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Soil Survey of Iowa, Report No. 2—Pottawattamie County Soils

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SOIL SURVEY OF IOWA
POTAWATTAMIE COUNTY SOILS

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 2
January, 1918
Ames, Iowa
IOWA AGRICULTURAL EXPERIMENT STATION

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36 Influence of some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.

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1 Bremer County.
2 Pottawattamie County.
3 Muscatine County.
4 Webster County. (In press.)
5 Lee County. (In press.)
SOIL SURVEY OF IOWA
Report No. 2—POTTAWATTAMIE COUNTY SOILS

By W. H. Stevenson and P. E. Brown, assisted by H. P. Hanson and H. W. Reid

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View showing characteristic type of upland topography in Pottawattamie county. The experiment station orchard is shown in the distance.
POTTAWATTAMIE COUNTY SOILS

By W. H. Stevenson, P. E. Brown, with the assistance of H. P. Hanson and H. W. Reid

Pottawattamie county is located in southwestern Iowa along the Missouri river. It is the second largest county in the state, having a total area of 957 square miles, or 612,480 acres. It is entirely within the Missouri loess soil area; 70% of its soils being loessial in origin, while the remaining types fall within the terrace and swamp and bottomland groups.

This county is one of the most important in the state agriculturally, not alone because of its size, but also because of the high normal fertility of its soils and the wonderful adaptation of soil and climatic conditions to the growth of certain valuable crops.

Of the total area of Pottawattamie county, 518,784 acres, or 84.7% is in farms numbering 3,101 in all with an average size* per farm of 167 acres.

The utilization of the farm land is indicated by the following figures, compiled by the state department of agriculture in 1915:

- Acreage in pasture ........................................... 131,000 acres
- Acreage in farm buildings, feed lots and public highways .... 24,639 acres
- Acreage in orchards ........................................ 4,962 acres
- Acreage in gardens ....................................... 1,106 acres
- Acreage in waste land .................................... 4,559 acres
- Acreage in general farm crops ......................... 356,050 acres
- Acreage in crops not otherwise listed ................. 745 acres

The type of agriculture is indicated rather definitely in the figures just given and consists in general farming combined to a considerable extent with livestock raising. The acreage in orchards is not large, but fruit growing is increasing rapidly in the county. With the information which is now being secured and disseminated regarding the growing and marketing of fruits, orcharding will undoubtedly become of much importance.* Systems of permanent fertility adapted to Pottawattamie county should, therefore, include not only general farming, and livestock farming, but also orcharding.

The area of waste land in this county is not great but it warrants attention and methods of reclamation or utilization should be devised. Definite advice along this line, of course, can only be given for individual conditions and no general recommendations can be made here.

* See Soil Survey of Pottawattamie County, Iowa, by A. L. Goodman of the U. S. Department of Agriculture, and Peter Hanson and Harold W. Reid of the Iowa Agricultural Experiment Station.

* An experiment orchard maintained by the Iowa Agricultural Experiment Station near Council Bluffs is yielding much information of value to fruit growers of Pottawattamie and adjoining counties.
TABLE I. ACREAGE, YIELDS AND VALUES OF FARM CROPS IN POTTAWATTAMIE COUNTY *

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>% total farm land in county</th>
<th>Bu. or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>194,000</td>
<td>37.3</td>
<td>33</td>
<td>6,402,000</td>
<td>0.45</td>
<td>$2,880,900</td>
</tr>
<tr>
<td>Oats</td>
<td>43,900</td>
<td>8.4</td>
<td>32</td>
<td>1,404,800</td>
<td>0.32</td>
<td>449,536</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>10,900</td>
<td>2.1</td>
<td>15</td>
<td>163,500</td>
<td>0.85</td>
<td>138,975</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>32,000</td>
<td>6.1</td>
<td>20</td>
<td>640,000</td>
<td>0.83</td>
<td>531,200</td>
</tr>
<tr>
<td>Barley</td>
<td>5,800</td>
<td>1.1</td>
<td>28</td>
<td>162,400</td>
<td>0.85</td>
<td>83,824</td>
</tr>
<tr>
<td>Rye</td>
<td>500</td>
<td>0.1</td>
<td>20</td>
<td>10,000</td>
<td>0.77</td>
<td>7,700</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1,850</td>
<td>0.3</td>
<td>76</td>
<td>140,600</td>
<td>0.53</td>
<td>74,518</td>
</tr>
<tr>
<td>Tame hay</td>
<td>34,900</td>
<td>6.6</td>
<td>1.7</td>
<td>59,300</td>
<td>8.94</td>
<td>530,142</td>
</tr>
<tr>
<td>Wild hay</td>
<td>2,700</td>
<td>1.8</td>
<td>1.5</td>
<td>14,500</td>
<td>7.41</td>
<td>107,445</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>22,500</td>
<td>4.3</td>
<td>3.6</td>
<td>51,000</td>
<td>11.18</td>
<td>905,680</td>
</tr>
<tr>
<td>Pasture</td>
<td>131,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Over three-fifths of the farm land is employed for general farming and the crops grown, in the order of their importance, are corn, alfalfa, winter wheat, tame hay, oats, spring wheat, wild hay, barley, potatoes, and rye.

POTTAWATTAMIE COUNTY’S FARM CROPS

Corn is particularly adapted to Pottawattamie county and does well on all the soil types, but it is especially suited to the Marshall silt loam where the yields are generally high. On the terrace and swamp and bottomland soils yields are usually lower than on the upland soils, but in favorable seasons quite satisfactory crops are obtained. The value of the corn crop is very much greater than that of any of the other crops grown, as will be seen in table I.

The Missouri loess soil area as a whole is especially suited to the growth of alfalfa and Pottawattamie county stands second among all the counties of Iowa in the production of this crop. Alfalfa grows well on all the soil types in the county but like corn, it does especially well on the Marshall silt loam. Very few failures to secure satisfactory yields are recorded and three or four cuttings are usually made with yields up to seven tons per acre as a common occurrence. The value of alfalfa in this county is second only to corn and the acreage is increasing each year. Sweet clover is being grown to some extent in place of alfalfa, but its use is not general and it is doubtful if it will ever prove as valuable as a forage crop.

The next crop of importance in this county is wheat. Both winter wheat and spring wheat have been grown, but spring wheat has been quite generally replaced by the more profitable winter variety. At the present time the acreage of the latter is three times that of the former. The average yield of the winter wheat is greater than that of the spring variety and the total value to the county is, therefore, much greater.

The tame hay crop in Pottawattamie county far exceeds the wild hay in acreage, yield and value. The tame hay is made up practically entirely of timothy and red clover and its value alone exceeds that of the grain crops, except corn and wheat.

Oats stand next to corn in acreage and production, but its value is less than that of alfalfa, wheat, and hay. It is a very important crop and is found in

* Iowa Year Book of Agriculture, 1915.
nearly all rotations, satisfactory yields being secured in most cases. Practically all the oats produced in Pottawattamie county is fed on the farms.

Barley, rye, and potatoes are grown to some extent, but the acreage is not large and their value is much less than that of the crops already mentioned.

The suitability of the land along the Missouri river to the production of apples and grapes was recognized by the early settlers. It is only within recent years, however, that these crops have been grown to any considerable extent. The yield of apples in the county in 1915 was 81,942 bushels and the production is constantly increasing. The varieties grown are Ben Davis, Roman Stem, Grimes Golden, Gano, Jonathan, Winesap, Mammoth Black Twig, and Northwestern Greening. Grape growing has also increased considerably. Over 600 acres are now in vineyards and the yields and profits are quite satisfactory. The disposal of the crop is much facilitated thru the aid of co-operative buying and selling associations. Grapes are particularly suited to the Knox silt loam and prove valuable on the steep bluff land near the Missouri river where field crops cannot be grown satisfactorily. Better methods of handling the vineyards are quite necessary in many cases and if proper treatment of the soil and vines is followed, this crop can be made one of the most profitable in the county.

POTTAWATTAMIE COUNTY LIVESTOCK INDUSTRY

The livestock industry is well developed in Pottawattamie county. Good market facilities and excellent blue grass pastures render it one of the leading stock raising counties in the state.

The extent of this industry is indicated in the following figures compiled in 1915:

- Horses (all ages) .................. 21,753
- Mules (all ages) ..................... 2,610
- Swine (July 1, 1915) .................. 195,496
- Cattle (cows and heifers kept for milk) .... 12,874
- Cattle (other cattle not kept for milk) .... 52,743
- Cattle (total, all ages) ................ 71,970
- Sheep (all ages on farms) .............. 5,627
- Sheep (shipped in for feeding) .......... 7,007
- Sheep (total pounds wool clipped) ...... 34,916

The livestock industry is profitable and should undoubtedly be developed to a much greater extent. Not only are there good returns on the investment made, but the drain on the natural fertility of the soil is less under livestock farming.

The value of land in Pottawattamie county is extremely variable. The bottom lands along the Missouri river, the least valuable because they are subject to overflow, sell for $65 to $100 per acre. They produce good crops in favorable seasons. In the eastern three-fourths of the county, where the land is gently rolling to hilly, the prices range from $125 to $250 per acre and here soil and climatic conditions are favorable for the very best crop production.

Yields of all crops in Pottawattamie county are good, but experiments show very definitely that they may be increased thru proper methods of management. The soils are not acid except in a few cases and do not generally need lime. They are low in organic matter or humus, however, and care should be taken to
Fig. 1. Rich alluvial soil on the Missouri river bottoms. Characteristic loess bluffs in the distance. The alluvial soils are classified in the Wabash soils provide enough of this important material. With proper treatment and cropping, the yields from the soils in this county may be increased to a considerable extent.

THE GEOLOGY OF POTTAWATTAMIE COUNTY

Pottawattamie county is located in the midst of the Missouri loess soil area bordering on the Missouri river. About three-fourths of the county consists of level to hilly loessial upland and the remaining portion is made up of flat to gently undulating alluvial plains or first bottoms.

The rock material underlying the soils of Pottawattamie county represents various geological eras and is of interest technically, but from the agricultural standpoint it is of no importance for it is so deep under the overlying loess that it can have practically no effect on the growth of crops.

The whole county was covered by at least one glacier in times past, for evidences of glacial deposits are frequently encountered. It is impossible, however, to ascertain whether more than one glacier extended over the county. Resting on this glacial material is a dark-blue to bluish gray or yellow clay known as "bowlder clay," a material undoubtedly of drift origin. It appears only on the steepest slopes where the loess runs out; ordinary slopes show no evidence of it. No great importance from the agricultural standpoint is therefore attached to the occurrence of this material. With the exception of the steep
slopes mentioned the upland soils everywhere are so deeply covered with loess that the underlying material has practically no influence on the fertility of the soil.

The loess is extremely variable, both in color and composition, due of course to the varying conditions under which it has existed. Frequently lime material occurs in considerable amounts. It may be rather uniformly distributed thru the loess but more commonly it is collected into lumps or concretions. These concretions, or "clay dogs," vary considerably in size and striking accumulations are occasionally found along the Missouri river. They are of particular interest in indicating the presence of sufficient lime, or the absence of acidity, in the soil.

The loess varies widely in thickness. It is generally much thicker in the western portion of the county and thins out somewhat in the east. The depth may alter within very short distances. The average greatest thickness in the eastern portion of the county is probably 50 feet but it is often less than 40 feet. Along the Missouri river it is usually 70 or 80 feet in thickness and frequently it becomes 150 to 200 feet thick.

The loess along the rivers has of course been modified to a considerable extent by the action of the streams in carrying away and depositing material. The terrace soils, or old bottom lands, are therefore distinguished from the loess. The present bottomland soils are likewise considered separately. These three groups of soils constitute the basis for the following discussion and description of the soils of Pottawattamie county.

PHYSIOGRAPHY AND DRAINAGE

The topography of Pottawattamie county is very uniform, consisting in the main of upland slopes and several flood plains, with some strips of upland plains and a few terraces.

The flood plain of the Missouri river covers about seven percent of the area. The elevation of this plain is generally less than 20 feet above the average height of water in the river. The flood plains of the West Nishnabotna and East Nishnabotna rivers are of minor importance, covering comparatively small areas. They are on the average from 100 to 120 feet above the Missouri river. There are also rather large plains or bottomlands formed by numerous smaller streams.

The main topographic feature of the county is an old drift plain into which the lowland plains just described have been cut and again partly filled. This plain has a gentle slope to the southwest. The average elevation above sea level is about 1,200 to 1,300 feet.

The main streams which cross the country from north to south divide this plain into a succession of broad, parallel swells with a central divide and two gentle slopes down to the bluffs of the streams. Thus the distinctive, gently undulating to hilly appearance of the loess soil area as a whole is accounted for.

The rougher portions of the county, which are found near the bluffs of the Missouri river and consist of numerous narrow ridges and ravines, are undoubtedly the result of erosion. Thus the topography of some areas has been considerably modified thru the action of streams and particularly of creeks.
Fig. 2. The natural drainage system of Pottawattamie county
The drainage of Pottawattamie county may be said to have a latticed arrangement; the heavy, continuous lines of the main streams run from north-northeast to south-west and the small, more irregular lines of the tributaries run from northwest to southeast. The lines of the secondary streams are separated by areas usually about four-fifths of a mile wide.

In general the drainage system of the county is excellent. The East Nishnabotna and West Nishnabotna rivers and the various creeks which run in the same direction as these rivers and the tributaries of all these streams provide thorough drainage of the county as a whole and artificial drainage is rarely necessary.

THE SOILS OF POTTAWATTAMIE COUNTY

The soils of Pottawattamie county may be grouped into three general classes: the loess soils, the terrace soils, and the swamp and bottomland soils. There are no drift soil areas of sufficient size to be mapped and no residual soils.

<table>
<thead>
<tr>
<th>TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loess........................................................................... 445,760 72.7</td>
</tr>
<tr>
<td>Terrace soils..................................................... 19,648 3.3</td>
</tr>
<tr>
<td>Swamp and bottomland soils............................. 147,072 24.0</td>
</tr>
<tr>
<td>Total........................................................................... 612,480</td>
</tr>
</tbody>
</table>

It is apparent from table II that the largest portion of the county, almost 75 percent, is covered by the loess soils. There is also a rather large percent of swamp and bottomland in the county. Terrace soils are found only to a small extent.

The terrace soils and the swamp and bottomland soils in Pottawattamie county are uniformly level, but the loess areas are quite variable. The topography of the Marshall silt loam, the most widely distributed loess soil, ranges all the way from level to hilly, and that of the Knox silt loam varies from level to hilly and in some cases to rough.

There are ten distinct soil types in Pottawattamie county, two loess soils, three terrace soils and five swamp and bottomland soils.

Table III shows that the Marshall silt loam is not only the chief loess soil, but

<table>
<thead>
<tr>
<th>TABLE III. TYPES OF POTTAWATTAMIE COUNTY SOILS AND THEIR AREAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil No.</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
</tr>
<tr>
<td>23</td>
</tr>
<tr>
<td>24</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
</tr>
<tr>
<td>26</td>
</tr>
<tr>
<td>26a</td>
</tr>
<tr>
<td>27</td>
</tr>
<tr>
<td>28</td>
</tr>
<tr>
<td>29</td>
</tr>
</tbody>
</table>
it covers by far the largest proportion of the total area of the county, over 68 percent.

The other loess soil is of much less importance, covering only 4.7 percent of the total area of the county.

The terrace soils are all of minor importance, the total area covered by the three being only 3.3 percent of that in the county. The Hancock silt loam covers the largest area of the three and the Osgood very fine sand is of very small extent, occupying only 0.1 percent of the area of the county.

Three of the swamp and bottomland soils are rather extensive in area, the Wabash silt loam, the Wabash silt loam (Colluvial phase), and the Wabash silty clay. The other two types are of minor importance and occupy only a small part of the county.

While the loess soils must be considered first in planning systems of soil management for Pottawattamie county, the swamp and bottomlands should not be neglected for they are of considerable extent. Furthermore, these latter soils are much more in need of special treatment to make them profitably productive than the loess soils, altho increases in crop yields on the loess types may also be secured by proper management. All the soil types must be considered, therefore, in working out systems of permanent fertility for the county.

THE FERTILITY IN POTTAWATTAMIE COUNTY SOILS

The plant food content of Pottawattamie county soils was determined by analyzing samples of all types found. These samples were secured with the usual precautions that they should be true to type and that all variations due to difference in treatment should be eliminated. Three samples were drawn from each of the main soil types and one sample from each of the minor types, just as in the case of the other counties surveyed. Each sample represented the surface soil from 0 to 6% inches deep, the subsurface soil from 6% to 20 inches deep, and the subsoil from 20 to 40 inches deep.

Total phosphorus, total nitrogen, organic carbon, inorganic carbon and limestone requirement determinations were made on the soils at the three depths according to the official methods, the Veitch method being employed for determining the limestone requirements.

THE SURFACE SOILS

Table IV presents the results of the analyses of the surface soils, the figures given being the average of duplicate determinations on several samples of each soil in the case of the major types. The results are expressed in pounds per acre of 2,000,000 pounds of surface soil.

This table shows wide differences in the plant food content of the various soil types. These variations are noticeable not only when the large soil groups are compared, but also appear among the types within these groups. To what extent the latter variations are due to natural differences or to modifications brought about by varying factors cannot be stated. It is certain, however, that loess soils are not necessarily lower or higher in any one constituent than terrace soils or swamp and bottomland soils, and so on.

The phosphorus content of the terrace soils in Pottawattamie county is gen-
erally higher than that of the loess soils or the swamp and bottomland soils. The organic carbon and the nitrogen content of the terrace soils are likewise somewhat greater than in the loess soils, but the differences are not large. The swamp and bottomland soils are on the average lowest in all three constituents. This is unusual as such soils generally contain accumulations of organic matter which lead to the presence of greater amounts of organic carbon, nitrogen and often also of phosphorus. It is evident that in this county these level, low-lying soils were originally lower in these elements than the other soils.

The content of inorganic carbon, which in a measure shows the lime requirements of soil, is extremely variable, but it does seem that the swamp and bottomland soils are somewhat higher in this constituent. None of the soils are acid except the Marshall silt loam, but the supply of lime is apparently not extremely high in any of the surface soils.

None of the soils in Pottawattamie county are so abundantly supplied with phosphorus that this element can be disregarded in systems of soil improvement and permanent fertility. There is enough phosphorus in all the soils for several crops if it is made available rapidly enough, but when the total phosphorus present is not abundant the rate at which it is made available is certain to be very low. It is doubtful, therefore, if sufficient phosphorus would be made available to keep crops properly supplied for any considerable length of time. In fact, in the case of some of the soil types applications of phosphorus might be of value at the present time. This point will be considered further in connection with the greenhouse experiment on the Marshall silt loam. In general phosphorus must be considered in all systems of fertility which are devised for the soils of this county.

The nitrogen supply is low in practically all Pottawattamie county soils. Only in the case of the Hancock silty clay is there anything like a fair amount of this constituent. The swamp and bottomland soils are notably low in nitrogen, a rather unusual state of affairs as has already been pointed out. The organic carbon content of the various soils is correspondingly low as is apt to

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime-stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Marshall silt loam</td>
<td>1313</td>
<td>3260</td>
<td>37,307</td>
<td>146</td>
<td>1779</td>
</tr>
<tr>
<td>11</td>
<td>Knox silt loam</td>
<td>1290</td>
<td>1710</td>
<td>16,065</td>
<td>4355</td>
<td>Basic</td>
</tr>
<tr>
<td>23</td>
<td>Hancock silt loam</td>
<td>1500</td>
<td>2860</td>
<td>34,104</td>
<td>2516</td>
<td>Basic</td>
</tr>
<tr>
<td>24</td>
<td>Hancock silty clay</td>
<td>1900</td>
<td>4380</td>
<td>52,428</td>
<td>132</td>
<td>Basic</td>
</tr>
<tr>
<td>25</td>
<td>Osgood very fine sand</td>
<td>1220</td>
<td>1340</td>
<td>10,670</td>
<td>3070</td>
<td>Basic</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>1360</td>
<td>2820</td>
<td>38,928</td>
<td>1042</td>
<td>Basic</td>
</tr>
<tr>
<td>26a</td>
<td>Wabash silt loam (Colluvial phase)</td>
<td>1300</td>
<td>2960</td>
<td>36,726</td>
<td>394</td>
<td>Basic</td>
</tr>
<tr>
<td>27</td>
<td>Wabash silty clay</td>
<td>1380</td>
<td>1740</td>
<td>22,644</td>
<td>7236</td>
<td>Basic</td>
</tr>
<tr>
<td>28</td>
<td>Sarpy very fine sandy loam</td>
<td>1020</td>
<td>1780</td>
<td>15,710</td>
<td>4230</td>
<td>Basic</td>
</tr>
<tr>
<td>29</td>
<td>Sarpy very fine sand</td>
<td>810</td>
<td>440</td>
<td>10,300</td>
<td>3900</td>
<td>Basic</td>
</tr>
</tbody>
</table>

TABLE IV. PLANT FOOD IN POTTAWATTAMIE COUNTY SOILS, IOWA POUNDS PER ACRE OF TWO MILLION POUNDS OF SURFACE SOIL (0-6-%)
be the case, the swamp and bottomland soils being particularly deficient in this constituent for soils of such a nature.

All of the soils are low in organic matter. That is evident because the nitrogen and organic carbon occur in such relatively small amounts in practically all cases. Farm manure should be applied in as large amounts as practicable and green manure crops, preferably legumes, should be turned under in order to bring these soils up to a proper content of organic matter, and to insure the best mechanical and chemical soil conditions for the growth of bacteria and the production of available plant food.

The relation between the carbon and nitrogen in some of these soils is such that there is not the best bacterial action or the best decomposition of the organic matter. In some instances, therefore, the need of organic matter which will undergo rapid decomposition is very clearly shown.

The greatest immediate need of the soils in Pottawattamie county is evidently for organic matter and steps should be taken to supply an abundance of fresh, easily decomposable material. Rotations should include a legume and a green manure "catch crop." Crop residues should be completely utilized and the farm manures should be preserved carefully and applied in as large quantities as available, if permanent fertility is to be maintained.

The inorganic carbon content of Pottawattamie soils is comparatively high. In a general way the swamp and bottomland soils are highest in this constituent. The abundance of inorganic carbon, reflecting as it does the lime content of the soil, indicates that the soils are not likely to be acid in reaction. This is the case. Only one soil type shows any limestone requirement whatever and the amount needed there is small. Of the three samples of the Marshall silt loam two showed slight acidity and one was basic. The average result given in

Fig. 3. A loess bluff. Erosion is very active on these loess hills and carves fantastic shapes in the loess
The results of the analyses of subsurface soil, and subsoil samples were calculated as pounds per acre of 4,000,000 pounds of subsurface soil and of 6,000,000 pounds of subsoil. The results are given in tables V and VI.

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

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime- stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall silt loam</td>
<td>2600</td>
<td>5733</td>
<td>55,914</td>
<td>298</td>
<td>1223</td>
</tr>
<tr>
<td>Knox silt loam</td>
<td>2340</td>
<td>1840</td>
<td>17,838</td>
<td>14,282</td>
<td>Basic</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hancock silt loam</td>
<td>2800</td>
<td>2840</td>
<td>28,312</td>
<td>24,006</td>
<td>Basic</td>
</tr>
<tr>
<td>Hancock silty clay</td>
<td>3120</td>
<td>6800</td>
<td>73,016</td>
<td>264</td>
<td>Basic</td>
</tr>
<tr>
<td>Osgood very fine sand</td>
<td>1560</td>
<td>1360</td>
<td>6,240</td>
<td>15,900</td>
<td>Basic</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wabash silt loam</td>
<td>2600</td>
<td>5520</td>
<td>52,396</td>
<td>2964</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash silt loam (Colluvial phase)</td>
<td>3040</td>
<td>6290</td>
<td>77,112</td>
<td>963</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash silty clay</td>
<td>2760</td>
<td>3880</td>
<td>71,416</td>
<td>17,824</td>
<td>Basic</td>
</tr>
<tr>
<td>Sarpy very fine sandy loam</td>
<td>2000</td>
<td>2520</td>
<td>25,560</td>
<td>8,900</td>
<td>Basic</td>
</tr>
<tr>
<td>Sarpy very fine sand</td>
<td>1560</td>
<td>560</td>
<td>13,304</td>
<td>8,136</td>
<td>Basic</td>
</tr>
</tbody>
</table>

**TABLE VI. PLANT FOOD IN POTTAWATTAMIE COUNTY SOILS, IOWA**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Lime- stone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall silt loam</td>
<td>3700</td>
<td>5080</td>
<td>65,590</td>
<td>9,230</td>
<td>Basic</td>
</tr>
<tr>
<td>Knox silt loam</td>
<td>3330</td>
<td>2070</td>
<td>12,909</td>
<td>22,761</td>
<td>Basic</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hancock silt loam</td>
<td>3900</td>
<td>2100</td>
<td>65,844</td>
<td>43,596</td>
<td>Basic</td>
</tr>
<tr>
<td>Hancock silty clay</td>
<td>4260</td>
<td>6600</td>
<td>63,834</td>
<td>426</td>
<td>Basic</td>
</tr>
<tr>
<td>Osgood very fine sand</td>
<td>3200</td>
<td>1200</td>
<td>13,640</td>
<td>22,860</td>
<td>Basic</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wabash silt loam</td>
<td>3960</td>
<td>7380</td>
<td>54,474</td>
<td>1,746</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash silt loam (Colluvial phase)</td>
<td>5280</td>
<td>11280</td>
<td>146,628</td>
<td>606</td>
<td>Basic</td>
</tr>
<tr>
<td>Wabash silty clay</td>
<td>3660</td>
<td>4380</td>
<td>40,578</td>
<td>31,962</td>
<td>Basic</td>
</tr>
<tr>
<td>Sarpy very fine sandy loam</td>
<td>2700</td>
<td>2160</td>
<td>21,774</td>
<td>23,796</td>
<td>Basic</td>
</tr>
<tr>
<td>Sarpy very fine sand</td>
<td>2520</td>
<td>420</td>
<td>22,050</td>
<td>11,790</td>
<td>Basic</td>
</tr>
</tbody>
</table>
No large amounts of any of the necessary plant food constituents are present in the lower soil layers with the exception of inorganic carbon. The amount of this element is rather large in some cases and indicates the absence of acid conditions. The content of nitrogen and organic carbon in the subsurface soils and subsoils is generally less than that in the surface soils as would be expected, although in some cases the differences are very slight. The phosphorus content consistently decreases in the lower soil layers, as it is apt to do, so that there is no possibility of any deficiencies in this element being supplied from the underlying soil. The amount is too small to do more than merely delay slightly the time when phosphorus must be applied.

As in the case of the surface soils, only one soil type shows any acidity. The subsurface soil of the Marshall silt loam shows a small lime requirement. None of the other subsurface soils show any need for lime. In the case of the subsoils, none of the samples were acid. It is evident, therefore, that in remedying acidity in the soil, the needs of the surface soil only must be considered.

**GREENHOUSE EXPERIMENTS**

Two greenhouse experiments were carried out on a typical Marshall silt loam, the main soil type in Pottawattamie county. One of these was conducted in 1906 and the other was carried on as part of the soil survey in 1914-15.

In the first experiment ten pots were used, the treatments consisting of lime in air-slacked lime, nitrogen in dried blood, phosphorus in steamed bone meal and potassium in sulfate of potash. The lime was applied at the rate of 4,250 pounds per acre, the dried blood at the rate of 2,000 pounds per acre, the bone meal at the rate of 450 pounds per acre and the sulfate of potash at the rate of 555 pounds per acre.

Wheat was grown on the pots and the grain weights obtained as usual. The results of the experiment are given in table VII.

The lime had no effect on the crop grown. When nitrogen was added with the lime there was an increase in the crop. Phosphorus, likewise, brought about...
TABLE VII. GREENHOUSE EXPERIMENT, 1906
MARSHALL SILT LOAM

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight Grain gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>Check</td>
<td>12.8</td>
</tr>
<tr>
<td>62</td>
<td>Lime</td>
<td>12.8</td>
</tr>
<tr>
<td>63</td>
<td>Lime + Nitrogen</td>
<td>14.9</td>
</tr>
<tr>
<td>64</td>
<td>Lime + Phosphorus</td>
<td>14.3</td>
</tr>
<tr>
<td>65</td>
<td>Lime + Potassium</td>
<td>11.9</td>
</tr>
<tr>
<td>66</td>
<td>Lime + Nitrogen + Phosphorus</td>
<td>16.6</td>
</tr>
<tr>
<td>67</td>
<td>Lime + Nitrogen + Potassium</td>
<td>15.4</td>
</tr>
<tr>
<td>68</td>
<td>Lime + Phosphorus + Potassium</td>
<td>10.8</td>
</tr>
<tr>
<td>69</td>
<td>Lime + Nitrogen + Phosphorus + Potassium</td>
<td>16.6</td>
</tr>
<tr>
<td>70</td>
<td>Nitrogen + Phosphorus + Potassium</td>
<td>14.5</td>
</tr>
</tbody>
</table>

An increase when used with the lime, the crop yield being just about the same as that secured when the nitrogen was added. Potassium had no effect on the crop. Nitrogen and phosphorus applied together with the lime increased the crop yield over that secured with each alone, but the increase was not large.

Potassium with nitrogen and lime had no influence over the lime, and nitrogen when used with phosphorus and lime showed no effect. The yield in this latter case was even somewhat lower than with the check soil to which no fertilizer was added. Some unknown factor evidently interfered with the results here. The nitrogen, phosphorus and potassium when added with the lime gave the same yield as when the nitrogen and phosphorus were used. The potassium evidently had no effect in this case. The nitrogen, phosphorus and potassium gave about the same result as the nitrogen and lime and the phosphorus and lime, but they had a smaller influence than when used with lime.

It is apparent from these results that potassium need not be applied to the main soil type in Pottawattamie county. Lime had no effect. Nitrogen and phosphorus each brought about a noticeable increase in crop yield. When nitrogen and phosphorus were employed together, the effect was greater than that produced by each alone.

The second experiment, conducted in the greenhouse in 1914-15, involved the more practical tests of the application of manure and of phosphorus in the available or acid phosphate form and in the rock phosphate or insoluble form. Lime was applied in sufficient amount to neutralize the acidity and supply two tons additional; manure was used at the rate of 10 tons per acre; acid phosphate at the rate of 200 pounds per acre, and rock phosphate at the rate of 1,000 pounds per acre. The results of this experiment are given in table VIII, the average dry weight in grams of the wheat crop from the duplicate pots being recorded.

An examination of table VIII reveals some interesting facts. In the first place, the addition of lime brought about a considerable increase in the crop yield. This seems to emphasize the fact that although this Marshall silt loam is not generally acid, its lime content is so low that acid conditions become noticeable in individual cases.

When rock phosphate was applied with the lime it had no influence whatever on the crop yield. Acid phosphate on the other hand caused a decided gain in crop. It is evident that in the absence of sufficient organic matter, rock phos-
Greenhouse experiment No. 2. The mature wheat growing in these pots shows the relative effect of various treatments of Pottawattamie county soil. Manure used with lime increased the yield four fold.

Phosphate has little or no effect on soils which are in need of phosphorus because without this organic matter the insoluble phosphate is not made available.

When manure was applied to the soil with lime, a striking increase in crop yield was secured, four times as large a crop being obtained as in the untreated soil and twice as large as in the limed, unmanured soil. The need for organic matter in the soil is very distinctly shown by these results.

When rock phosphate was applied with the lime and manure the crop yield was apparently decreased. Only one result was secured, however, and it should not be considered as it is not probable that the rock phosphate would bring about any decrease in crop. With 

The results of this experiment are shown in fig. 5.

The greenhouse experiment indicated that the prime need of this soil, the major soil type in the county, is for organic matter. Applications of manure would be distinctly valuable and if enough manure is not available, green manures should be employed. This experiment does not include any results to show the relative merits of farm manure and green manures on this soil, but as a general thing farm manure is considered better unless nitrogen is decidedly deficient in which case leguminous green manure crops should be grown. The greater value of manure is probably due to the presence of numerous bacteria which bring about a rapid decomposition of the organic matter added and hence a rapid production of available plant food. Green manures are, however, the best substitutes for manure when the latter is available only in small amounts.

Lime is shown to be of use on this particular soil, but no general conclusion
TABLE VIII. GREENHOUSE EXPERIMENT, 1915
MARSHALL SILT LOAM

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Weight Grain gms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>4.37</td>
</tr>
<tr>
<td>2</td>
<td>Lime</td>
<td>7.75</td>
</tr>
<tr>
<td>3</td>
<td>Lime + Rock Phosphate</td>
<td>7.75</td>
</tr>
<tr>
<td>4</td>
<td>Lime + Acid Phosphate</td>
<td>10.50</td>
</tr>
<tr>
<td>5</td>
<td>Lime + Manure</td>
<td>17.50</td>
</tr>
<tr>
<td>5</td>
<td>Lime + Manure + Rock Phosphate</td>
<td>11.00*</td>
</tr>
<tr>
<td>7</td>
<td>Lime + Manure + Acid Phosphate</td>
<td>20.00</td>
</tr>
</tbody>
</table>

should be drawn from these results other than to call attention to the importance of testing the soils of this type to ascertain their reaction and need of lime. When acid, lime should be applied. Furthermore if some areas of the same type are not acid, it should not be assumed that all areas are not acid. In short, other treatments of soils will be practically useless if lime is not applied when needed.

Phosphorus in the form of acid phosphate gave an appreciable increase, both when applied with lime and manure and with lime alone. The rock phosphate used with the lime alone gave no effects and the results when it was employed with the lime and manure is questionable, so definite conclusions cannot be drawn and no comparisons between the two phosphatic materials can be made. It would seem, however, that phosphorus is not present in this soil type in any considerable amounts and applications of some phosphatic material, if not profitable at the present time, will undoubtedly be necessary in the rather near future.

FIELD EXPERIMENT

The soil upon some of the more hilly portions of the Missouri loess area in Pottawattamie county has sometimes become rather thin and occasionally outcrops of the underlying drift material occur. The removal of organic matter from the loess soils, which is generally rapid, is increased in such a topographic situation.

A field experiment was conducted during the seasons of 1905, 1906, and 1907 to ascertain the needs of such rather poor areas of Missouri loess soil. The experiment field was located at Leeds, in Woodbury county, near the Plymouth county line. The general situation and the conditions are very similar to those in Pottawattamie county so that the results of that experiment may well be considered here.

The complete data secured in the experiment were presented in bulletin no. 95 of the Iowa Agricultural Experiment Station published in 1908 and hence only summarized data and conclusions will be given here.

This experiment was carried out on an infertile hilltop, the field being situated on a divide and the road between the two series of plots being in the center of the ridge. The plots sloped east or west and the general slope of the area was north. The soil was a true loess, the underlying glacial material appearing only in a few places in the vicinity. The field had been under cultivation for only two years. Prior to that time it was in native pasture.

* The yield from one pot discarded.
On the top of the divide the organic matter content was very low due to the constant removal of the surface soil by erosion as well as to rapid decomposition. The organic matter content of the soil increased toward the lower part of the slopes and the growth of crops was much better in these portions of the plots. This hilltop was probably less fertile than the most of the area covered by the Missouri loess, but it was typical of a large number of unproductive areas which occur thruout the region.

The field was laid out into 44 one-twentieth acre plots, each 1 rod wide and 8 rods long, with a border 6 feet, 10 inches wide separating it from the next plot. A regular four-year rotation was followed, consisting of corn, corn, oats, and clover. The clover yields were not secured separately so there are no results for this crop. The oats were not threshed and hence the grain and straw yields were not secured separately. The total oats yield is given, however, for the two years 1905 and 1906 and the yield of corn for the years 1905, 1906 and 1907 is likewise given. Only the weight of grain was secured in the case of the corn.

The treatments of the soils consisted in the application of manure at the rate of 8 tons per acre, bone meal at the rate of 200 lbs. per acre annually, and cowpeas for a green manure by seeding the crop in the corn at the last cultivation and turning it under in the spring.

The yields of oats are given in table IX and the average yields of corn for the three years appear in table X together with the average increase and value of the increase calculated on the basis of bushels per acre.

Little value can be attached to the oat results inasmuch as it is quite impossible to determine how much of the increase in total crop was in the grain and how much was in the straw.

It is apparent from the results as a whole, that the plots to which manure was applied produced approximately one-third more grain and straw than did the plots which received no manure. This is a significant fact, and its importance accounts for the inclusion of the data at this place. It should be kept in mind in considering the results secured by the growth of corn for three years under the same treatments.

The effects of the various treatments on the corn crop are clearly shown in table X by the increases calculated for the average yield for the three years. The cowpeas gave a very slight increase, which might be expected since the crop turned under was rather small. Manure gave a larger increase in the yield of corn and when cowpeas were applied with the manure, a further gain was shown.

**TABLE IX. FIELD EXPERIMENT — OATS**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1905 Average Weight Crop</th>
<th>1906 Average Weight Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>91</td>
<td>156</td>
</tr>
<tr>
<td>Manure</td>
<td>126</td>
<td>228</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>99</td>
<td>186</td>
</tr>
<tr>
<td>Manure + Phosphorus</td>
<td>126</td>
<td>231</td>
</tr>
<tr>
<td>Potassium (KCl)</td>
<td>89</td>
<td>...</td>
</tr>
<tr>
<td>Manure + Potassium</td>
<td>126</td>
<td>197</td>
</tr>
<tr>
<td>Phosphorus + Potassium</td>
<td>103</td>
<td>193</td>
</tr>
<tr>
<td>Manure + Phosphorus + Potassium</td>
<td>134</td>
<td>251</td>
</tr>
</tbody>
</table>
Bone meal with the cowpeas had practically no effect but with manure showed a small gain over the plot treated with manure alone. Potassium sulfate exerted little influence on the crop when used with cowpeas or with manure. A slight gain was noted, both when it was applied with bone meal and cowpeas and when it was used with bone meal and manure.

The beneficial effect of the manure is the most prominent fact brought out by the results as a whole. It shows its influence distinctly in each crop, as well as in the general average. The calculation of the value of the increases due to the various treatments shows a large value for the manure.

Evidently, altho phosphorus was not abundant in these infertile hill tops, the use of sufficient organic matter encouraged decomposition processes and the production of available phosphorus to such an extent that the addition of a phosphate fertilizer did not give large increases. The same is true of potassium sulfate. The large increase in crop brought about by the manure may have been due in part to the plant food supplied in the material, but by far the greatest effect was probably due to the organic matter introduced which brought about an improvement of the physical condition of the soil. The ability to retain moisture, less extensive aeration and consequently better bacterial action, with the more economic production and utilization of plant food, are the direct results of the application of manure to this soil.

The system of management recommended for the improvement of the hilltops in the Missouri loess area involves, therefore, the maintenance of a sufficient supply of organic matter. This may be accomplished by the use of manure and by the proper rotation of crops. The rotation used should include the growing at frequent intervals of a crop which leaves a large portion of its material on the land and clover is the best crop for this purpose.

* Value calculated on basis of 33 cents per bushel.
When this crop is grown and the seed only is removed, or even where the first crop is cut and fed, there is considerable value in clover from the standpoint of maintaining the organic matter content of the soil. It is a valuable addition to farm manure which so often is not produced in large enough amounts to keep up all the soil on a farm.

FIELD EXPERIMENTS WITH GUMBO

Within the state there are areas of soil popularly called "gumbo" which have received special attention for several years because of the difficulty in farming them and because of their need for special treatment.

The term "gumbo" is not a recognized name for a particular class of soils, according to any accepted scheme of soil classification. It is a popular name for a group of soils which possess characteristics well known and dreaded by farmers. It is very different from the gumbo referred to in geological reports which includes almost impervious gray or yellow clay subsurface soils.

The soil that Iowa farmers call "gumbo" is a heavy, "greasy" black clay soil, occurring in flat areas, either river bottoms or level uplands. It is usually inky black and is stickier and bakes more easily than any other type of soil in the state. If such soil is plowed when too wet it balls up before the plow point in such a way that the best implement cannot be made to stay in the ground. On the other hand, if it becomes too dry it will turn up in clods which cannot be worked down during the whole season. Where such clods are formed, freezing and thawing is the only process which will restore the loose, mealy structure. This soil can, however, be put in excellent tilth, with a fine, mealy appearance and kept so during the entire season provided it is not cultivated when too wet.

The total area of "gumbo" in Iowa is probably about 1 percent of the entire state, occurring in small patches in various localities. The principal areas are in southeastern Iowa and along the Missouri river in western Iowa. The counties in which "gumbo" has been found are Muscatine, Washington, Louisa, Henry, Des Moines, Van Buren, Lee, Woodbury, Monona, Harrison and Pottawattamie.

Pottawattamie county has a typical "gumbo" soil, known as the Wabash silty clay. It covers about 8 percent of the area of the county and occupies level or depressed areas within the broader bottomlands. The management of "gumbo" may profitably be considered at this point, therefore, and the results of a field experiment presented. While this experiment was not carried on in this county, it yielded results applicable to "gumbo" soils everywhere in the state.

This experiment was located on a typical area of "gumbo" bottomland near Wapello, Louisa county. Two series of plots were laid out in 1908, one consisting of six plots which were undrained and one of ten which were as well drained as conditions would permit. The treatment and yields of corn in 1909 are given in table XI.

Plots 101, 102, 103, 201 and 202 were green manured in 1908 with rape, buckwheat, clover and clover and timothy, respectively. The clover and timothy on plots 201 and 202 had been a meadow for several years and produced a crop of hay in 1908 which made a yield of 2½ tons per acre. The aftermath was
TABLE XI. FIELD EXPERIMENTS ON "GUMBO"

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Bu. corn per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Drained</em></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>Rape (too wet)</td>
<td>24</td>
</tr>
<tr>
<td>102</td>
<td>Buckwheat</td>
<td>62</td>
</tr>
<tr>
<td>103</td>
<td>Clover</td>
<td>94</td>
</tr>
<tr>
<td>104</td>
<td>Check</td>
<td>77</td>
</tr>
<tr>
<td>105</td>
<td>Lime — 10 T per acre</td>
<td>68</td>
</tr>
<tr>
<td>106</td>
<td>Straw — 4 T per acre</td>
<td>47</td>
</tr>
<tr>
<td>107</td>
<td>Check</td>
<td>40</td>
</tr>
<tr>
<td>108</td>
<td>Manure — 12 T per acre (too wet)</td>
<td>23</td>
</tr>
<tr>
<td>109</td>
<td>Manure — 6 T per acre (too wet)</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><em>Undrained</em></td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>Clover and timothy sod</td>
<td>7</td>
</tr>
<tr>
<td>202</td>
<td>Clover and timothy sod</td>
<td>10</td>
</tr>
<tr>
<td>203</td>
<td>Manure — 12 T per acre</td>
<td>15</td>
</tr>
<tr>
<td>204</td>
<td>Check</td>
<td>27</td>
</tr>
<tr>
<td>205</td>
<td>Manure — spring plowed</td>
<td>20</td>
</tr>
<tr>
<td>206</td>
<td>Check — spring plowed</td>
<td>20</td>
</tr>
</tbody>
</table>

plowed under for green manure. All, except plots 205 and 206, were fall plowed in 1908, the treatments indicated being made prior to plowing.

In the fall plowing it was noticed that the clover and buckwheat plots worked much more easily than the others. The following season the plots which received manure dried out more slowly after a wet spell than the others. Further observations on the effects of treatment could not be made.

Great differences in yield occurred but these should undoubtedly be attributed to differences in drainage rather than to the effects of treatment. It was impossible to get a satisfactory outlet for the tile drain and on each side of the experiment field there was a swampy place in which the water stood nearly all summer and this surely affected the results from the outside plots. (101, 108, 109).

Where the soil was fall plowed, a fine mealy seed bed was obtained for the corn which was planted on May 13. Surrounding undrained land which was not fall plowed could not be planted until about June 10. The undrained plots were too wet nearly all summer and the outside plots in the drained series were also too wet. In the latter part of the summer all of the plots dried out well at the surface and the undrained ones cracked open, leaving wide fissures to a depth of more than a foot. On the best drained plots, the fine crumbly surface soil prevented this cracking. On the hard, cracked ground the corn turned yellow and "fired" about the middle of August, but on the other plots it remained green at least three weeks longer.

The fall plowed plots were fairly clean of weeds and grass while the others were very foul. The lime treatment of plot 105 seemed to have no effect on the "gumbo."

This experiment shows very definitely the possibilities of "gumbo" soils when properly drained and fall plowed. The drainage of "gumbo" is more readily accomplished than would be supposed. On the upland the tile should be laid 8 rods apart to secure good drainage, altho reports have been made of successfully drained "gumbo" when the tile was 10 to 12 rods apart. On the lowland "gumbo" the tile should be somewhat closer together, but the securing
of a satisfactory outlet is the chief necessity for thorough drainage and in some cases it may be necessary to run an open ditch thru to the river, in which case a drainage district must be organized. When properly tilled out such "gumbo" soil is equal to any other soil in the state in producing power for general farm crops. Fall plowing improves the soil very decidedly and the use of clover or some other green manure is also of value. Lime apparently is of no use on such soils.

The occurrence of "gumbo" on a farm need not be a cause of lower value of the farm. It may be made and kept productive thru the treatments mentioned above and is then equal in value to the best farm land.

THE NEEDS OF POTTAWATTAMIE COUNTY SOILS INDICATED BY CHEMICAL, GREENHOUSE AND FIELD TESTS

MANURING

The value of a sufficient amount of organic matter in soils is well known. Commercial plant food materials alone are quite insufficient to keep a soil in the proper condition for satisfactory growth. The physical conditions soon become unfavorable, bacterial action is restricted and the plant food present in the soil largely remains in its normally useless condition if the organic matter or humus content of the soil becomes low.

The soils of Pottawattamie county are noticeably deficient in organic matter even in the case of swamp and bottomland soils, which is unusual. Pottawattamie soils are so open and thoroughly aerated that the decomposition of organic matter proceeds at a very rapid rate. The accumulation of organic matter from plant residues is, therefore, very slow, if any increase at all occurs. In fact, in a great majority of cases there has been a gradual loss of humus, the removal of organic matter by decomposition having proceeded faster than the addition of material thru the ordinary methods of cropping which are followed. Furthermore, with this rapid removal of organic matter there has been a continual loss of plant food thru the production of greater amounts of available food than necessary for the crops grown. If the loess soils had not been especially well supplied with plant food originally, still greater deficiencies in certain constituents would be found now. These soils were once evidently very rich in plant food, especially in lime, and hence in spite of the large losses, their supply of food constituents is not generally depleted to a danger point. However, if steps are not taken in the near future to check the heavy losses that are going on the time will soon come when extreme measures will be necessary to make the soils profitably productive. Better methods of management than are at present followed will not only prevent the wearing out of the soils, but will also make them more productive immediately.

The laboratory, greenhouse and field tests show beyond doubt that organic matter should be used on these soils to increase their fertility and keep them fertile. Organic matter may be added in the form of farm manure, green manures and crop residues and all three should be used.
POTTAWATTAMIE COUNTY SOILS

Crop residues, consisting of the straw, stover, roots and stubble of crops, add considerable organic matter or humus and also return much plant food to the soil. Under ordinary farming conditions roots and stubble remain in the soil. Too often, however, the straw, and stover are not returned. Nothing should interfere with the return of these materials. On the livestock farm they should be utilized for feed and bedding and returned in the manure and on the grain farm they should be even more carefully used, because the manure which has additional value is not available. The "life" of a soil, or the time during which it will remain productive, is much longer where the crop residues are carefully utilized.

Crop residues alone are insufficient, however, to keep up the organic matter supply in soils. This fact is especially noticeable in the loess soils, such as are found in Pottawattamie County. Farm manures and green manures must be used in addition.

Farm manure supplies a large amount of organic matter and considerable plant food and besides it adds enormous numbers of bacteria. These organisms are responsible for decomposition processes and hence bring about the production of available plant food in the soil.

The value of farm manure on the Marshall silt loam, the main soil type in Pottawattamie county, has been well shown by the greenhouse and field results referred to earlier in this report. No other material apparently can take its place in increasing crop production. The experiment with the rather infertile hill top soil showed especially the great value of manure in making this soil more productive. Other fertilizing materials, while of some value, had comparatively small effects. All the manure produced on the livestock farm, should, therefore, be added to the soils. Furthermore, the manure should be very carefully stored while awaiting use. Great losses may occur thru improper storage and the more readily available and valuable plant food may disappear almost entirely. As much as 85% of the valuable matter in manure may be lost thru careless handling. The ordinary application of 10 tons of manure to the soil once in the four-year rotation is not sufficient to keep soils fertile indefinitely. The soils of Pottawattamie county, and particularly the Marshall silt loam, should receive heavier applications at the present time to improve their physical condition and make them more productive. Too large amounts are not likely to be applied because of the lack of material, but 16 to 20 tons per acre should not be exceeded.

On livestock farms manure may often be applied as recommended, but on grain farms green manure crops must be used in place of manure. Furthermore, farm manure is not alone sufficient to keep the soil fertile and green manures also have a place on livestock farms. Green manure crops are so varied that they may be employed under almost any conditions. Legumes are particularly valuable because when well inoculated, as they should be, they take nitrogen from the air and thru their use the nitrogen content of the soil may be increased. At the same time such crops supply organic matter as well as do non-legumes.

There can be no question of the value of such green manures on the soils of
Pottawattamie county. The experiment reported hardly gives a fair evidence of their value, inasmuch as the cowpea crop was so small. They should be used in addition to farm manures, either by introduction into the rotation as "catch" crops or by turning under a full season's crop. The relative merits of farm manures and green manures need not be considered here, for both are valuable and the latter should be regarded as supplementing or taking the place of the former. It is often advisable to make a small application of farm manure along with a green manure crop to start the necessary decomposition.

There are some dangers in the use of green manures, chiefly in the reduction of soil moisture, which may occur in turning under a large crop. In dry seasons the time for turning under a green manure crop should be carefully chosen to avoid any injurious action. The crop should be green and full of moisture, for it decomposes more rapidly under those conditions, and it should be plowed under before the soil is cool. Both green manures and farm manures should be used with care and common sense and then there will be no danger in their employment.

In choosing the crop for a green manure, select one which will be suitable for the particular soil and climatic conditions and which will not interfere with the regular rotation. The cost of seeding and the monetary value of the crop for hay or pasture should also be considered.

Acid conditions in the soil are increased by the use of all materials furnishing organic matter and the lime content of the soil must be carefully looked after if farm manure or green manures are employed.

COMMERCIAL FERTILIZERS

Pottawattamie county soils do not have an abundance of nitrogen or phosphorus and hence it might be assumed that applications of commercial fertilizers might prove profitable. The greenhouse and field experiments show, however, that such materials do not give large increases in crop yields.

Nitrogen should not be applied as a commercial fertilizer as long as it is possible to keep up the supply by the use of leguminous green manure crops. Commercial nitrogenous materials should be used on Iowa soils only in special cases where a certain crop needs an initial stimulus or where experiments have shown them to be profitable. Leguminous green manures are cheaper and have the additional value of maintaining the organic matter supply in the soil.

Phosphorus is not abundant in Pottawattamie county soils, but while applications of phosphates bring about some gains, they do not always give sufficient crop increases to warrant their use. Compared with the use of manure, the use of phosphorus is of small value. When added with manure it brings about only small gains. Altho the amount of phosphorus is low in loess soils, when organic matter or humus is supplied and the soil bacteria are active, enough phosphorus becomes available in the soil to supply crop needs and at present additions of phosphorus do not increase yields to any large extent. The amount of phosphorus in some of the other soils of the county is less than that in the Marshall silt loam and on such soils the effects of phosphorus fertilizers might be greater.

While farm yard manure returns some of the phosphorus removed from soils
by crops, the amount available on the average farm is entirely too small to keep up the supply of phosphorus. Sooner or later commercial phosphorus fertilizers will be necessary. Unfortunately the experiments thus far carried out on the loess soils do not show definitely which form of phosphorus fertilizer should be employed. Bone meal was used in the field test and the results showed an increase, but bone meal cannot be recommended because of the difficulty in obtaining it. That leaves a choice between the insoluble rock phosphate and the soluble acid phosphate. The greenhouse experiment showed slight gains from acid phosphate while the rock phosphate for some unknown reason depressed the yield. This must be regarded as an accidental result and hence no comparison of the two materials is possible at the present time and no recommendation of one over the other can be made. Field experiments carried out under a wide variety of soil conditions are necessary in order to reach definite conclusions. Farmers are urged to test both materials under ordinary farming conditions. Complete directions for such tests and advice for specific conditions will be given by the Soils Section upon application by farmers.

No analyses for potassium were made of Pottawattamie county soils for this element is so abundant in all the soils of the state that it hardly seemed necessary. In the field experiment with the hill top soil a few tests were made with potassium, and while a slight gain was secured in one case, in general the effect was practically negligible. It is evidently true that potassium fertilizers are unnecessary on the soils of Pottawattamie county at the present time. Only where special crops need stimulation during the early stages of their growth should potassium salts be applied.

It is apparent that the maintenance of the permanent fertility of Pottawattamie soils does not require the application of complete commercial fertilizers. Potassium is not necessary and will not be needed for a long time. Nitrogen is low, but this can be more cheaply and better supplied in leguminous green manure crops than in commercial nitrogenous fertilizers. Phosphorus is the only element which must be supplied in a commercial form. The amount present is so small that evidently means must soon be taken to replenish the supply. Just what form of phosphorus fertilizer to employ cannot be definitely stated now and neither can the value of its use at the present time be given.

LIME

The soils in Pottawattamie county are generally well supplied with lime, but some types are low in lime and therefore need applications of this material from time to time to keep them from becoming acid. For example, the Marshall silt loam is occasionally acid. All of the soils in this county should be carefully tested for acidity, and especially the upland loess and hill top soils. The application of other necessary fertilizers will be practically useless if lime is lacking in the soils. The use of organic matter, which has been shown to bring about such striking increases in yields, would not prove as valuable in the absence of lime. Furthermore, those soil types which are apparently well supplied with lime at the present time will gradually lose it. The use of organic matter will increase the production of acids which will in turn cause the rapid disappearance of lime. Whenever the crop producing power of a soil rich in lime is
increased by proper methods of treatment, lime is rapidly removed and must be supplied eventually.

If tests show a soil to be acid, three to four tons of lime will supply all that is necessary for several years on practically any soil in Pottawattamie county. This amount will neutralize all the acidity and leave two tons additional in the soil. Such an amount applied in a four-year rotation will keep the soil in the proper condition for crop growth as far as acidity is concerned. However, the very best results are always secured by testing each soil and applying the amount which the soil is found to need.

**DRAINAGE**

Practically all the soils in Pottawattamie county are well drained. In fact, most of them are too thoroughly drained. They are so open, and so well aerated that the organic matter content has been rapidly decreased and valuable plant food has been lost. In general, therefore, there is more need in this county for the adoption of methods of retaining moisture in the soils than of providing drainage.

There are two soil types, however, the Hancock silt loam, a terrace soil, and the Wabash silty clay, a bottomland soil, which show the need of drainage in their level portions. The poorly drained areas of these types are small and hence drainage cannot be considered of great importance in the county. But whenever it is necessary, an efficient drainage system should be installed. No amount of fertilization, care or treatment of any kind will offset the injurious effect of poor drainage.

**ROTATION OF CROPS**

For the continued fertility of any soil, a well defined crop rotation should be followed. The continuous growing of any one crop seems to deplete the soil very rapidly and to reduce crop production.

Whatever rotation of crops is used, legumes should be included and green manure crops, crop residues and farm manure should be carefully employed to build up and keep up the organic matter in the soil. Definite rotations are difficult to suggest, owing to the wide range of conditions which must be met, but the following would serve quite satisfactorily in many cases:

1. **FOUR OR FIVE-YEAR ROTATION**

   **First year**: Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
   **Second year**: Corn.
   **Third year**: Oats (with clover or with clover and timothy).
   **Fourth year**: Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2. **FOUR-YEAR ROTATION WITH ALFALFA**

   **First year**: Corn.
   **Second year**: Oats.
   **Third year**: Clover.
   **Fourth year**: Wheat.
   **Fifth year**: Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above).

3. **THREE-YEAR ROTATION**

   **First year**: Corn.
   **Second year**: Oats or wheat (with clover seeded in the grain).
   **Third year**: Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil).
In livestock farming the products grown in the rotation should, for the most part, be fed or used for bedding and the manure carefully saved and used as a fertilizer.

"Catch" crops, such as cowpeas, soybeans, vetch and clover seeded in standing corn, are frequently unprofitable in Iowa because of the high cost of the seed and the failure of the crop to make a satisfactory growth. The non-legumes, such as rye and rape, usually do well when seeded in standing corn.

**THE PREVENTION OF EROSION**

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

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroughly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action. The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manures, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil will be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to
grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient. In Pottawattamie county gullying occurs to an injurious extent mainly in the bluffs along the Missouri River and a belt one-half mile to three miles back from the bluffs.

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

**EROSION DUE TO DEAD FURROWS**

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

"**Plowing In.**"—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

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

**Earth Dams.**—Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

**SMALL GULLIES**

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them, for an immense amount of labor is involved and the effect will not be permanent.

"**Staking in.**"—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left
near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water flowing upon it. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to he use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving in time, labor and inspection.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided
with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the dangers of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass. Considering the cost, maintenance, permanence, and efficiency, the Christopher or Dickey dam, especially when arranged in series of two or more, may be regarded as the best method of filling ditches and gullies and as especially adapted to the larger gullies.

The stone or rubble dam.—Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when tile openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The rubbish dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The woven wire dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for preventing erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod strips.—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The concrete dam.—One of the most effective means of controlling erosion is by
the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

**Drainage.**—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

**LARGE GULLIES**

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher dam, already described, may also serve in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

**BOTTOMLANDS**

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

**Straightening and tiling.**—The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

**Trees.**—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

**HILLSIDE EROSION**

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.
Use of organic matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw, corn stalks, etc., may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing of crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite necessary for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Deep plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN POTTAWATTAMIE COUNTY*

LOESS SOILS

There are two soil areas in Pottawattamie county which are classed as loess soils, the Marshall silt loam and the Knox silt loam. These two types cover over 72 per cent of the area of the county and constitute, therefore, the most important soils.

MARSHALL SILT LOAM (9)

This soil type covers 68 per cent of the area of Pottawattamie county. In depth, the surface soil ranges from 10 to 24 inches, while the subsoil extends to a depth of 10 to 20 feet in the more shallow deposits, and from 20 to 80 feet in the more fully developed deposits. When wet the surface soil is a solid black; near the line between the soil and subsoil the color becomes lighter and

* The descriptions of individual soil types given in the Bureau of Soils report on Pottawattamie county, Iowa, have been rather closely followed in this section of the report.
sometimes a mottling of yellow, gray or drab is found. When timbered the soil is lighter in color than where it is in prairie. Only in a few cases, at the base of high hills, is there any occurrence of gravel or sandy material. Lime concretions are found in the subsoil. These vary in size from one-half inch to six inches in diameter and in some localities occur in considerable numbers. In other cases, as has been noted, they are absent and the soil type is acid.

The topography of this soil is nearly level to undulating, rolling, or hilly. It occupies an elevation throughout the county ranging from 1,000 to 1,200 feet above sea level. The natural drainage is very thorough. The streams have often cut deep channels and some bad cases of erosion are found on these hill slopes.

General farm crops such as corn, oats, and wheat produce satisfactory yields on this soil and they are the principal crops grown. The average yields of these crops are greater on this type than for the county as a whole, indicating quite distinctly their adaptation to this soil. Alfalfa is particularly well suited to this soil and it is being grown on rapidly increasing areas. Other legumes, such as red clover and sweet clover, also do well. The production of grapes and apples is unusually good on this type and the number of vineyards and orchards is becoming greater as the value of these crops is recognized. Vegetables, such as tomatoes, potatoes, beans, cabbage, eggplant, beets, turnips, and parsnips, grow well on this soil but they are not cultivated to any considerable extent for marketing.

The chief need of this soil type, as has been pointed out in the previous pages, is for organic matter. The greenhouse and field experiments have shown unusually large effects from the application of farm manure. This material apparently supplies the conditions which are necessary in this soil for the best growth of crops. Lime is sometimes necessary, as in many instances the original content has been completely lost by leaching, and tests should always be carefully made for acidity. Commercial fertilizers seem to be unnecessary at the present time. Phosphorus, however, is low in the soil and applications show slight increases. This leads to the conclusion that this element will be necessary in the more or less distant future. Organic matter, however, either as farm manure or as green manures, seems to be the best material to be applied to the soil at the present time and the results secured with the use of these substances show them to be of economic value.

KNOX SILT LOAM (11)

This soil covers 4.7 per cent of the area of the county. The surface soil extends to a depth of 15 to 20 inches where it grades into a light-brown to buff-colored silt loam. There is no sharp line of separation between the surface soil and subsoil, the yellowish-brown soil gradually merging into the yellow subsoil. In some places the surface soil is somewhat darker than the true soil type and resembles more nearly the Marshall silt loam.

The texture of the soil is practically a silt loam to a depth of 10 to 50 feet, only a small quantity of clayey or sandy material being encountered within the 3-foot soil section. Sand and stones are normally absent. In local areas, however, where there has been some wash from other soils there is occasionally a little sand.
This soil type occurs in a narrow strip bordering the lowlands of the Missouri river and is characterized by steep bluffs and a generally rough topography. The bluffs rise 100 to 150 feet above the lowlands. The drainage is normally good; in places where there are steep, unprotected slopes, it is excessive. Many gulches or drainage ways occur in the bluff section, and the slopes leading to stream channels are frequently so steep as to prohibit cultivation.

This soil is especially adapted for the production of grapes and many large vineyards are found on it. The steep slopes on which it occurs can be utilized very satisfactorily for vineyards when other crops do not do well. Practically all the grape growing in the county occurred on this soil a few years ago, but now the Marshall silt loam is also being used for this crop. With the better methods of soil treatment, pruning, etc., which are being followed, grapes are becoming a more and more valuable crop. On the more level slopes, the ordinary farm crops and many vegetables do well on this soil. Orcharding is also profitable and the growing of apples and other fruits is increasing.

This soil is especially deficient in organic matter, and it therefore is in need of farm yard manure and green manure crops. It is not generally acid and is not in striking need of phosphorus, but the latter element will soon be necessary. The chief needs of this type to make it more productive are the use of methods to prevent erosion which is so often extensive and the abundant application of farmyard manure or the turning under of green manure crops.

**TERRACE SOILS**

There are three terrace soils in Pottawattamie county included in the Hancock series and the Osgood series. These three types are all of minor importance in the county, covering only 3.3 per cent of the total area.

**HANNOCK SILT LOAM (23)**

This terrace soil is a second bottom soil bordering the overflowed bottoms of some of the main drainage ways of the county, especially the East and West Nishnabotna rivers and the creeks. The surface soil extends to a depth of 12 to 15 inches, grading into a lighter subsoil from chocolate brown to mottled yellowish-brown and gray, and ranging in texture from a silt loam to a silty clay loam. In some places layers of very fine sandy material are found. Evidence is frequently found of the alluvial nature of this soil, but it also receives the wash from the surrounding soil and is somewhat variable in composition.

This type is almost level, sloping gently toward the streams in some cases. In general it is very well drained, but the water may stand in level areas and in depressions after heavy rains and in such cases artificial drainage is required.

Corn is grown the most extensively of any crop on this soil and its value is the greatest. Wheat is also grown to a considerable extent and produces satisfactory yields. Other crops such as alfalfa, clover, timothy and rape, and truck crops such as cabbage, tomatoes, squash, beans, potatoes, etc., do well but they are not grown in any large quantities.

This soil is not so low in organic matter as the loess soils, but it will respond to applications of farmyard manure, and these should therefore be made. Drain-
Fig. 7. Surface, subsurface and subsoils of five of the individual soil types of Pottawattamie county

19. Osgood very fine sand
20. Hancock silty clay
21. Marshall silt loam
22. Hancock silt loam
23. Marshall silt loam
Fig. 8. Surface, subsurface and subsoils on five of the individual soil types of Pottawattamie county

24. Knox silt loam
25. Wabash silty clay
26. Sarpy very fine sand
27. Wabash silt loam
28. Wabash silt loam
age of some areas is necessary and the use of phosphorus may be required in the near future. Lime is not necessary at the present time.

HANCOCK SILTY CLAY (24)

This soil is a minor type in Pottawattamie county. The surface soil is only 4 to 6 inches in depth, and the subsoil extends to 12 to 15 inches, giving way below to a gray and brown mottled or drab heavy plastic clay which extends to three feet or more.

The topography of this soil is level, a gentle slope toward the river being noticeable. Underdrainage is generally well established, but in some cases the water stands in depressions and makes the soil slippery and muddy.

Corn, alfalfa and truck crops, such as beets, tomatoes, cabbage, potatoes and beans give good yields on this soil, corn and alfalfa being especially valuable.

The needs of this soil, apart from drainage which is the first essential, include the use of organic matter and phosphorus although neither of these materials is so necessary as on the loess soils or the other terrace types.

OSGOOD VERY FINE SAND (25)

This type is mapped only in four very small areas near the Missouri river, west and south of Council Bluffs. The surface soil extends to 12 to 15 inches and grades into the lighter subsoil of the same texture throughout the 3-foot section.

It is almost level in topography and possesses a very loose structure, hence the drainage is excessive. Crops are apt to suffer for moisture on this soil during dry seasons.

It is very low in organic matter and hence its chief need is for farm yard manure or green manure crops. These materials would not only provide better mechanical soil conditions, preventing the rapid drying out, but they would supply plant food and enable proper decomposition processes to occur. These materials together with phosphorus fertilizers which will undoubtedly be necessary in the near future will make this soil type more productive. It is an extreme type and of small occurrence, but it is worth special effort to make it fertile.

When well fertilized, early truck crops, melons and cantaloupes can profitably be grown on this soil. General farm crops such as corn may also be grown satisfactorily.

SWAMP AND BOTTOMLAND SOILS

Five types of soil are included in the group of swamp and bottomland soils. The total area covered by them is 24 per cent of the area of the county, and includes the Wabash and Sarpy soils.

WABASH SILT LOAM (26)

This soil type covers over 13 per cent of the area of Pottawattamie county and it is largely developed throughout the county along the overflowed bottoms of Walnut and Pigeon creeks.

The surface soil of this type, which grades from a dark-brown to almost black mellow silt loam, ranges from 8 to 15 inches in depth and in places ex-
tends as deep as 25 inches. The subsoil is lighter in color, varying from a light-brown to mottled yellow and gray heavy silt loam. Pockets of sand occur in places.

The topography of this type is almost level. It occupies the first bottoms and is therefore subject to overflow at least in part. The type as a whole suffers considerably from erosion, especially those portions adjoining the streams. Frequently rather considerable areas are removed from one place to another. Straightening the channels of the streams is the best way to protect the land. The portions of the soil near the uplands adjoining the terrace soils are fairly well drained, while the lower flat areas are of course poorly drained. The deepening of the streams by dredging will lower the water level and make these flat areas more productive and the crop less liable to be flooded out.

Corn is the most important crop grown on this soil. Oats and other farm crops which can be planted and harvested the same season also do well. Winter wheat or long season crops are liable to injury from drowning out, or from the heaving of the land under the action of the winter freezes. Much of the type is seeded to grass and makes an excellent pasture. Alfalfa can be grown provided the stream channels are straightened and the water level lowered to at least 5 feet below the surface. The low lying parts of this soil are allowed to grow up to native grasses and serve as pasture land.

The Wabash silt loam is fairly well supplied with plant food, but like the other soils in the county it is rather low in organic matter and phosphorus and these are the constituents which are necessary to make it fertile. That is, after the soils have been protected from flooding, the next requisite is the use of farm manure or green manures, preferably the former, to start the proper decomposition processes and supply the best physical conditions. Phosphorus will be necessary in the near future for the phosphorus content is so low that crops will soon be in need of that element. Lime is not necessary in general at the present time, but it probably will be required in a short time on this soil when under intensive cultivation. With these treatments, crop production should be very satisfactory and the permanent fertility of the soil should be maintained.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

(This type is indicated on the map by number 26, but is shown in a darker color than the typical Wabash silt loam.)

This soil type occurs throughout the county in a narrow strip of alluvial and colluvial material along the minor streams and drainage ways. This material also occurs on the outer edge of the lowlands along nearly all the larger streams, but the areas are in many cases too narrow to be shown on the map. The color of the soil is practically the same as that of the true Wabash silt loam and it is somewhat similar in other characteristics. In many places it is flooded at periods of heavy rainfall, but as it occurs on steep slopes the surplus water runs off quite rapidly and in general it may be said that it is not in need of drainage. In this respect, therefore, it differs from the Wabash silt loam.

Practically all the crops grown in the county seem to do well on this phase. Corn is the most important crop, both in acreage and production. Wheat, oats, rye, barley, alfalfa, timothy, clover and small truck crops are also grown ex-
POTTAWATTAMIE COUNTY SOILS

Oats and spring wheat do not usually do as well as on the upland soils but the yields of some of the other crops mentioned are frequently quite as satisfactory as on the better types of soil. Much of the phase which lies above overflow is seeded to alfalfa, red clover and rape, all of which do well. The low-lying portions are often allowed to grow up to native grasses and used for pasture.

The varying conditions under which this type occurs with respect to overflow, drainage, and general location, make it exceedingly variable in value and the land sells for $75 to $150 per acre.

In chemical composition, the soil is practically the same as the main type and hence its needs are very similar. It is quite low in organic matter and phosphorus and it should receive applications of farm manure and green manures in order to build it up in humus, and in the near future phosphorus fertilizers must be used. With these treatments and the application of lime, if found necessary in special cases, this soil can be made very productive and kept so, provided of course it is protected from flooding.

WARASH SILTY CLAY (27)

This soil covers about 8 per cent of the area of the county. It is also locally known as "gumbo." It occupies level or depressed areas within the broader bottomlands, and is typically developed along the first bottoms of the East and West Nishnabotna rivers and along the Missouri river, lying somewhat back from the main stream channel.

The surface soil extends to a depth of 4 to 6 inches and rests on a heavy, stiff, sticky, plastic clay, bluish gray or drab to gray and brown mottled in color. The surface soil when wet becomes slippery and on drying cracks and separates into irregular cakes or blocks. In places fine sand is mixed with the clay, lying between two layers of heavy clay.

It is subject to overflow, but the larger portion of the type is quite suitable for agricultural purposes when well drained. The lower depressions and old lake beds retain excessive amounts of moisture and cannot be cultivated. Even protected areas are apt to be covered during freshets, the water covering the soil until after planting time. Very little tile drainage has been done and the cost is great. The proper drainage of the soil is, however, the prime essential for the preparation of the soil for crop growth and the cost involved is more than offset by the returns secured. When this is accomplished, proper cultivation and treatment will make the soil very productive, provided of course, that the rainfall is not so heavy that the soil is flooded. The time of plowing is very important. The soil should neither be too wet nor too dry when plowed or it will be lumpy and difficult to cultivate.

The addition of farm manure and green manures would prove of value on this soil. Phosphorus will be required and may be necessary now, and lime while not needed at the present time, must be used sooner or later. Proper drainage and fall plowing have been found to be very effective in making this "gumbo" soil productive. Under such treatment land of little value may be made equal in value to the best land in the state. Corn is the principal crop grown on this soil, and gives satisfactory yields. Oats, spring wheat and al-
falfa also do well altho the small grains often grow so rank that they lodge. Bluegrass is grown on the lower more poorly drained areas and the pastures are used for fattening beef cattle.

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

This soil type is of minor importance in Pottawattamie county, covering only 1.8% of its area. It is usually associated with the Wabash silty clay just described, but it occupies a somewhat higher elevation above the main channel of the river.

The surface soil is 10 to 15 inches deep and varies from a light-brownish gray to grayish-brown very fine sandy loam and the subsoil is very similar in color, but is generally more open in structure and coarser in texture. The percentage of sand increases with the depth, the soil often grading into a fine sand at a depth of thirty-six inches or more.

The topography is level to slightly undulating, with occasional sandy ridges. The drainage is good. Like the other bottomland soils, this type is subject to overflow and there is danger of floods during the growing season, causing loss of crops.

Corn is the main crop grown on this soil and the yields are quite satisfactory. Wheat, oats, timothy, clover and alfalfa are grown to a small extent. Alfalfa gives good yields but is apt to be drowned out by flood waters. Truck crops such as sweet potatoes, Irish potatoes, cabbage, melons and cantaloupes are being grown in increasing quantities and are proving quite profitable. The use of the soil for pasture crops is also profitable.

The main need of this soil type is for organic matter. It is particularly deficient in this material and should receive heavy applications of farmyard manure. Green manure crops should also be used in addition to the farm manure to supply the necessary organic matter.

Phosphorus is also necessary or will soon be required, and lime must undoubtedly be used in the near future. With the proper supply of organic matter and phosphorus and lime the soil can be made very fertile and kept so.

**SARPY VERY FINE SAND (29)**

This soil type is of extremely minor importance, covering only 0.4% of the total area of the county. There are a few small areas along the old channels of the Missouri river, occurring as long, narrow ridges, and also in the flood plains adjoining the river. These fine sands are easily moved by the wind and are constantly shifting. The surface soil occurs to a depth of 10 to 15 inches and grades into a darker colored sand, the texture remaining the same, through the three-foot section.

The topography of these sand areas is level to gently undulating, altho in a few places small sand dunes have been found. Corn, watermelons and cantaloupes are the principal crops grown on this soil. Corn does only fairly well, but melons prove quite profitable. The chief use of this soil is for pasture.

The soil is so loose and open in texture that the drainage is excessive. The chief need of this soil type therefore is the use of humus-forming materials to improve the physical, chemical and bacteriological conditions in the soil. Farm-
Fig. 9. Surface, subsurface and subsoils of three of the individual soil types of Pottawattamie county


Yard manure will serve this purpose, but leguminous green manures have been found on similar soils to be particularly efficient in building them up and making them productive. Such green manures not only supply organic matter, but also nitrogen and are, therefore, doubly efficient. Phosphorus is also lacking in this soil and should be applied if satisfactory yields are to be secured. Lime is not necessary at the present time, but undoubtedly will be in the near future. When proper methods of treatment are followed and satisfactory crop yields are secured, this material will soon become deficient and will need to be supplied. Such light soils can be built up into a satisfactory state of fertility and maintained so if the above methods of treatment are carefully carried out.
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 Iowa farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

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

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers’ organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins, as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

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

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

Knowledge of the nitrogen content of soils is important in showing whether sufficient green
Fig. 10. Map of Iowa showing the counties surveyed

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

THE "SOIL DERIVED" ELEMENTS

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

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished care should always be taken that the soil be in the best condition for the growth of bacteria.

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

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

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

It is evident from the table that the continuous growing of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil there is a large loss of fertility, and if the entire crop is removed and no return made, the
Calculating Nitrogen (N) at 16¢ (Sodium Nitrate (NaNO₃)), Phosphorus (P) at 12¢ (Acid Phosphate), and Potassium (K) at 6¢ (Potassium Chloride (KCl))

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Plant Food, Lbs.</th>
<th>Value of Plant Food</th>
<th>Total Value of Food Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>Phosphorus</td>
<td>Potassium</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>36</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Corn crop</td>
<td>111</td>
<td>17.25</td>
<td>53</td>
<td>17.76</td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>15</td>
<td>2.4</td>
<td>27</td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>9.6</td>
<td>34.8</td>
<td>9.21</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>29</td>
</tr>
<tr>
<td>Oats crop</td>
<td>48.5</td>
<td>8</td>
<td>34</td>
<td>7.76</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>30.6</td>
<td>13.5</td>
<td>18.5</td>
<td>5.20</td>
</tr>
<tr>
<td>Rye grain</td>
<td>30 bu.</td>
<td>29.4</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>Rye straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>21</td>
<td>1.92</td>
</tr>
<tr>
<td>Rye crop</td>
<td>41.4</td>
<td>9</td>
<td>28.8</td>
<td>6.62</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>

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

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 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

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

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

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus.

In spite of the fact that Iowa soils are still comparatively fertile and crops are still large,

* Bulletin 150 Iowa Agricultural Experiment Station.
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 crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements which are 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**

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

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

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

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

**THE ROTATION OF CROPS**

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

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

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

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

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

**MANURING**

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

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

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

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated, and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.
By using all the crop residues, all the manure produced on the farm, and giving well inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions given in bulletin 151, referred to above.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one to two tons per acre.

SOIL AREAS IN IOWA

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

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.
The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching action in the time which has elapsed since its formation.

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

The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

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

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thorough and complete study of them in place in small areas. The climatic conditions,
topography, depth and character of the soil, chemical and mechanical composition, and in short all the factors which may affect 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 soil areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

**GENERAL SOIL CHARACTERISTICS**

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

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

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or eemulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture 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 according to the Bureau of Soils:

- **Organic Matter**
  - All partially destroyed or undecomposed vegetable and animal material.
  - Stones—over 32 mm.*
  - Gravel—32—2.0 mm.
  - Very coarse sand

- **Inorganic Matter**
  - Coarse Sand—1.0—0.5 mm.
  - Medium Sand—0.5—0.25 mm.
  - Fine Sand—0.25—0.10 mm.
  - Very fine Sand—0.10—0.05 mm.
  - Silt—0.05—0.00 mm.

**SOILS GROUPED BY TYPES**

The different general groups of soils by types are indicated thus by the Bureau of soils:

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

* 25 mm. equals 1 in.
1 Bur. of Soils Field Book.
2 C.
Sandy Clays—20 per cent silt and small amounts of clay up to 30 per cent.

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

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

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

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

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

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

Gravel—More than 50 per cent very coarse sand.

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

METHOD USED IN THE SOIL SURVEY

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

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all the 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 it is the first duty of the field party to prepare one.

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

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

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

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

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