phosphate</td>
<td>56.0</td>
<td>40.3</td>
<td>33.6</td>
<td>2.94</td>
<td>53.3</td>
<td>41.7</td>
<td>66.1</td>
<td>0.57</td>
<td>58.2</td>
<td>29.0</td>
<td>43.9</td>
<td>49.9</td>
</tr>
<tr>
<td>5</td>
<td>Manure+limestone+superphosphate</td>
<td>59.2</td>
<td>39.0</td>
<td>32.6</td>
<td>2.85</td>
<td>54.7</td>
<td>39.2</td>
<td>66.7</td>
<td>0.65</td>
<td>62.4</td>
<td>26.4</td>
<td>41.7</td>
<td>53.4</td>
</tr>
<tr>
<td>6</td>
<td>Manure+limestone+complete commercial fertilizer</td>
<td>55.4</td>
<td>40.9</td>
<td>30.9</td>
<td>2.97</td>
<td>55.4</td>
<td>38.3</td>
<td>69.5</td>
<td>0.64</td>
<td>62.7</td>
<td>29.4</td>
<td>43.1</td>
<td>50.3</td>
</tr>
<tr>
<td>7</td>
<td>Check</td>
<td>46.0</td>
<td>37.1</td>
<td>24.11.80</td>
<td>44.6</td>
<td>35.8</td>
<td>44.9</td>
<td>36.5</td>
<td>0.40</td>
<td>54.9</td>
<td>26.5</td>
<td>45.7</td>
<td>44.3</td>
</tr>
<tr>
<td>8</td>
<td>Crop residues</td>
<td>51.4</td>
<td>36.4</td>
<td>24.9</td>
<td>2.00</td>
<td>45.6</td>
<td>36.4</td>
<td>40.7</td>
<td>0.43</td>
<td>52.8</td>
<td>25.8</td>
<td>44.1</td>
<td>38.5</td>
</tr>
<tr>
<td>9</td>
<td>Crop residues+limestone</td>
<td>54.1</td>
<td>37.0</td>
<td>24.4</td>
<td>2.22</td>
<td>44.5</td>
<td>38.7</td>
<td>64.8</td>
<td>0.36</td>
<td>56.3</td>
<td>23.4</td>
<td>42.0</td>
<td>39.2</td>
</tr>
<tr>
<td>10</td>
<td>Crop residues+limestone+rock phosphate</td>
<td>57.0</td>
<td>37.3</td>
<td>28.2</td>
<td>2.30</td>
<td>51.5</td>
<td>38.8</td>
<td>56.2</td>
<td>0.41</td>
<td>57.7</td>
<td>23.4</td>
<td>39.8</td>
<td>42.5</td>
</tr>
<tr>
<td>11</td>
<td>Crop residues+limestone+superphosphate</td>
<td>56.2</td>
<td>35.1</td>
<td>30.6</td>
<td>3.13</td>
<td>51.9</td>
<td>41.3</td>
<td>62.1</td>
<td>0.56</td>
<td>62.7</td>
<td>26.3</td>
<td>41.9</td>
<td>50.5</td>
</tr>
<tr>
<td>12</td>
<td>Crop residues+limestone+complete commercial fertilizer</td>
<td>57.6</td>
<td>37.9</td>
<td>26.8</td>
<td>3.00</td>
<td>51.7</td>
<td>37.5</td>
<td>54.1</td>
<td>0.41</td>
<td>60.8</td>
<td>21.1</td>
<td>37.9</td>
<td>44.3</td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>47.2</td>
<td>35.1</td>
<td>23.1</td>
<td>1.87</td>
<td>40.9</td>
<td>33.3</td>
<td>37.8</td>
<td>0.41</td>
<td>50.3</td>
<td>18.8</td>
<td>36.1</td>
<td>37.4</td>
</tr>
</tbody>
</table>

(1) Poor stand of oats.  
(2) First cutting only.  
(3) Dry summer reduced yield.  
(4) Very small crop due to dry weather.  
(5) Hot, dry weather damaged corn.  
(6) Mixture of oats and barley; no yields recorded.  
(7) Dry weather during August seriously damaged corn, especially fertilized plots which were further advanced.  
(8) Very dry season; only one cutting.  
(9) Season dry for second and third cuttings.  
(10) The Everly Field, Series I, was established in the fall of 1917 on the farm of John Henck, east of Everly, in Clay County. It is located on the east side of the SE ¼ of the NW ¼ of Section 6, T. 96 N, R. 37 W, in Lone Tree Township.

Phosphate gave larger crop increases, as on the alfalfa in 1932, but in general the differences were not pronounced. The complete commercial fertilizer with the residues and lime had no greater effect on the crop yields than did superphosphate. In fact, in most cases slightly smaller yields were secured with the complete fertilizer.

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 XIX. 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
<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1922 oats lb. per A.</th>
<th>1923 clover tons per A.</th>
<th>1924 clover tons per A.</th>
<th>1925 clover tons per A.</th>
<th>1926 oats lb. per A.</th>
<th>1927 clover tons per A.</th>
<th>1928 clover tons per A.</th>
<th>1929 clover tons per A.</th>
<th>1930 alfalfa tons per A.</th>
<th>1931 alfalfa tons per A.</th>
<th>1932 clover tons per A.</th>
<th>1933 alfalfa tons per A.</th>
<th>1934 clover tons per A.</th>
<th>1935 alfalfa tons per A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>63.8</td>
<td>1.45</td>
<td>74.6</td>
<td>66.8</td>
<td>0.57</td>
<td>31.8</td>
<td>57.9</td>
<td>47.4</td>
<td>1.05</td>
<td>2.03</td>
<td>1.63</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Manure</td>
<td>100.3</td>
<td>1.60</td>
<td>83.2</td>
<td>70.4</td>
<td>1.83</td>
<td>69.4</td>
<td>58.8</td>
<td>76.8</td>
<td>2.82</td>
<td>4.71</td>
<td>5.84</td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Manure + superphosphate + muriate of potash</td>
<td>91.2</td>
<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>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Manure + rock phosphate</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>
<td>5.31</td>
<td>5.49</td>
<td>2.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Crop residues</td>
<td>73.0</td>
<td>1.68</td>
<td>66.9</td>
<td>54.5</td>
<td>0.77</td>
<td>43.2</td>
<td>44.0</td>
<td>54.7</td>
<td>1.22</td>
<td>2.61</td>
<td>2.31</td>
<td>1.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Crop residues + superphosphate + muriate of potash</td>
<td>69.9</td>
<td>1.56</td>
<td>54.7</td>
<td>52.8</td>
<td>0.87</td>
<td>39.6</td>
<td>43.4</td>
<td>53.4</td>
<td>1.02</td>
<td>2.76</td>
<td>2.24</td>
<td>1.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Crop residues + rock phosphate</td>
<td>73.0</td>
<td>1.56</td>
<td>70.4</td>
<td>61.0</td>
<td>1.47</td>
<td>56.5</td>
<td>44.2</td>
<td>71.6</td>
<td>2.26</td>
<td>4.22</td>
<td>4.30</td>
<td>2.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Crop residues + complete commercial fertilizer</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>
<td>4.34</td>
<td>2.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check</td>
<td>97.3</td>
<td>1.68</td>
<td>61.2</td>
<td>54.0</td>
<td>0.85</td>
<td>35.7</td>
<td>38.3</td>
<td>50.4</td>
<td>1.00</td>
<td>2.64</td>
<td>1.75</td>
<td>0.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Manure</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>
<td>2.72</td>
<td>4.37</td>
<td>4.99</td>
<td>2.68</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 and 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.

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. Usually 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 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, on the clover in 1923, on the oats 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 oc­
casioned 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 SOILS

Peat 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. Peat occurs in Iowa
mainly in the Wisconsin drift soil area. Pocahontas County is located in this
area and has several areas of peat and muck, together aggregating 5,056 acres,
or 1.4 percent of the county.

The peat in Pocahontas 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
peat soils in the county may be reclaimed and made productive by proper methods
of treatment and cropping.

Field Experiments on Peat Soils

Field experiments were carried out several years ago on some typical shal­
low 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. 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 Pocahontas County are recommended.

Treatment of Peat Soils

Drainage is the most important treatment needed for peat soils in Pocahontas
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 tile should
be laid in the underlying subsoil rather than in the peat itself, as in the latter
case the compacting of the peat would bring the tile too close to the surface
and make relaying necessary. The tile should not be laid too deeply in the
subsoil, as the heavy clay is very 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 to the action of the frost, rain
and snow during the winter and hasten decay. Fall-plowed peats may be

2 Stevenson, W. H., Brown, P. E., and Boatman, J. L. The management of peat and alkali soils in
worked earlier in the spring, hence the seedbed may be more thoroughly prepared. Deep plowing is also valuable, especially when the peat is very shallow, permitting some of the underlying heavy clay to be mixed with the peat.

Peat 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 is deeper than this careful rolling may be desirable. The practice cannot be generally recommended.

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

Applications of manure are not advisable on peat 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 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, 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 soils, especially when properly fertilized. After a few years of pasturing or growing fertilized vegetable crops, peat soils are usually in better condition for growing corn and small grains successfully.

“ALKALI” SOILS

There are areas of so-called “alkali” soils in Pocahontas 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 washing out the excess of salts more rapidly. The lines or 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 of “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 muriate of potash has been found to be of value on these alkali soils, applying 200 pounds per acre. Tests of the effect of this fertilizer are very desirable.

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

The laboratory, greenhouse and field experiments which have been discussed
in this report indicate fairly definitely the needs of the soils in the county
generally. The field experiments described were not carried out in Pocahontas
County, but the soil types are the same as those occurring in the county and the
results may, therefore, be considered to show accurately the results which may
be expected from the same fertilizing materials in this county.

The suggestions offered here are based upon the experiments discussed, but
they are also based upon the general experiences of Iowa farmers. No recom­
mendations are made except such as have been proved to be of value on individ­
ual farms. Any farmer may carry out the suggestions offered without any
special difficulty.

In a number of instances, it is suggested that tests of certain fertilizing
materials be carried out on individual farms. Many farmers are now conducting
simple tests along these lines and are securing information of much value to
themselves and to their neighbors on the same soils. The Soils Subsection of the
Iowa Agricultural Experiment Station is ready to aid any farmers who may
wish to test any fertilizers on their own soils.

MANURING

Many of the soils in Pocahontas County are very dark or even black in color
and hence well supplied with organic matter. Some of the types, however, are
not so rich in organic matter, and this is shown in the lighter color of the surface
soil. The Webster soils on the level uplands are very dark in color and rich in
organic matter. The Clarion and Pierce soils are not so rich and hence the
color is lighter. The Rogers and Bremer types on the terraces are black in color,
while the Sioux, O'Neil, Waukesha and Judson types are somewhat lighter and
are not so high in organic matter. The bottomland soils are all dark in color
and high in organic matter, but the Lamoure and Wabash soils are richer than
the Cass types. Even on those soils which are apparently well supplied, it has been
found that applications of fertilizing materials supplying organic matter are
very much worth while. On all the soils it is important that organic matter be
added regularly if the supply is to be kept up. On the lighter colored soils, and
especially those with sandy or gravelly subsoils such as the Pierce, the O'Neil,
the Sioux and the Cass types, the addition of organic matter is particularly de­
sirable. This is true also in the case of the Waukesha and Judson types on the
terraces. Large effects are also secured on the Clarion loam on the uplands.

Under the livestock system of farming, farm manure serves as the chief
material which may be employed to keep up the supply of organic matter in
the soil. By properly conserving the manure produced and applying it to the
land, the livestock farmer will go far toward maintaining the fertility of his
soil. He will be able at least to keep up the organic matter content. He will also
find large beneficial effects on crop yields appearing as a result of the application.
Tests described earlier in this report have shown the value of farm manure on
the Clarion loam, the Webster silty clay loam, the Webster loam, the O'Neil loam,
and the Lamoure silty clay loam. Many of the other soils in the county would
undoubtedly show even greater effects from the use of manure, as several of the
types used in the tests reported are the richest soils in the area. The application of manure is of value on all the soils, larger applications being made to the lighter-colored sandy types. Small applications are preferable on the richer, blacker soils, and large additions should not be made to these types. Regular applications of small amounts are very desirable, however, even on these better soils.

On grain farms where little or no manure is produced, and on many livestock farms where there is not a sufficient amount of manure produced to permit an application to all the land on the farm, some other source of organic matter must be sought. In such cases the use of inoculated legumes as green manures is desirable. It not only provides for the maintenance of the organic matter content of the soils, but also adds nitrogen to the land. When legumes are well inoculated, they take much of their nitrogen content from the air, and hence, when used as green manures, they function as a nitrogen fertilizer. On many of the soils in Pocahontas County, green manuring would be of value, especially where the soil is lighter in color and sandy in texture. Green manuring should never be practiced blindly or carelessly, however, as undesirable effects may occur if the green materials are not properly decomposed in the soil.

The proper utilization of crop residues on every farm will aid materially in keeping up the supply of organic matter in the soils. On the livestock farm, the residues may be used for feed or bedding and returned to the land with the manure. On grain farms, they may be stored, allowed to decompose partially or applied directly to the land.

**LIMING**

Many of the soils in Pocahontas County are acid in reaction in the surface soil and hence need lime to produce the best crop yields, and especially of legumes. The steep phase Clarion loam has a high lime content at the surface, owing to the fact that the surface soil has been largely washed away, but the typical Clarion loam is acid in the surface soil, showing a lime content and no acidity in the subsoil. The Webster silty clay loam is not acid in the surface soil and shows, in fact, a rather high lime content. The Webster loam, however, like the Clarion loam, is acid in the surface soil, but has a high lime content in the subsoil. The Pierce sandy loam is well supplied with lime. On the terraces the soils are all acid in the surface soil except the Rogers silt loam which is high in lime. The Sioux loam shows a lime content in the subsoil. The Lamoure soils on the bottoms are high in lime in the surface soil as well as in the lower soil layers. The Wabash silty clay is acid throughout the surface soil and subsoil, but the Cass loam which is acid in the surface soil shows a lime content in the subsoil.

The data given in table IV indicate roughly the lime requirements of the different soils, but they do not show exactly the amount of lime which should be used in any particular case. The acidity and need for lime vary considerably, and often soils from different areas near each other will show wide differences in lime requirements. The best plan to follow to insure the proper application of lime is to test the particular soil. Farmers may test their own soils for acidity or lime requirement, but it will usually prove more satisfactory if they will send a small sample of the soil to the Soils Subsection of the Iowa Agricultural Experiment Station where it will be tested free of charge. The Clarion
loam, Webster loam, all the terrace types and the Wabash and Cass soils on the bottoms should be tested for lime needs, especially before seeding to legumes. Only by tests is it possible to apply lime when needed and to put on the proper amount.

Acid soils do not generally prove as satisfactory for crop growth as do soils which are slightly basic or not acid in reaction. Some crops, such as sweet clover and alfalfa, frequently will not grow where the soil is acid. Most other crops show large increases when lime is applied to acid soils. The legumes are benefitted the most, but general farm crops are often largely affected. Even on soils which are acid in reaction only in the surface soil, the application of lime is necessary to insure early growth of legumes.

The beneficial effects of liming some of the soils in the county have been noted in the experiments discussed earlier in this report. The Clarion loam, Webster silty clay loam (when it is acid), Webster loam and O’Neill loam have been found to respond to liming. Other soils would show equally good effects from the application of lime. Many tests and the experiences of farmers have shown the importance and value of applying lime to acid soils. Only by keeping the soils well supplied with lime is it possible to keep crop growth satisfactory and permit maintenance of the permanent fertility of the land.

Lime must be applied regularly to soils if they are to be kept from becoming deficient. One application may last for a number of years, but the best plan is to test the soil each time the legume comes around in the rotation. Then if lime is necessary, the proper application may be made and the best growth of the legume crop insured.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of Pocahontas County is rather low and it is evident that the supply will not be sufficient to meet the needs of crops for any number of years. In fact, it seems that phosphorus fertilizers will certainly be needed on these soils in the very near future, and it is probable that a phosphate might bring profitable results at the present time.

Rock phosphate or superphosphate may be applied to soils to meet any deficiency in available phosphorus. Rock phosphate is usually employed at the rate of 500 or 1,000 pounds per acre once in 4 years. Superphosphate is used at the rate of 120 pounds per acre annually, 3 years out of 4 in the 4-year rotation. Superphosphate contains the phosphorus in a readily available form, while the phosphorus in rock phosphate is more slowly available and utilizable. Superphosphate gives immediate results, while rock phosphate often does not show its greatest effect until the second year after application. There is considerable difference in the cost of the fertilizers, and as the rock phosphate application is more costly, it must show much greater effects on crops to prove as economically desirable.

The field and greenhouse experiments which have been described have shown that one or the other of these two phosphates may be used profitably on some of the soils in this county. The Clarion loam, Webster silty clay loam, Webster loam, O’Neill loam and Lamoure silty clay loam all showed beneficial effects from phosphate additions. The effects on some of the other types would certainly be
quite as definite, and perhaps even more so. In some of the tests superphosphate gave the better results, while in other instances rock phosphate gave just as large or even larger effects. Definite conclusions regarding the relative value of the two phosphates cannot be drawn at the present time. Farmers are urged to test their effects on small areas, and thus they may determine which material will give the better results for their particular conditions.

There is no striking deficiency in nitrogen in any of the soils in this county, but in some cases the content is not very high and actual deficiencies may sometimes occur. In any case, however, nitrogen must not be overlooked when systems of permanent fertility are planned. Nitrogen is constantly disappearing from cultivated soils through cultivation and removal by crops, and some fertilizing material supplying nitrogen must be added to soils regularly if the supply is to be kept up.

The proper use of farm manure and crop residues aids materially in keeping up the nitrogen content of soils. The use of leguminous crops as green manures is the cheapest and best means of increasing the nitrogen content of the soil and keeping up the supply. If they are well inoculated, legumes take up a large part of their nitrogen from the atmosphere, and hence when turned under in the soil they not only add organic matter, but they may also increase the nitrogen content of the soil. When inoculated legumes are grown and used as green manures, the nitrogen supply of the soil may be built up and kept up without the use of expensive commercial nitrogenous fertilizers. For special crops commercial nitrogenous fertilizers may give profitable results, but for general farm crops they cannot be recommended for use, at least not until tests have been carried out on small areas and the value of the application definitely shown for the particular conditions.

Experiments have shown that commercial potassium fertilizers may sometimes have beneficial effects on crop growth. This is particularly true on peat and muck soils and in “alkali” areas. But on normal soils, potash often pays. For general farm crops, however, the use of a potash fertilizer cannot be recommended now. Tests should be carried out on small areas before any extensive applications are made. Where the effects are large, the fertilizer may be applied to large areas with assurance of profit.

Complete commercial fertilizers have been compared with the phosphates in all the tests reported here, and in general it appears that superphosphate gives just as large or even larger benefits. Rock phosphate often has as great effects. As the complete fertilizers cost much more than the phosphates, it is obvious that they must bring about much greater increases in crops if they are to prove as desirable. In general, they do not give much larger crop yields. Hence their general use in the county cannot be recommended. In all cases where complete fertilizers are to be employed, tests should be carried out on small areas, comparing the fertilizer to be tested with superphosphate in order to determine the actual field value of the material and the profit which may come from its use.

DRAINAGE

The natural drainage system of Pocahontas County is rather poorly developed, and in many areas the soils are not yet adequately drained in spite of the atten-
tion which has been given to the drainage situation and the tile and ditches which have been installed. On the level to depressed Webster soils and on some Clarion areas, drainage is not adequate. The Rogers and Bremer types on the terraces and the Lamoure and Wabash soils on the bottoms are not well drained. The first treatment needed to reclaim peat and muck soils is drainage.

There is no possibility of securing good crops on land which is not properly drained, and wherever land is too wet the first treatment needed is drainage.

**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 rotation may be used, provided it contains a legume, and the money crops, all of which must, of course, 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 principally 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 gullying. Sheet erosion is the washing away of the surface soil. Gullying is more striking in appearance, since gulches or ravines may be formed.

There is some erosion in Pocahontas County in the Clarion loam areas. Where the steep phase of this type occurs, considerable erosion has occurred. Some of the other types show some evidence of erosion. Wherever this 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. Gullies may be prevented from forming 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 POCAHONTAS COUNTY

There are 15 individual soil types in the county and these with the steep phase Clarion loam and the muck and peat make a total of 17 separate soil areas. They are divided into three groups, drift soils, terrace soils and swamp and bottom-land soils.

DRIFT SOILS

There are four drift soils in the county and with the steep phase Clarion loam, five drift areas. Together, they cover 89.9 percent of the county.

Clarion Loam (138)

The Clarion loam is the largest drift soil and the largest individual soil type in the county. With the steep phase, which is rather limited in area, it covers 43.2 percent of the total area. It is developed in all parts of the county, the largest continuous bodies occurring in the extreme northwestern corner and in the eastern half along the slopes to the West Des Moines River and the larger creeks.

The surface soil of the Clarion loam is a very dark grayish-brown friable loam extending to a depth of 12 to 15 inches. Plowed fields when wet are almost black. Between 15 and 20 inches there is a layer of yellowish-brown friable silty clay loam, streaked with dark material from above. The subsoil is a brownish-yellow or yellow friable silty clay loam or silty clay which generally grades at a depth of 30 to 35 inches into a yellowish-brown, gritty, silty clay, mottled with gray, rusty-brown and grayish-white. From 24 inches down small rock fragments occur, many of them containing lime. Below 48 inches the subsoil is a mottled gray, rusty-brown and yellowish-brown gritty, sandy clay streaked with reddish-brown, orange and white lime-bearing materials. Numerous rock fragments occur.

In topography the Clarion loam is gently rolling to strongly rolling. In a few places the slope is steep enough to cause damage from erosion. In the more rolling areas the surface soil has become thinner than typical, and ranges in thickness from 8 to 10 inches. Included with the soil as mapped there are a few areas of Clarion fine sandy loam, too small to separate on the map. Most of these areas occur on small isolated knolls.

The greater part of the soil is in cultivation or pasture. Along the large streams the slopes are often wooded, the tree growth consisting mainly of oak, elm, cottonwood, maple and walnut. Corn is the chief crop, yielding 40 bushels per acre.

---

5 The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report. Pocahontas County adjoins Buena Vista County on the west and Webster County on the south. In some cases the soil maps do not agree on the boundaries. This is due to changes in correlation resulting from a fuller understanding of the soils of the state. The greater part of the Carrington loam mapped in Buena Vista and Webster counties is mapped as Clarion loam in Pocahontas County and the greater parts of the areas of the Fargo soils in Webster County are placed in the Webster series in Pocahontas County.
on the average. Much larger yields are obtained in some cases. Oats are grown on all farms, yielding 35 to 65 bushels per acre. Barley, alfalfa, sweet clover and soybeans are grown successfully.

Crop yields are usually highly satisfactory on the Clarion loam, but yields may be increased by proper treatments. The application of farm manure, the use of lime to correct acidity, and the addition of a phosphate fertilizer have been shown in the experiments described earlier in this report to bring about very desirable effects on crops.

**Clarion Loam (steep phase)** (151)

The steep phase Clarion loam is of minor occurrence, covering only 0.4 percent of the total area. It occurs as narrow ribbon-like areas, bordering the bottoms of the West Des Moines River and Pilot, Beaver and Lizard creeks.

The surface soil of the type is a dark grayish-brown friable loam, 9 to 11 inches in depth. There is considerable sand in the soil, and in some areas it approaches a fine, sandy loam in texture. Between 11 and 17 inches there is a dark brown crumbly loam streaked with black. The subsoil is a yellowish-brown, sandy clay loam or clay loam to 22 to 24 inches, where it changes to a grayish-yellow, distinctly calcareous sandy clay. Below 34 inches the subsoil is a grayish-yellow or pale yellow till, streaked with white calcareous materials. On the steeper slopes, the surface soil is often much less than 8 inches thick, owing to the erosion which has occurred, while on the lower slopes the surface layer is thicker.

The soil differs little from the typical Clarion loam, except that it is steep rather than rolling in topography, and in many places it is badly gullied. It is generally considerably eroded and the surface soil has been largely removed by washing. Drainage is well established, and in places is excessive.

Practically none of the soil is in cultivation, but it is used for pasture. Bluegrass does well. Some of the slopes are forested with oak, elm, cottonwood and walnut. The more gentle slopes might be cultivated if precautions were taken to protect the land from washing. In cultivated areas the soil would be benefited materially by additions of farm manure and the turning under of leguminous crops as green manures. The use of a phosphate fertilizer would also undoubtedly prove of value. Many of the pasture areas might be improved through discing, reseeding and fertilization with manure and a phosphate fertilizer.

**Webster Silty Clay Loam** (107)

The Webster silty clay loam is the second largest drift soil and the second type in the county, covering 28.0 percent of the total area. It is developed in all parts of the county, occurring in the more level areas on the uplands between the natural drainage channels. It is broken only by low, narrow ridges, small knolls of Clarion loam and by shallow stream bottoms.

The surface 2 or 3 inches of the type in virgin areas is a very dark grayish-brown silty clay loam, filled with grass roots. In cultivated areas the surface 9 to 12 inches is a very dark grayish-brown or almost black silty clay loam, finely granular in structure. In the lower part of the 30-inch section the color changes from a dark grayish-brown to a drab or yellowish-brown, and the texture be-
POCAHONTAS COUNTY SOILS

WEBSTER SILTY CLAY LOAM

A.  very dark grayish or black silty clay loam

B.  very dark grayish brown to black brownish silty clay

C.  dark gray or dark grayish-brown silty clay

D.  dark brown or pale yellowish-brown silty clay, mottled with gray and yellowish-brown

E.  gray or pale yellow silty clay streaked yellowish brown and rust brown

The Webster silty clay loam is the third largest soil type in the county, covering 18.4 percent of the total area. It occurs in all parts of the county in association with the Webster silty clay loam, generally at a little higher elevation, lying between the silty clay loam and the Clarion loam.

The surface soil of the Webster loam is a very dark grayish-brown or almost black, heavy friable loam, from 12 to 14 inches deep. In virgin areas there are two layers, a very dark grayish-brown granular loam, 2 to 3 inches thick, and a layer of very dark grayish-brown or almost black, heavy loam, containing some fine white sand. From 14 to 18 inches the soil is more brown in color and usually contains some carbonates. Below this point there is a dark gray slightly gritty...
clay loam or clay splotched with dark brown and some rusty-brown. Some rock fragments and sand occur in the lower part of the layers, and carbonates are abundant. Between 26 and 42 inches the soil is a mottled gray, rusty-brown and yellowish-brown sandy clay, containing iron stains and streaks of white calcareous materials. Below this and extending to a depth of 4 or 5 feet, the color is dark gray, light gray, yellowish-brown and orange, and the texture is a gritty silt clay. The sand content decreases with depth, while the mottlings of orange and rusty-brown increase.

The type is level to gently undulating in topography. Drainage is likely to be poor, although the soil is naturally better drained than the silty clay loam. Open ditches and tile are provided in practically all areas to insure adequate drainage.

The total area of the type is in cultivation or pasture. Corn, oats and hay are the chief crops. Yields are much the same as on the Webster silty clay loam. The soil is naturally productive when thoroughly drained. Drainage is the first treatment needed. The surface soil is acid and liming is necessary for legume crops. The application of farm manure is of value and a phosphate fertilizer will help. The tests reported earlier have shown the value of manure, lime and rock phosphate or superphosphate on this soil.

**Pierce Sandy Loam (191)**

The Pierce sandy loam is a minor type, covering only 0.3 percent of the total area. It occurs on small isolated knolls and narrow ridges in all parts of the county. The most extensive development is in the vicinity of Gilmore City.

The surface 2-inch layer of the Pierce sandy loam is a dark grayish-brown sandy loam, underlaid by a very dark grayish-brown sandy loam, which at 10 inches changes to a brown, gravelly, sandy loam, mottled with rusty brown and gray. Some fine and coarse gravel are present, often being coated with white carbonates. At 22 inches there is a gray, slightly sticky calcareous layer which at 36 inches is underlaid by layers of sand and fine gravel. These materials are highly calcareous. Many variations occur in color and texture of the surface soil and in thickness of the underlying beds of sand and gravel. In Section 12, township 91 north,
range 31 west, the surface is rather flat and the soil is thicker and a very dark grayish-brown or almost black in color.

The Pierce sandy loam has practically no agricultural value except the area 1 mile southwest of Gilmore City. Corn is the chief crop. The soil needs organic matter principally. Liberal applications of farm manure, or the turning under of leguminous crops as green manures, would be of value on cultivated areas. The use of a phosphate would also help, applying superphosphate in normal amounts. Most of the areas of this type are used for gravel pits and furnish good road material.

TERRACE SOILS

There are seven terrace soils in the county, classified in the Sioux, O’Neill, Rogers, Bremer, Waukesha and Judson series. Together they cover 2.5 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 occurs on the terraces of practically all the streams of the county; most of the bodies are small and widely separated. The most extensive development is along Beaver Creek in the northeastern part of Powhatan Township.

The surface soil to a depth of 12 inches is a dark brown loam or fine sandy loam, containing some white, fine sand. Between 12 and 20 inches the soil is a brown or yellowish-brown, gritty, loamy sand. Some gravel and boulders are found in this layer. Below this point and extending to depths of 10 or 12 feet there are beds of stratified gravel, fine sand, and much of the material is coated with white calcareous coverings.

The soil lies 2 to 5 feet above the first bottoms. Drainage is excessive, and in dry seasons the soil is drouthy. About 60 percent of the type is in cultivation. Corn is the chief crop, and in favorable seasons yields 25 to 45 bushels per acre. Oats yield 35 to 40 bushels per acre. The soil needs to be built up in organic matter to be made more productive. Liberal applications of farm manure or the turning under of leguminous crops as green manures would be of particularly large value. If the surface soil is acid, as is often the case, lime should be applied to insure good legume growth. The use of a phosphate fertilizer would help, and tests with superphosphate are urged.

O’Neill Fine Sandy Loam (110)

The O’Neill fine, sandy loam is the second largest terrace soil, covering 0.4 percent of the total area. It occurs only in the extreme northeastern corner of the county on the terraces along the West Des Moines River.

The surface soil of the type is a dark brown, fine, sandy loam, underlaid at 2 or 3 inches by a very dark grayish-brown fine, sandy loam. Plowed fields ap-
pear almost black when wet. Between 16 and 40 inches the soil is a yellowish-brown, slightly loamy fine sand, containing some coarse sand and fine gravel. At 40 inches there is a pale grayish-yellow gravelly sand that becomes more gravelly at lower depths. There are a few isolated knolls of the type where the surface soil is a fine sand underlaid to depths of 3 feet or more by beds of sand and fine gravel. The topography of the type is level or slightly sloping. It is drouthy in dry seasons.

All the land in the type is in cultivation or in pasture. Yields of corn average 25 to 35 bushels per acre. Oats yield from 30 to 45 bushels per acre.

This soil needs organic matter additions, especially if it is to be made more satisfactorily productive and less drouthy. Liberal applications of farm manure would help materially, and turning under leguminous crops as green manures would be much worth while. The soil is acid, and liming is necessary. The use of superphosphate would also undoubtedly prove of value for general farm crops.

Rogers Silt Loam (140)

The Rogers silt loam is a minor type, covering 0.3 percent of the total area. It occurs only in depressions that were formerly shallow lakes. The most extensive areas of the type are found in the northwestern corner of the county.

The surface soil to an average depth of 12 inches is a gray or light grayish-brown silt loam. When dry the soil is a light gray. Small shells are scattered over the surface and throughout the soil. The subsoil is much like the surface soil except that the color is lighter.

Most of the areas of the type are now well drained with tile leading into large open ditches. Corn and oats are the chief crops grown. Corn yields from 25 to 40 bushels per acre and oats from 35 to 50 bushels. Oats are likely to lodge unless the short stiff-strawed varieties are grown. Some potatoes are produced.

When adequately drained the Rogers silt loam may be made fairly productive through proper cropping and fertilization. The use of small amounts of farm manure will help on newly drained areas to stimulate the production of available plant food. Large applications should not be made. Fertilization with superphosphate or rock phosphate will increase the yields of corn and oats, hastening
maturity and improving the grain quality in the case of corn and making oats less likely to lodge. Muriate of potash will also help. For potatoes the use of superphosphate and potash will prove of large value.

O’Neill Loam (108)

The O’Neill loam is a minor type, covering 0.2 percent of the total area. It occurs on low terraces along Pilot and Beaver creeks which cut across the northeastern part of the county.

The surface soil is a very dark grayish-brown loose, mellow, friable loam, extending to a depth of 10 to 13 inches. Below this point and continuing to a depth of 24 to 27 inches the soil is a brown or yellowish-brown fine sandy loam. The subsoil is more sandy and is usually a gritty, somewhat sticky sand.

The O’Neill loam lies 2 to 3 feet above the general level of the first bottoms. The drainage is likely to be excessive, owing to the sandy, gravelly subsoil, and in dry seasons the soil is drouthy.

Corn and small grains are the chief crops grown, and in seasons of normal rainfall good yields are secured. Corn yields from 30 to 35 bushels and oats from 35 to 50 bushels. In dry years the yields are very low.

The soil needs organic matter chiefly, in order to build up the supply and make the type less subject to drouth. The application of liberal amounts of farm manure is of large value, and the turning under of leguminous crops as green manures would also help. The soil is acid and in need of lime, especially for legumes. The addition of superphosphate would undoubtedly prove of value.

Bremer Loam (12)

The Bremer loam is a minor type, covering 0.2 percent of the total area. It occurs as small more or less isolated bodies on the terraces of the West Des Moines River and North Branch Lizard and South Branch Lizard creeks.

The surface soil is a grayish-brown loam to a depth of 4 inches, underlaid by a very dark grayish-brown mellow loam, 11 inches thick. There is some fine gravel in the upper layer and some fine sand in the lower part. The subsoil at 15 inches is a grayish-brown silty clay, containing some sand. Below 24 inches and extending to varying depths the grayish-brown silty clay is mottled with gray and rusty-brown. Small areas of Bremer silty clay loam, too small to show on the map, are included with the type. It is level to flat in topography and the natural drainage is poor.

Corn is the chief crop grown, yielding about 35 bushels per acre. Oats have a tendency to lodge. The poorly drained bodies are left in their native state and used for pasture.

The chief need of this soil is for adequate drainage. It will be benefited by small applications of farm manure, especially on newly
drained areas. It is acid and in need of lime for general farm crops and particularly for legumes. It will be increased in productivity by the addition of a phosphate fertilizer, and tests of superphosphate or rock phosphate are recommended.

**Waukesha Loam (60)**

The Waukesha loam is a minor terrace type, covering only 0.1 percent of the total area. The most extensive areas occur on the terraces of the West Des Moines River.

The surface soil consists of a dark grayish-brown mellow friable loam, 10 or 12 inches deep. Between 12 and 20 inches the soil is a dark grayish-brown loam, changing into a yellowish-brown heavy loam in the lower part of the layer. The subsoil from 20 inches to about 42 inches is a yellowish-brown or light-yellow, friable silty clay loam or heavy loam with some dark colored streaks. Below 42 inches there is a brownish-yellow or yellowish-brown friable silty clay loam, mottled with gray and faint iron stains. Small areas of Waukesha fine sandy loam, too small to show on the map, are included with the type.

In topography the Waukesha loam is flat or gently sloping. It occurs on terraces 10 to 20 feet above the first bottoms. Drainage is entirely adequate.

Practically all the type is in cultivation or in pasture. Corn is the chief crop, yielding 40 bushels per acre on the average. Oats, wheat and barley are grown to some extent.

The soil will respond to applications of farm manure, and large increases in crop yields are brought about when manure is used. The type is acid and in need of lime. The use of a phosphate fertilizer would help, and tests of superphosphate or rock phosphate are very desirable.

**Judson Fine Sandy Loam (251)**

The Judson fine sandy loam is a minor terrace type, covering only 0.1 percent of the total area. It occurs only in the extreme northeastern corner of the county on the terraces of the West Des Moines River.

The surface soil is a very dark grayish-brown fine sandy loam. The subsoil is slightly lighter in color and about the same in texture. In topography the soil is level to very gently sloping. Drainage is good.

Corn is the chief crop grown, yielding 35 to 45 bushels per acre. Oats yield from 35 to 60 bushels per acre, and barley from 15 to 18 bushels per acre. Hay crops usually produce from 1½ to 3 tons per acre.

The Judson fine sandy loam will be increased in productivity by the use of farm manure. It is acid, and liming will increase crop yields. The use of a phosphate fertilizer will certainly help, and tests of superphosphate and rock phosphate are recommended.
SWAMP AND BOTTOMLAND SOILS

There are four bottomland soils in the county and with the muck and peat five individual soil areas. The soil types present are mapped in the Lamoure, Wabash and Cass series.

Lamoure Silty Clay Loam (111)

The Lamoure silty clay loam is the largest of the bottomland soils and the fourth largest type in the county, covering 5.1 percent of the total area. It occurs along practically every creek in the county, being most extensively developed south of Clinton, northwest of Pocahontas and north of Fonda.

The surface soil of the type is a very dark grayish-brown or almost black mellow silty clay loam, extending to a depth of 10 to 12 inches. Below this point there is a very dark grayish-brown silty clay, mottled with white calcareous materials and some yellow specks. From 20 inches to about 3 feet the subsoil is a dark grayish-brown silty clay, mottled with gray, yellowish-brown and yellow.

Some small areas of Lamoure silty clay loam, Wabash silty clay loam, and Wabash silty clay, too small to show on the map, are included with the type. In some areas the separation of the soil from the Wabash silty clay was difficult, and the boundaries were established somewhat arbitrarily. The Lamoure silty clay loam typically contains considerable amounts of carbonates, especially in the upper subsoil, but in some cases the amounts present are small and there is a gradual transition into the Wabash silty clay which shows no carbonate content.

In topography the Lamoure silty clay loam is flat or gently sloping toward the streams. It lies 5 to 9 feet above the normal water level. Since most of the streams have been straightened and ditched, drainage is usually sufficient to permit good crop growth.

Corn is grown extensively, and yields in normal seasons are much the same as on the upland Webster types. Oats yield from 35 to 60 bushels per acre, but are likely to lodge. Alfalfa and sweet clover grow well on the areas where drainage is well established.

The Lamoure silty clay loam is chiefly in need of drainage to be made more productive. When this is accomplished, good crop yields may be secured. Small applications of farm manure will be of value on newly-drained areas. Large additions should not be made.

A phosphate fertilizer would undoubtedly help, and tests of rock phosphate or superphosphate would be very desirable. Either of these fertilizers would certainly give better crop yields, as was indicated by the field experiments reported earlier.
Muck and peat occur in areas of varying size in the western and southeastern parts of the county. A few bodies contain about 300 acres, but the areas average between 10 and 20 acres. The total acreage in muck and peat covers 1.4 percent of the total area of the county.

The surface soil is usually a brown or black, more or less finely divided organic material, sometimes being a black muck and in other cases a brown material, showing the slightly decomposed plant remains. The surface layer varies from 20 inches to 3 feet in thickness and is underlaid by a drab-colored clay or clayey material. Small shells occur on the surface and throughout the soil, and the entire mass is calcareous.

Drainage is the first treatment necessary to bring peat areas under cultivation. Then they will be benefited by fall plowing, deep plowing and proper cultivation. Timothy and alsike clover make a good crop to grow on newly drained areas, the crop being used for pasture. When partly decomposed, becoming a muck, general farm crops and truck crops may be grown successfully, provided proper fertilization is practiced. The application of superphosphate or muriate of potash or both will aid materially in making these areas productive. Frequently fertilization with these materials means the difference between no crop at all and a very satisfactory crop.

Lamoure Loam (112)

The Lamoure loam is the third largest bottomland soil, covering 0.7 percent of the total area. It occurs most extensively in the extreme northeastern corner of the county on the first bottoms of the West Des Moines River. Other areas of the type are found on the bottoms along some of the other streams.

The surface soil is a very dark grayish-brown, friable, somewhat sticky loam, extending to a depth of about 14 inches. From 14 to 18 inches there is a dark grayish-brown structureless clay loam, mottled in the lower part with faint gray and rusty-brown. At 18 inches the soil is a dark grayish-brown friable silty clay, mottled with dark gray. This is underlaid at depths of 22 to 24 inches by a mottled gray, dark gray and grayish-brown friable clay that becomes grayer in color with depth. Some rusty brown spots and white sand occur. Below 30 inches the color is mottled light gray and dark gray, and the texture is a gritty clay, containing some fine gravel and carbonates. From 36 to 40 inches the material is a gray or pale yellowish-gray or grayish-yellow sandy clay, faintly mottled with rusty brown and dark gray, resting at 42 or 45 inches on gray, sticky sand splotched with orange and yellow.

Small areas of the very fine sandy loam and clay loam, too small to show on the map, are included with the type. Small areas of a silty phase of the type occur along Cedar Creek in the western part of the county and along Pilot Creek in the northeastern part. Here the soil contains more silt in the surface layer. In depressed areas material has been washed in from the higher uplands, and the surface soil is rather variable. In places, it resembles the Webster types. The subsoil usually is high in carbonates in all areas, but the amount of lime in the various subsoil layers varies widely in the different areas of the type.
The Lamoure loam lies 8 to 10 feet above the normal water level and is subject to overflow. Most of the land is in pasture and supports a good growth of grass. There are a few wooded areas where the tree growth consists mainly of elm, ash, cottonwood, hickory and ironwood.

In the drained areas, corn is the chief crop grown when the land is cultivated. Its yields range from 35 to 60 bushels, with an average of about 37 bushels per acre. Some small grains are grown, but they are likely to lodge.

The Lamoure loam needs to be well drained first of all, if it is to be cultivated. Then it will be benefited by small applications of farm manure, especially on newly drained areas. Large applications should not be made. The addition of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are desirable.

### Wabash Silty Clay (27)

The Wabash silty clay is a minor type, covering 0.3 percent of the county. It occurs only on the first bottoms of the West Des Moines River.

The surface soil of the type is a very dark grayish-brown or almost black silty clay, 10 or 12 inches in depth. The subsoil is a black silty clay which at 24 to 28 inches is underlaid by a dark-gray or dark slate-colored plastic clay. The type has poor natural drainage and is subject to overflow.

About 60 percent of the soil is cultivated and very low corn is grown. The remainder is in pasture. Corn yields are much the same as on the Webster silty clay loam, when seasonable conditions are favorable. Average yields, however, are lower than on the Webster soils.

The Wabash silty clay needs, first of all, to be drained if it is to be cultivated. It will be benefited by small applications of farm manure. It is acid and needs lime. Phosphate fertilizers would prove of value in many cases, and tests of rock phosphate and superphosphate are recommended.

### Cass Loam (18)

The Cass loam is a minor type, covering 0.1 percent of the total area of the county. It occurs almost exclusively in the northeastern quarter of the county where it is developed in the bottoms of Pilot and Beaver creeks.

The surface soil is a dark grayish-brown or almost black loam, containing some fine sand, extending to a depth of about 8 inches. From 8 to 15 inches there is a somewhat darker-colored layer that is distinctly lighter textured, in most places being a very fine sandy loam. At a depth of 28 or 30 inches there is a dark grayish-brown loam which has a yellowish-brown cast. From 30 to 49 inches the subsoil is a gray or grayish-brown fine sandy loam or loamy fine sand. Some
white calcareous material is present in the subsoil and frequently throughout the soil mass. Some small areas of very fine sandy loam and sandy loam are included with the type. The land is flat and lies from 2 to 4 feet above the normal stream level.

Practically none of the type is farmed. It is used for pasture and supports a good growth of natural grasses. When cultivated the soil will be benefited materially by liberal applications of farm manure and the turning under of leguminous crops as green manures. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended. When the surface soil is acid, lime should be applied, especially if legumes are to be grown.
APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proved value are suggested.

Map of Iowa showing the counties surveyed.
SOIL SURVEY OF IOWA

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 by their ever running out, 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 16c (Sodium Nitrate (NaNO₃)), Phosphorus (P) at 12c (Superphosphate), and Potassium (K) at 6c (Potassium Chloride (KCl)).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant food, 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</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>7.5</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn, crop</td>
<td></td>
<td>111</td>
<td>17.25</td>
<td>53</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td></td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>33</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.25 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>Oats, crop</td>
<td></td>
<td>48.5</td>
<td>8</td>
<td>94</td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Barley, crop</td>
<td></td>
<td>32.5</td>
<td>6</td>
<td>18.5</td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>19</td>
<td>4</td>
<td>21.0</td>
</tr>
<tr>
<td>Rye, crop</td>
<td></td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>300 bu.</td>
<td>63</td>
<td>12.7</td>
<td>90</td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>300</td>
<td>27</td>
<td>144</td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>3 T.</td>
<td>72</td>
<td>9</td>
<td>67.5</td>
</tr>
<tr>
<td>Clover, hay</td>
<td>3 T.</td>
<td>120</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

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 destruction 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 does not occur in a form available for plants, but with proper physical conditions 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 rotation of crops.

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 destruction 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 does not occur in a form available for plants, but with proper physical conditions 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 rotation of crops.

The humus and nitrogen content of soils need be resorted to. 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 phosphates 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
POCAHONTAS COUNTY SOILS

loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions and 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 "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are 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
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 by the Illinois Experiment Station in its Soil Report No. 1. They are:

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

- **Organic matter**: All partially destroyed or decomposed vegetable and animal matter.
  - Stones—over 32 mm.*
  - Gravel—32—2.0 mm.
  - Very coarse sand—2.0—1.0 mm.
  - Coarse sand—1.0—0.5 mm.

- **Inorganic matter**: Medium sand—0.5—0.25 mm.
  - Fine sand—0.25—0.10 mm.
  - Very fine sand—0.10—0.05 mm.
  - Silt—0.05—0.00 mm.

**SOILS GROUPED BY TYPES**

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

- **Peats**—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.
- **Peaty Loams**—15 to 35 percent organic matter mixed with much sand and silt and a little clay.
- **Mucks**—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.
- **Clays**—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.
- **Silty Clay Loams**—20 to 30 percent clay and more than 50 percent silt.
- **Clay Loams**—20 to 30 percent clay and less than 50 percent silt and some sand.
- **Silt Loams**—20 percent clay and more than 50 percent silt mixed with some sand.
- **Loams**—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.
- **Sandy 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 very fine sand and less than 25 percent 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

* 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 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.
IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

(Those followed by a * are out of print, but are often available in public libraries.)

BULLETINS

No. BULLETINS

78 Drainage Conditions in Iowa.*
92 The Principal Soil Areas of Iowa.*
98 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
102 Clover Growing on the Loess and Till Soils of Southern Iowa.*
150 The Fertility of Iowa Soils.*
150a The Fertility of Iowa Soils (Popular Edition).*
151 Soil Acidity and the Liming of Iowa Soils.*
151a Soil Acidity and the Liming of Iowa Soils (Abridged).*
157 Improving Iowa's Peat and Alkali Soils.*
161 Maintaining Fertility in the Wisconsin Drift Soil Areas of Iowa.*
167 Rotation and Manure Experiments on the Wisconsin Drift Soil Areas.*
177 The Alkali Soils of Iowa.
183 Soil Erosion in Iowa.*
191 Reclaiming Iowa's Push Soils.
203 Iowa System of Soil Management.*
208 Crop Yields on Soil Experiment Fields in Iowa.*
232 Field Experiments with Gypsum.*
236 The Economic Value of Farm Manure as a Fertilizer on Iowa Soils.
239 Crop Rotations Under Various Rotations in the Wisconsin Drift Soil Area.
261 Inoculation of Non-Legumes.*
261a Inoculation of Non-Legumes (Abridged).*
266 The Management of Peat and Alkali Soils in Iowa.
269 Field Experiments with Fertilizers on Some Iowa Soils.
272 A Soil Management Program for Carrington Loam.
278 A Soil Management Program for Grumy Silt Loam.
283 Soil Management on the Carrington Silt Loam.
288 Effects of Inoculation and Liming on Soybeans Grown on the Grumy Silt Loam.

CIRCULARS

102 Inoculation of Legumes.*

RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
3 Influences of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
8 Bacteria at Different Depths in Some Typical Iowa Soils.*
9 Amino Acid and Acid Amides as Sources of Ammonia in Soils.*
11 Methods for the Bacteriological Examination of Soils.*
13 Bacteriological Studies of Field Soils, III.*
17 The Determination of Ammonia in Soils, 1.
18 Sulfonation of Soluble Bacteria in Fertilizers.
25 Bacterial Activities and Crop Production.*
26 Studies of Sulfonation.
30 Effects of Some Manganese Salts on Ammonification and Nitrification.
39 Carbon Dioxide Production in Soils and Carbon and Nitrogen Changes in Soils Various Conditions Treated.*
45 Effect of Sulfur and Manure on the Availability of Rock Phosphate in Soils.*
48 The Effect of Certain Alkali Soils on Ammonification.
50 Soil Inoculation with Azotobacter.
52 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.
56 Nitrification in Acid Soils.
57 The Color of Soils in Relation to Organic Matter Content.
58 The Relationship between Hydrogen Ion, Hydroxyl Ion and Salt Concentrations and the Growth of Seven Soil Molds.
57 A Study of the Secondary Effects of Hill Fertilization.*
104 Some Effects on Methods of Application of Fertilizers on Corn and Soils.*
109 The Numbers of Microorganisms in Carrington Loam as Influenced by Different Soil Treatments.
110 Studies on Nitrification and its Relation to Crop Production on Carrington Loam Under Different Treatments.
113 Physiological Studies on the Nitrogen Fixing Bacteria of the Genus Rhizobium.*
114 Soybean Inoculation Studies.*
126 The Production of Artificial Farm Manures.
128 The Effects of Artificial Farm Manures on Soils and Crops.
132 Microbiological Studies of Some Typical Iowa Soil Profiles.
135 Nitrate Assimilation in Soils.
139 The Measurement of the Degree of Saturation of Soils with Bases.
143 Methods for Determining Carbon Dioxide Production in Soils.
148 Some Chemical and Bacteriological Effects of Various Kinds and Amounts of Lime on Certain Southern Iowa Soils.
157 The Winogradsky Spontaneous Culture Method for Determining Certain Soil Deficiencies.
158 The Production of Gum by Certain Species of Rhizobium.