Soil Survey of Iowa, Report No. 26—Madison County Soils

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# IOWA AGRICULTURAL EXPERIMENT STATION

# PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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SOIL SURVEY OF IOWA

Report No. 26—MADISON COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and L. W. Forman

Typical valley scene in Madison county. Wabash loam is the soil in the bottom, and Lindley loam on the slopes.
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MADISON COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and L. W. Forman.

Madison county is located in south central Iowa in the third tier of counties north of Missouri and the fourth tier east of the Missouri river. It is entirely within the southern Iowa loess area and hence the soils of the county are mainly loessial in origin. There is, however, a considerable acreage on which drift soils are mapped, these soils being derived from the glacial material of the Kansan drift. These drift soil areas are found where the covering of loess has been removed by erosion.

The total area of Madison county is 563 square miles or 360,320 acres. Of this area 331,141 acres or 91.9 percent is in farm land. The total number of farms is 2,197 and the average size of the farms is 151 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land in the county:

- Acreage in general farm crops: 160,454
- Acreage in pasture: 122,900
- Acreage in farm buildings, feedlots and public highways: 15,927
- Acreage in waste land: 3,563
- Acreage in crops not otherwise listed: 560

The agriculture of Madison county at present is mainly a combination of grain and livestock farming. Practically all of the corn grown (the principal crop) is utilized for the feeding and fattening of hogs and beef cattle. Dairying is carried on to a small extent on some farms in conjunction with the raising of other stock. Much of the oats grown is sold to outside markets and practically all of the wheat produced is shipped out of the county. There is some income from the sale of other crops which are grown to a minor extent. In general the farm income of the county is derived from the sale of livestock and some of the grain crops and it might be considered therefore that the system of agriculture is really a general farming system. The livestock industry, however, is increasing in significance and dairying is also becoming more important.

The area in waste land in the county is rather large, but this land may be reclaimed thru proper methods of soil treatment. It is not possible to make general recommendations for the treatment of such land, inasmuch as the causes of infertility are various. Special treatments which are desirable under individual soil conditions will be suggested in a later section of this report. In special cases, for more or less abnormal conditions, advice regarding treatment may be obtained from the Soils Section of the Iowa Agricultural Experiment Station.

MADISON COUNTY CROPS

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

*See Soil Survey Report of Madison County, Iowa, by T. H. Benton of the Iowa Agricultural Experiment Station and Hugh B. Woodroffe of the U. S. Department of Agriculture.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Percent of total farm land of county</th>
<th>Bushels or tons per acre</th>
<th>Total bushels or tons</th>
<th>Average price</th>
<th>Total value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>88,500</td>
<td>26.7</td>
<td>49.0</td>
<td>4,336,000</td>
<td>$0.47</td>
<td>$2,037,920</td>
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<tr>
<td>Oats</td>
<td>27,600</td>
<td>8.3</td>
<td>46.0</td>
<td>1,269,600</td>
<td>$0.36</td>
<td>457,054</td>
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<tr>
<td>Spring wheat</td>
<td>1,440</td>
<td>0.4</td>
<td>11.0</td>
<td>15,800</td>
<td>1.35</td>
<td>21,338</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>15,800</td>
<td>5.0</td>
<td>19.0</td>
<td>319,200</td>
<td>1.41</td>
<td>450,072</td>
</tr>
<tr>
<td>Barley</td>
<td>3,000</td>
<td>0.9</td>
<td>31.0</td>
<td>95,000</td>
<td>0.055</td>
<td>58,590</td>
</tr>
<tr>
<td>Rye</td>
<td>610</td>
<td>0.1</td>
<td>17.0</td>
<td>10,370</td>
<td>1.35</td>
<td>12,132</td>
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<tr>
<td>Potatoes</td>
<td>264</td>
<td>0.07</td>
<td>113.0</td>
<td>29,100</td>
<td>1.22</td>
<td>36,335</td>
</tr>
<tr>
<td>Tame hay</td>
<td>20,790</td>
<td>6.2</td>
<td>1.4</td>
<td>29,100</td>
<td>1.22</td>
<td>47,2584</td>
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<tr>
<td>Wild hay</td>
<td>1,070</td>
<td>0.3</td>
<td>1.8</td>
<td>1,301</td>
<td>1.22</td>
<td>17,651</td>
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<tr>
<td>Alfalfa</td>
<td>480</td>
<td>0.1</td>
<td>2.4</td>
<td>1,152</td>
<td>1.22</td>
<td>22,152</td>
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<tr>
<td>Pasture</td>
<td>132,960</td>
<td>40.1</td>
<td></td>
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</tbody>
</table>

Corn is the most important crop in the county, both in acreage and in value. It is grown in all parts of the area and on practically all soil types. Slightly over one-fourth of the total area of farm land in the county is used for this crop. Average yields of 49 bushels per acre were secured in 1920. The most extensively grown variety is Reid's Yellow Dent. Other popular varieties are Boone County White, Pride of the North, Leaming and Little Calico. Practically all of the corn produced is fed on the farms. A large part of it is cut, shocked and fed whole or shredded or used for ensilage. Hogging down is practiced quite extensively and rape or cowpeas are often sown in the corn after the last cultivation.

Hay is the second crop in value in the county, occupying, however, a somewhat smaller acreage than oats. The chief hay crops of the county are timothy and clover mixed and timothy alone. Average yields of tame hay amount to 1.4 tons per acre. Some clover is grown alone and both clover and timothy are sometimes grown for feed. There is only a relatively small acreage in wild hay, chiefly in the bottomlands along the North river.

Oats is the second crop in acreage and the third in value. Average yields amounted to 46 bushels per acre in 1920. The principal varieties grown are Green Russian and Iowa 103. Some Kherson and Early Champion are also grown. A part of the oats produced is used as feed for the work stock. A considerable quantity is sold, chiefly to the markets in Chicago and Kansas City.

Wheat is the fourth crop in acreage and value, being grown on 5.4 percent of the total farm land of the county. Average yields of 19 bushels per acre are secured for the winter varieties and 11 bushels per acre for the spring varieties. Winter wheat is grown most extensively and only a relatively small acreage is devoted to spring wheat. This crop has only recently been grown to any extent in Madison county, but during the past few years, it has come to be of considerable importance. Turkey is the principal variety grown, and occasionally Iowa 404 and Fultz are grown. Bluestem and Marquis are the principal spring varieties. Practically all of the wheat produced in the county is shipped to outside markets.

Barley is grown to a small extent in the county, with average yields of 31 bushels per acre. Potatoes are grown on practically all farms, with average yields of 113 bushels per acre. Early Rose, Early Ohio, Snowflake, and Rural

*Iowa Yearbook of Agriculture for 1920.
MADISON COUNTY SOILS

New Yorker are the principal varieties. The potatoes grown are all used to supply the home demand and considerable quantities must be shipped in each year to make up the deficit.

Alfalfa is being grown on a small acreage in the county with average yields of 2.4 tons per acre. This crop can undoubtedly be grown very successfully in the county when the soil is properly prepared and all precautions are taken in securing good seed and seeding. Lime is needed and inoculation should be practiced if the crop is to prove successful. Where care has been taken, success has followed the growing of this crop. It will undoubtedly be utilized more extensively in the county as more is learned regarding its value.

Rye is grown on a small area in the county and it is comparatively minor in importance. Buckwheat, kafir, sweet corn and popcorn are all grown to a minor extent. There are also small patches of millet and sorghum. Sudan grass is being grown in a small way with success, chiefly in the northern part of the county. Bluegrass is utilized mainly for pastures. In addition to alfalfa, other legumes grown on small areas include soybeans, vetch, red clover, peas, beans and peanuts.

Trucking is practiced to a very minor extent, chiefly to supply the local markets. Fruit growing is not of much significance in the county. There are a few commercial apple orchards but they are small. The principal varieties grown are the Duchess, Red June, Yellow Transparent, Ben Davis, Jonathan, Grimes, Wealthy, Winesap, and Delicious. Many of the farm orchards are being replanted and in general more care is being taken of the trees. Plums, cherries, grapes, strawberries and raspberries are grown in sufficient quantities in the county to supply the local markets.

THE LIVESTOCK INDUSTRY IN MADISON COUNTY

The livestock industries of the county include cattle raising and feeding, hog raising and feeding, sheep raising, and dairying. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the extent of the livestock industry in the county:

Horses, all ages .......................................................... 12,207
Mules, all ages ......................................................... 913
Swine (on farms July 1, 1920) ........................................ 86,675
Swine (on farms January 1, 1921) ................................. 92,246
Cattle (cows and heifers kept for milk) ......................... 7,954
Cattle (other cattle not kept for milk) .......................... 24,533
Cattle (total all ages January 1, 1921) ......................... 32,487
Sheep (all ages on farms) ............................................ 18,530
Sheep (shipped in for feeding 1920) .............................. 3,924
Sheep (total pounds of wool clipped) ........................... 106,884
Poultry (total number, all varieties, January 1, 1921) ...... 245,994
Poultry (number of dozen eggs received 1920) ................ 1,046,441

The raising and feeding of cattle is the most important livestock industry in the county. The beef cattle raised are mostly grade Shorthorns and Aberdeen Angus. There are, however, some purebred herds, principally Angus, Hereford and Shorthorn. From 115 to 120 carloads of feeders are shipped in annually from St. Paul, Omaha and Kansas City. On nearly every farm a few head are fattened and sold, while in many cases several carloads are shipped in and fed. They are marketed in December and January, being shipped to Chicago, St. Joseph, Kansas City and Ottumwa.
Hog raising is almost as important as cattle raising in the county. The breeds are mainly Poland-China and Duroc-Jersey. There are also some Hampshire and Chester White. Most of the hogs shipped from the county are sent to the larger markets at Chicago, St. Joseph and Kansas City. Hogs are butchered on every farm to supply meat for home consumption.

Sheep raising is a minor industry, but it is gradually increasing in importance. The rougher lands in the Lindley and Shelby series are well adapted to sheep raising, as excellent bluegrass pastures are maintained. Shropshire, Merino and Delaine are the principal breeds. A few carloads of grade westerners are shipped in and fed, principally in the southern part of the county.

Dairying is developed to a small extent in the county, but in general enough cows are maintained on every farm to supply the home demand for dairy products. Near the larger towns there are a few fair sized dairy herds. Holsteins and Jerseys are the favorites. There are no creameries in the county and the dairy products are nearly all utilized locally, only a small amount of cream being shipped. On the general farms, dairy cattle are mainly grade Shorthorns.

Some horses are raised, enough to maintain a small number on all farms. There are a few mules in the county and in some of the extremely rough areas there are a few herds of goats.

Poultry raising is proving a very important industry in the county and the egg production in 1920 was considerable.

The value of land in Madison county is somewhat variable, depending upon the location with reference to towns and to railroad facilities, the improvements on the farms, topography, soil type and general soil conditions. The selling price ranges from $70 to $325 per acre. Small areas of the rougher land in the timbered sections are valued at about $40 per acre. The average price of the better farm land would range from $250 to $325. In some instances even larger prices than this have been secured and it is generally recognized that the more level areas of upland in the county are very valuable for general farming purposes.

THE NEEDS OF MADISON COUNTY SOILS

The yields of general farm crops in Madison county are quite satisfactory, but they may be increased in many instances thru the adoption of proper methods of soil treatment. The particular treatment which should be followed in any case will depend upon the individual soil conditions and particularly the topographic condition. In general, it may be said that crop production may be increased thru proper drainage, liming, manuring and fertilization and protection of the soil from erosion.

In some instances the soils are improperly drained. When this is true the installation of tile is the first treatment needed to bring about satisfactory crop growth. No other treatment of the soil will be of value if it is too wet and even tho the expense of tiling is considerable, tile should be installed whenever it is necessary if satisfactory crop yields are to be secured.

Madison county soils are practically all acid and lime must be applied if the best growth of general farm crops is to be secured, particularly with legumes. All of the soils of the county should be tested for lime requirement.
Many of the soils in the county are rather poorly supplied with organic matter and in all cases applications of farm manure have been found to be of value. If farm manure is not available in sufficient amounts, it may be desirable in many cases to turn under a legume crop as a green manure in order to keep up the organic matter content of the soil. Such crops also aid in keeping up the nitrogen supply and in many of the types in the county it is very important that the nitrogen content be increased and in all cases care should be taken to keep up the supply. Leguminous crops as green manures are the cheapest and most satisfactory source of nitrogen.

The phosphorus content of the soils of the county is low and phosphorus fertilizers will need to be used at some time in the near future if this element is not to become deficient. It seems quite possible that these materials may be used with profit in some cases at the present time. Until the field experiments now under way in the county are more complete, the testing of phosphorus fertilizers on small areas on individual farms is the only definite recommendation which can be made along this line. Complete commercial fertilizers cannot be recommended for general use in the county at the present time. They may be tested, however, on individual farms and their actual value determined.

Erosion has occurred to a large extent in some parts of Madison county and there is some formation of gullies and much sheet erosion. It is very important that some method of treatment, as suggested later, be followed to control the destructive action of erosion.

THE GEOLOGY OF MADISON COUNTY

The early geological history of Madison county need not be considered at length, as it has had very little effect upon the present soil conditions. The original bedrock material in the county has been buried deeply by the later deposits of glacial drift and loess and hence has very little influence on the soil characteristics. This bedrock material consists mainly of limestones, shales and sandstones; there are two residual soil types mapped in the county which are derived in large part from the bedrock limestone, the Sogn and Hagerstown series. They are not important, agriculturally, in the county, occurring only in small areas. These soils are mapped on the sides of steep slopes where the coverings of loess and drift have been washed away to a large extent and the limestone material has been exposed.

At least once during the glacial age a great glacier crossed the county and upon its retreat left behind a vast deposit of drift or till. This material, which is known as Kansan drift, is quite variable in depth, extending to many feet in some areas. Apparently the topographic features of the county preceding the invasion by the glacier were modified to some extent and the glacial material covered the older topographic features, completely filling the depressions or valleys and also covering the higher land. The depth of the deposit, however, varies somewhat, depending upon the earlier topographic features. The drift material is naturally a bluish-gray mixture of clay, silt, sand and gravel containing numerous boulders. Where exposed to the weather, the drift has been oxidized to a yellowish or reddish-brown and this weathered layer may vary.
from a few inches to three or four feet in depth. The subsoil usually consists of a silty clay to clay, very tenacious and plastic. Fairly large mixtures of coarse sand, gravel and boulders occur throughout the surface soil and subsoil. Lime has been leached away from the soil quite completely. Calcareous material is found only in the lower sections at depths of from five to seven feet. The surface soil has been modified in many cases through mixtures with organic matter and it has become darker in color. The soils of the Shelby and Lindley series are derived from this Kansan till, having been formed by the washing away of the surface covering of loess.

At some previous geological period, when climatic conditions were very different than at present, a layer of loess was deposited by the wind over the entire surface of the county. In its unweathered condition loess is an even-grained material, composed mainly of silt with some clay. It ranges in color from a light grayish-brown to a yellowish-brown. There has been an accumulation of organic matter in the surface soil and the color has been darkened. Under prairie conditions the greater plant growth and accumulation of residues has led to the formation of the dark colored Grundy and Tama soils, while under wooded conditions the soils of the Clinton series, which are lighter colored, have been developed. The lime has been removed practically completely from all the loess areas and there has been considerable washing of the loess soil. In some instances the covering of loess has been completely removed. This is true where the Shelby soils are mapped. In other cases only a partial removal has occurred and here the soils are in the Lindley series. In much of the remainder of the county the loess covering which remains is quite extensive and where the topography is more nearly level, there has been very little washing away of the surface soil.

There are rather extensive areas of first and second bottomlands in the county and these are made up in large part of the loessial material washed down from the uplands. There is, however, also a considerable mixture with drift material carried down from the higher land along with the loess. Where the soils are above overflow, soil types have developed which are quite distinct in characteristics from the bottomland soils.

PHYSIOGRAPHY AND DRAINAGE

The original topography of the county was that of a rather level loess-covered plain, sloping to the northeast at the rate of about 10 feet per mile. This earlier topography has been greatly modified, however, through the erosional action of the streams and two distinct types of topography have developed. In the northwestern quarter of the south central part of the county, the surface is gently undulating to level in topography. Here the action of erosion has been less extensive, the valleys of the main streams are V-shaped, deeply cut, the slopes rather steep, the bottomlands narrow and the tributary streams short. In the area east of Clanton creek, from St. Charles south to South river, the topography is similar to that just described. In the area between Middle and Grand rivers in the southwestern part of the county, the topographic features are more extreme. Here the original surface deposits have been very largely carried away by stream action, but the tributaries of the streams have cut back so far into the
upland that there is very little of the original upland between them which has not been affected by washing.

The eastern part of the county, except the plain east of Clanton creek, has been quite extensively cut by stream action. Broad, flat valleys have developed along the main streams and the smaller streams have cut into the remaining upland areas so that the topography is rolling to hilly or even steep. There are some flat areas on the tops of divides between the streams, but in general the uplands in the county are rolling to rough in topography and are quite thoroughly drained thru the intermittent drainageways of small streams leading to the larger rivers.

The natural drainage of the county, with the exception of a few small areas just mentioned, is good. The county drains in general toward the east thru the Clanton river, Middle river and the North river with their tributaries. Badger creek, Jim creek, North Branch, Howerdon and Cedar creek are the chief tributaries of the North river draining the entire northern half of the county.
Middle river has only a few small tributaries, none of them being developed to any extent. This river drains the central portion of the county. Clanton creek with its tributaries, Jones creek, North Fork Clanton creek and South Fork Clanton creek, drains most of the southern part of the county. South river crosses the extreme southeastern corner of the county, draining that area, while Grand river crosses the southwestern corner of the county, draining that portion.

Some of the larger streams have developed channels 100 to 250 feet below the upland plain. The south slopes of the stream channels are generally rough and abrupt, with a growth of forest trees. On the north side of the streams there are more gentle hills and slopes. Terraces occur along all the larger streams and range in width from one-eighth to three-fourths of a mile. They generally lie five to twenty feet above the flood plains and occur in irregular bodies and discontinuous strips. The terraces are most extensively developed along Middle river and Clanton creek. Bottomlands are found along nearly all the streams of the county and much of the material is being continually reworked thru the action of the streams.

In general the drainage system of the county is quite adequate, as will be apparent from an examination of the drainage map. Areas of upland in the northwest and central parts of the county, however, would be benefited by drainage. The areas mapped as Grundy silt loam on the soil map would indicate very largely the location of areas where drainage may be inadequate and where tiling should be practiced. With the exception of this one soil type and of the more level to flat areas where it occurs on the uplands, drainage is only infrequently needed. The installation of tile may be of value, however, in some cases in the county and adequate removal of excessive moisture may readily be secured because of the quite complete drainage system.

THE SOILS OF MADISON COUNTY

The soils of Madison county are grouped into five classes, according to their origin and location: drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are formed from the materials carried by glaciers and deposited upon the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Loess soils are fine, dustlike deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by decreases in the volume of the streams which deposited them or by a deepening of the river channels. Swamp and bottomland soils are those occurring in low, poorly drained areas and they are subject to more or less frequent overflow. Residual soils are produced by the weathering of the underlying rock material and remain in the location where they were formed.

The extent and occurrence of these five groups of soils of Madison county are shown in table II.

Considerably over one-half of the total area of the county, 63.7 percent, is covered by the loess soils. On almost one-quarter of the county’s area the
loess has been removed and the drift soils exposed, 24.2 percent of the county being in drift soils. The terrace types are of minor extent in the county, covering only 2.1 percent of the total area. Swamp and bottomland soils are of considerable importance, together covering 6.9 percent of the county. Residual soils are minor in area and are relatively unimportant agriculturally. Together they cover 3.1 percent of the total area of the county.

There are 15 individual soil types in the county. Two of these are drift soils, three are loessial in origin, four are terrace types, four are bottomland soils and two are residual soil types. These individual soil types are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type in the county, covering half of the total area. The Shelby loam is the second largest type and the largest drift soil, covering 19.9 percent of the county. The Clinton silt loam is the third largest type, and the second largest loess soil, covering 9.3 percent of the total area. The Lindley loam is the second largest drift soil, covering 4.3 percent of the county. The Grundy silt loam, a loess soil, is somewhat smaller in area, covering 4.1 percent of the county. The terrace soils are all minor in area, the Waukesha silt loam, the largest, covering one percent of the

### Table II. Areas of Different Groups of Soils in Madison County

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift soils</td>
<td>87,104</td>
<td>24.2</td>
</tr>
<tr>
<td>Loess soils</td>
<td>229,568</td>
<td>63.7</td>
</tr>
<tr>
<td>Terrace soils</td>
<td>7,744</td>
<td>2.1</td>
</tr>
<tr>
<td>Swamp and bottomland soils</td>
<td>24,896</td>
<td>6.9</td>
</tr>
<tr>
<td>Residual soils</td>
<td>11,008</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>360,320</td>
<td></td>
</tr>
</tbody>
</table>

### Table III. Areas of Different Soil Types in Madison County, Iowa

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil type</th>
<th>Acres</th>
<th>Percent of total area of county</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>71,744</td>
<td>19.9</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>15,360</td>
<td>4.3</td>
</tr>
<tr>
<td>130</td>
<td>Tama silt loam</td>
<td>181,184</td>
<td>50.3</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>33,472</td>
<td>9.3</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>14,912</td>
<td>4.1</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>3,584</td>
<td>1.0</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,688</td>
<td>0.7</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>1,152</td>
<td>0.3</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>320</td>
<td>0.1</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>11,840</td>
<td>3.3</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>5,248</td>
<td>1.4</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>4,908</td>
<td>1.3</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>3,200</td>
<td>0.9</td>
</tr>
<tr>
<td>155</td>
<td>Sogn stony silt loam</td>
<td>10,368</td>
<td>2.9</td>
</tr>
<tr>
<td>156</td>
<td>Hagerstown silt loam</td>
<td>640</td>
<td>0.2</td>
</tr>
</tbody>
</table>
SOIL SURVEY OF IOWA

county. The other terrace types are much smaller in area, the smallest, the Calhoun silt loam, covering only 0.1 percent of the county. The swamp and bottomland soils are all small in area, the largest, the Wabash silt loam, covering 3.3 percent of the total area. The other types cover 1.4 percent, 1.3 percent and 0.9 percent, respectively, for the Wabash fine sandy loam, Wabash loam and Wabash silt loam. The residual soils are both small in area, the Sogn stony silt loam covering 2.9 percent of the county while the Hagerstown silt loam covers only 0.2 percent of the county.

The loessial upland soils of the county are in general gently undulating to rolling, which is characteristic of the Tama silt loam. The Clinton silt loam is more steeply rolling to rough and in the wooded sections may be quite steep. The Grundy silt loam, on the other hand, is more level and rather poorly drained. The Shelby loam and Lindley loam of the drift uplands are both rolling to rough, many of the areas being steep and utilizable only for pasture. The terrace types and swamp and bottomland soils are quite generally level and in the case of the bottomlands, drainage is somewhat inadequate and the types are subject to overflow. The residual soils are rough, the land is not agricultural, and much of it is not even available for use as pasture.

THE FERTILITY IN MADISON COUNTY SOILS

Samples were taken for analyses from each of the soil areas in Madison county except the two residual soils, the Sogn stony silt loam and the Hagerstown silt loam. These latter types were not sampled nor analyzed, owing to their small occurrence and unimportance agriculturally. The more extensive types were sampled in triplicate while only one sample was taken in the case of the minor types. All the samplings were made with the greatest care that the samples should be representative of the particular soil type and that variations due to local conditions or to previous treatment should be eliminated. The samples were drawn at three depths, 0-6 2/3", 6-2/3—20" and 20—40", representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official method, and the Veitch method was followed for the limestone requirement determinations. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of 4 or 12 determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is extremely variable, ranging from 942 pounds in the Shelby loam up to 2,949 pounds in the Wabash loam. There is no distinct relationship evident between the phosphorus content and the various soil groups, altho it is apparent that the drift soils are somewhat lower in this constituent than the other soil groups. The average of the loess soils seems to be somewhat lower than that of the terrace
TABLE IV. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS
Pounds per acre of Two Million Pounds of Surface Soil (0"—6 2-3")

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>942</td>
<td>4,398</td>
<td>51,640</td>
<td>0</td>
<td>2,802</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>990</td>
<td>1,050</td>
<td>10,524</td>
<td>32,616</td>
<td>Basic</td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>1,691</td>
<td>5,179</td>
<td>63,600</td>
<td>0</td>
<td>3,203</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,017</td>
<td>2,615</td>
<td>30,580</td>
<td>0</td>
<td>2,135</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,070</td>
<td>4,456</td>
<td>52,440</td>
<td>0</td>
<td>5,005</td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>1,665</td>
<td>4,806</td>
<td>58,450</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>1,668</td>
<td>4,316</td>
<td>57,720</td>
<td>0</td>
<td>3,003</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>1,434</td>
<td>3,533</td>
<td>45,220</td>
<td>0</td>
<td>1,201</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>1,549</td>
<td>3,334</td>
<td>40,780</td>
<td>0</td>
<td>2,402</td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,175</td>
<td>7,203</td>
<td>83,627</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>1,495</td>
<td>3,134</td>
<td>40,025</td>
<td>0</td>
<td>1,471</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>2,949</td>
<td>5,912</td>
<td>63,038</td>
<td>0</td>
<td>1,201</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>1,682</td>
<td>5,520</td>
<td>69,046</td>
<td>Trace</td>
<td>Basic</td>
</tr>
</tbody>
</table>

group and the swamp and bottomland group. It is, however, somewhat greater than the average of the drift soils, but the differences here are not large enough to be very distinct. It might be expected that the bottomland soils would be somewhat richer in phosphorus than the upland types, owing to the fact that there has been less crop production on these types and hence a smaller removal of phosphorus as well as of all other plant food constituents. Similarly the terrace types might be expected to be somewhat richer than the upland soils, but not as high as the bottomland types. These relations seem to be fairly apparent in the case of the soils of this county.

There are, however, some rather wide variations in phosphorus content within the various soil groups, and there is a much more definite relation between the phosphorus supply and the soil series; undoubtedly the soil type bears a very important relation to the phosphorus content.

The Tama silt loam is better supplied with phosphorus than the Clinton and Grundy soils in the loess group. The Waukesha and Bremer soils of the terrace group are richer in phosphorus than the Jackson and Calhoun types. These differences may be traced to the topographic conditions, the accumulation of organic matter, or the way in which the various soils have been handled, but they are all differences which are characteristic of the particular soil types. It is not possible to draw any very extensive conclusions as to the effect of soil texture on phosphorus, as so many of the types in the county are silt loams. Only in the swamp and bottomland group is there any opportunity to make a comparison of the effect of texture within a soil series. Here it would seem that the Wabash fine sandy loam is lower in phosphorus than the heavier textured types. The loam, however, is better supplied than the silty clay loam; in fact, the silt loam is higher than the silty clay loam. This is contrary to the results usually secured, as ordinarily the heavier textured types contain the largest amount of phosphorus. Perhaps the silty clay loam in this county is somewhat abnormal and the phosphorus content has been influenced by some
unusual factor. It does seem to be evident, however, that fine textured soils, such as sandy loams, may be lower in phosphorus than heavier types like the silt loam and loam.

It is quite apparent from the figures given that the phosphorus content of the soils of the county in general is not very high and in many cases phosphorus fertilizers would probably prove of value at the present time. These materials will undoubtedly be needed in the near future and they must be taken into account in planning systems of permanent fertility for this county. Analyses do not show how much phosphorus is produced in an available form, but if there is a large total supply and the soil conditions are satisfactory, it is usually quite safe to conclude that there will be a sufficiently rapid production of the element in an available form and crops will be well supplied. If the total supply is low, however, it is usually safe to assume that there will not be a sufficient production of available phosphorus to meet the crop demands.

Inasmuch as the phosphorus content of the soils in Madison county is usually rather low, it seems quite probable that in many cases available phosphorus is not being produced as rapidly as it is needed. Whenever this is true, phosphorus fertilizers may be used with profit. Farmers may test the value of applications of phosphorus to their soils and thus determine for their own conditions, whether or not phosphorus fertilizers should be used. If crop yields are increased to a profitable extent on small areas, then the same fertilizer may be used on a larger area with the assurance of profit.

The nitrogen content of the soils of the county is quite variable, ranging from 1,050 pounds in the Lindley loam up to 7,202 pounds in the Wabash silt loam. With the possible exception of the Lindley loam, the soils of the county do not seem to be strikingly deficient in nitrogen, but this element must be considered in planning systems of permanent fertility for the soils of this county. There is no relation apparent between the nitrogen content of the soils and the various soils groups except that as in the case of phosphorus the terrace soils are somewhat better supplied with nitrogen than the upland types, while the bottomland soils are richer than the terrace types. Again this relation might be expected because of the smaller crop growth and less utilization of nitrogen in terrace and bottomland types.

There are some relations evident between the soils of different series even within the same soil group. These differences, as in the case of phosphorus, may be very closely linked up with the soil series or the characteristics which determine a soil series. Thus the Tama silt loam is higher in nitrogen than the Clinton. The Grundy is likewise higher than the Clinton. Both the Tama and the Grundy differ markedly from the Clinton in topography conditions and they have been formed from the original soil material under different conditions. The Clinton was originally a wooded soil while the others were prairie types. The Shelby loam is higher than the Lindley loam in the same group, which is again a difference dependent upon the characteristics of the soil series. The Waukesha and Bremer soils of the terrace group are higher than the Jackson and Calhoun types. The Wabash fine sandy loam is much lower in nitrogen than the other types of the Wabash group. The silt loam is the highest among the Wabash soils. Considering the effects of texture
which appear only in this group of soils, it is evident that the silt loam is somewhat an abnormal soil and probably contains a much higher amount of nitrogen in relation to the other Wabash types than is usually the case. The silty clay loam seems to be somewhat lower than would be expected, and while it is not possible to draw conclusions regarding the soil textures and the nitrogen content, it would seem that the light textured soils are poorer in nitrogen than the heavier textured types. This difference would undoubtedly be more apparent if other types of the same series had been mapped on the uplands.

As will be noted later, there is a relation between the nitrogen content and color, which means a distinction on the basis of soil series. Apparently none of the soils of the county is extremely low in nitrogen, but the treatments practiced in all these soils must include the addition of some nitrogenous fertilizer if the supply of this element is not to become lacking.

Considerable amounts of nitrogen are returned to the soil in farm manure and this material is a most important fertilizer from the nitrogen standpoint. It may return to the land a considerable portion of the nitrogen removed by crops grown. Crop residues also return to the soil some of the nitrogen removed by crops, but these materials alone are not sufficient on the average farm to permit the nitrogen supply to be kept up. It is necessary in practically all systems of farming to make use of leguminous crops as green manures to increase the nitrogen content of the soil. Wherever farm manure is lacking or is insufficient, green manuring should be practiced and the nitrogen content in the soil built up by utilizing that element as taken from the air. The actual amount of nitrogen added to soils by growing legumes and turning them under will depend upon many factors, such as the character of the crop grown, the thoroughness of inoculation and the nitrogen content of the soil. In the case of clover, the nitrogen content of the tops seems to be about equal to that taken from the air and hence the addition of nitrogen to the soil will depend upon the size of the clover crop and whether or not it is all turned under. Leguminous green manure provides the cheapest and best source of nitrogen and the practice of green manuring is of large value in keeping up the supply of nitrogen in soils.

There is a rather distinct relation between the nitrogen and the organic carbon in soils and the content of both these constituents is rather definitely indicated by the color of the soil. If it is black, the organic carbon and nitrogen content is high. If it is light the supply of these constituents is low. The soils of Madison county show a wide variation in organic carbon content, but rather definite relations occur between the organic carbon and the nitrogen in the case of all the soil types. Where the nitrogen is high there is a large amount of organic carbon. Where the nitrogen is low, the organic carbon content is likewise low. Thus the Lindley loam, which is the lowest in nitrogen of all the types, is the lowest also in organic carbon, while the Wabash silt loam, which showed the highest content of nitrogen, gives likewise the largest amount of organic carbon.

The same relations between the soil groups, the soil series and the individual types of this texture in the case of nitrogen, all hold true for the organic carbon. The heavier textured types are in general higher in both these con-
stituents while the soils of certain series whose characteristics are determined by topography, origin, color and other factors, are higher in organic carbon as well as in nitrogen than some of the other types. In series of different characteristics, the soils under more level topography conditions seem to be higher in these constituents than the more rolling types. The Wabash fine sandy loam is the lowest in organic carbon of any of the Wabash soils, as would be expected. The Wabash loam is somewhat lower than the silt loam, as would also be expected, but the silty clay loam is not as high as the silt loam, which is contrary to the usual results secured in comparing soils of these textures.

The relation between the carbon and nitrogen present in soils gives some evidence of the rate at which plant food is being made available. In practically all cases the relation between these constituents in the soils of Madison county is quite satisfactory. There are a few instances, however, where decomposition is not going on properly and, when this is true, applications of farm manure will be of especial value, because this material increases the rate of decomposition and brings about a greater production of available plant food. It is urged that farm manure be used on all the soils of the county, even on those types where the color is dark and the content of organic matter seems to be rather high. Experiments and farm experience have shown the large profit from the use of this material in liberal amounts.

Only in two of the soil types in the county is there any supply of inorganic carbon and in both of these soils the occurrence is not at all constant. Only occasionally will lime be found to as large an extent in the surface soil as the analyses show. The occurrence of lime or inorganic carbon in the Wabash loam is not characteristic and other samples of this type would undoubtedly be acid. In general, the upland soils of the county seem to be lacking in inorganic carbon and in need of lime. Most of the terrace types are likewise in need of lime. The bottomland soils, while not supplied with any large amount of lime, are apparently basic in reaction. Very soon, however, these soils will need lime, as there is a constant removal of material thru leaching and the inorganic carbon will decrease rapidly.

No large lime requirement is shown for any of the soil types, but as crop production continues, the need of lime will become more and more evident. Soils vary widely in lime requirement and every soil should be tested before lime is applied.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

Taking into account the plant food content of the lower soil layers, the needs of the soils of the county would not be shown to be any different than indicated by the analyses of the surface soils. Unless there is a large amount of plant food in the lower depths, the composition of the surface soil determines quite definitely the fertilizer requirements. The lower soil layers in Madison county do not contain any larger amounts of plant food than the surface soils and hence the conclusions reached in the analyses of the surface soils are confirmed by the results secured from the analyses of the lower soils layers. It will not
### TABLE V. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>2,034</td>
<td>4,036</td>
<td>48,240</td>
<td>0</td>
<td>8,808</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>1,320</td>
<td>3,504</td>
<td>28,920</td>
<td>0</td>
<td>8,808</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>2,536</td>
<td>7,078</td>
<td>85,240</td>
<td>0</td>
<td>7,740</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>1,807</td>
<td>5,588</td>
<td>33,240</td>
<td>0</td>
<td>5,472</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>1,324</td>
<td>4,484</td>
<td>49,840</td>
<td>0</td>
<td>5,605</td>
</tr>
<tr>
<td><strong>TERRACE SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>3,212</td>
<td>7,312</td>
<td>93,622</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>2,640</td>
<td>5,492</td>
<td>77,620</td>
<td>0</td>
<td>8,007</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>2,155</td>
<td>3,308</td>
<td>29,480</td>
<td>0</td>
<td>4,004</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>3,044</td>
<td>4,392</td>
<td>44,400</td>
<td>0</td>
<td>6,906</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>2,990</td>
<td>6,612</td>
<td>84,322</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>2,963</td>
<td>3,584</td>
<td>64,854</td>
<td>Trace</td>
<td>Basic</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>4,175</td>
<td>9,080</td>
<td>105,457</td>
<td>1,263</td>
<td>Basic</td>
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<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,141</td>
<td>5,436</td>
<td>81,541</td>
<td>Trace</td>
<td>Basic</td>
</tr>
</tbody>
</table>

Phosphorus fertilizers will certainly be needed on the soils of Madison county in the future, as the supply of this constituent is low. There are indications that these materials may prove of value in some instances at the present time. The supply of organic matter and nitrogen must be maintained. Farm manure, crop residues and leguminous green manures should be utilized on all the soils of the county. Most of the soils in the county are acid and in need of lime and even in those cases where acidity is not shown at present, there is no large content of inorganic carbon and the soils will become acid in the near future. Even in the few instances where there is considerable lime in the subsoil, there will be no effect upon the needs of the surface soils, as lime rarely

### TABLE VI. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Total phosphorus</th>
<th>Total nitrogen</th>
<th>Total organic carbon</th>
<th>Total inorganic carbon</th>
<th>Limestone requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DRIFT SOILS</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>79</td>
<td>Shelby loam</td>
<td>1,717</td>
<td>3,528</td>
<td>44,400</td>
<td>0</td>
<td>19,217</td>
</tr>
<tr>
<td>65</td>
<td>Lindley loam</td>
<td>2,222</td>
<td>2,604</td>
<td>30,660</td>
<td>0</td>
<td>19,217</td>
</tr>
<tr>
<td><strong>LOESS SOILS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Tama silt loam</td>
<td>3,576</td>
<td>9,542</td>
<td>112,120</td>
<td>0</td>
<td>11,611</td>
</tr>
<tr>
<td>80</td>
<td>Clinton silt loam</td>
<td>2,774</td>
<td>4,132</td>
<td>35,033</td>
<td>0</td>
<td>11,210</td>
</tr>
<tr>
<td>64</td>
<td>Grundy silt loam</td>
<td>2,101</td>
<td>4,392</td>
<td>42,762</td>
<td>0</td>
<td>1,038</td>
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<tr>
<td><strong>TERRACE SOILS</strong></td>
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<td></td>
</tr>
<tr>
<td>75</td>
<td>Waukesha silt loam</td>
<td>4,000</td>
<td>6,594</td>
<td>90,224</td>
<td>1,096</td>
<td>Basic</td>
</tr>
<tr>
<td>88</td>
<td>Bremer silt loam</td>
<td>4,202</td>
<td>4,584</td>
<td>64,710</td>
<td>0</td>
<td>4,605</td>
</tr>
<tr>
<td>81</td>
<td>Jackson silt loam</td>
<td>3,414</td>
<td>4,626</td>
<td>33,340</td>
<td>0</td>
<td>6,006</td>
</tr>
<tr>
<td>42</td>
<td>Calhoun silt loam</td>
<td>2,748</td>
<td>3,318</td>
<td>27,780</td>
<td>0</td>
<td>12,012</td>
</tr>
<tr>
<td><strong>SWAMP AND BOTTOMLAND SOILS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Wabash silt loam</td>
<td>3,656</td>
<td>5,382</td>
<td>76,560</td>
<td>0</td>
<td>13,213</td>
</tr>
<tr>
<td>62</td>
<td>Wabash fine sandy loam</td>
<td>3,939</td>
<td>4,626</td>
<td>57,579</td>
<td>981</td>
<td>Basic</td>
</tr>
<tr>
<td>49</td>
<td>Wabash loam</td>
<td>4,445</td>
<td>7,314</td>
<td>85,453</td>
<td>917</td>
<td>Basic</td>
</tr>
<tr>
<td>48</td>
<td>Wabash silty clay loam</td>
<td>2,626</td>
<td>4,710</td>
<td>60,279</td>
<td>981</td>
<td>Basic</td>
</tr>
</tbody>
</table>
moves upward in the soil. If the surface soil is acid, lime will need to be applied.

**GREENHOUSE EXPERIMENTS**

Three greenhouse experiments were carried out on soils from Madison county to secure some indications of the fertilizer needs of the soils and to determine the value of the application of certain common fertilizing materials. Two of these experiments were carried out on the Tama silt loam, the most important soil type in the county, and one on the Clinton silt loam, a minor type.

The plan followed in all these experiments was the same and the amounts of the various materials applied were the same as those employed in the field experiments; hence the results of the greenhouse tests may be considered to indicate quite definitely the results which will be secured in the field. Manure was applied at the rate of eight tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test and two tons additional were supplied in order to put the soil in the best condition for crop growth. Rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in these experiments, but the wheat yields were secured in only one of the tests. The clover yields were secured in all cases but in two of the experiments only the green weights were taken.

The results of the experiment on the Tama silt loam are given in table VII, the figures being the averages of the yields on duplicate pots. The application
of manure brought about a distinct increase in the yields of both the wheat and the clover, the gain being particularly evident on the clover crop. Lime in addition to manure increased the yield of clover quite distinctly. The yield from this treatment on the wheat crop was evidently abnormal and is not included. The phosphate fertilizers all gave increases in crop yields, the acid phosphate showing up the best on the wheat, while the complete commercial fertilizer was slightly superior to the acid phosphate in the case of the clover. With the latter crop, the acid phosphate and complete brand gave very much greater effects than the rock phosphate. In the case of the wheat the rock phosphate and complete commercial fertilizer gave almost the same results.

It is evident from these results that manure is a very valuable fertilizing material for use on this soil and that it should be applied in as large amounts as practicable. Lime added with manure had an important influence on clover and would undoubtedly benefit other legume crops used in the rotation. Ordinarily this material would not benefit the grain crops of the rotation except indirectly. Rock phosphate, acid phosphate and a complete commercial fertilizer all gave increases in crop growth and indications are that phosphorus may probably be used on this soil type with profit. It seems that the acid phosphate is somewhat superior to the other materials but definite conclusions should not be drawn from this experiment as other tests may indicate somewhat different results.

The second greenhouse experiment was carried out on the same soil type from Madison county and the results are given in table VIII. Again it is apparent that the application of manure increased the crop growth on the Tama silt loam. Lime in addition to manure increased the clover yield, rock phosphate had practically no effect, while the acid phosphate and complete commercial fertilizer showed a very large gain in crop growth. These results confirm those secured in the preceding test and show the value of manure and lime on this soil type and indicate also the possibility of using acid phosphate or a complete commercial fertilizer profitably. The results seem to show that the acid phosphate is of more value than the other materials.
The third greenhouse experiment was carried out on the Clinton silt loam and the results of this experiment are given in table IX. The value of manure showed up very distinctly in this experiment, a very large increase in the yield of the clover being secured. Lime brought about a further increase in crop yield and all the fertilizing materials increased the clover to a considerable extent. The rock phosphate showed up a larger effect than the other materials. The acid phosphate appeared somewhat better than the commercial fertilizer. However, the differences in the effect of these materials are not large enough to be very distinctive. It would seem from the experiment that there is no doubt but that phosphorus fertilizers will probably yield profitable returns when applied to this particular soil. Just which material should be used must be determined by more extensive field experiments. There is no question but that manure is a particularly valuable fertilizing material for this soil and that lime should be used when the soil is acid, especially if the best growth of legumes is to be secured.

These greenhouse experiments as a whole indicate quite definitely the value of manure as a fertilizer on the soils of this county and they show also the

TABLE IX. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, MADISON COUNTY

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Treatment</th>
<th>Green weight of clover in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>182.44</td>
</tr>
<tr>
<td>2</td>
<td>Manure</td>
<td>206.58</td>
</tr>
<tr>
<td>3</td>
<td>Manure+lime</td>
<td>213.19</td>
</tr>
<tr>
<td>4</td>
<td>Manure+lime+rock phosphate</td>
<td>235.55</td>
</tr>
<tr>
<td>5</td>
<td>Manure+lime+acid phosphate</td>
<td>247.21</td>
</tr>
<tr>
<td>6</td>
<td>Manure+lime+complete commercial fertilizer</td>
<td>235.39</td>
</tr>
</tbody>
</table>
large value which may be secured by using lime on acid soils. There are indications of value from the use of phosphorus and it is urged that tests with various phosphorus fertilizers be carried out on individual farms in order to determine the desirability of using these materials.

FIELD EXPERIMENTS

Several field experiments are just being started in Madison county and hence it will be several years before the results of these experiments will be sufficiently complete so that conclusions can be drawn from them. The data secured in these field tests will be published later in a supplementary report. For the present the results secured in other counties on the same types of soil must be depended upon primarily for supplying indications of the needs of the soil of the county in general.

An experiment on the Tama silt loam, the main soil type in Madison county, has been under way for several years in Black Hawk county. The results which have been secured in this field may be considered to indicate quite definitely the results which would be secured with the same treatments in Madison county. Hence the results of this field experiment are given here to further support the greenhouse data and laboratory tests in showing the treatments which will prove most profitable on the soils of Madison county. This field experiment is laid out on land which is entirely representative of the particular soil type. It is located permanently by the installation of corner stakes and every precaution is taken in the application of fertilizers and in the harvesting of crops to be sure that accurate results are secured. The plots are 156' 6" by 28' in size, representing one-tenth of an acre.

In that portion of the test reported here, the livestock system of farming is represented, manure being applied along with other fertilizing materials. The other fertilizers used include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of eight tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is used at the rate of 2,000 pounds per acre once in the rotation. A standard 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually.

THE HUDSON FIELD

The Hudson field was laid out in 1917 on the Tama silt loam near Hudson in Black Hawk county. The results obtained on this field in 1918, 1919, and 1920 are given in Table X. Crop yields were not secured in 1921, owing to an oversight on the part of the cooperator.

The yields of corn and oats are apparently influenced to a considerable extent by the fertilizer treatment. Applications of manure, lime and phosphorus fertilizers all affected, to some extent, the crop yields. Manure seemed to be of particular value, and it is particularly interesting to note the beneficial effect of lime when applied along with the manure. Ordinarily this material would not be expected to increase the yields of corn and oats, but beneficial
effects were secured on both crops in this experiment. The legume grown in the rotation is usually expected to show the large effect from the use of lime and frequently the only effect which that material exerts. It seems evident that lime must exert some indirect effect on this soil which results in greater crop growth.

Rock phosphate, acid phosphate and a complete commercial fertilizer all brought about beneficial effects on the crop grown, the relative value of the three materials being somewhat different on the two crops and somewhat different also on the same crop in different seasons. It is quite probable that phosphorus fertilizers might be used on this soil in many cases at the present time with beneficial effects. It is not possible, however, as yet, to choose the particular phosphorus fertilizer which should be employed. More complete data must be secured with these materials before definite, comparative statements can be made. For the present it can only be recommended that phosphorus fertilizers be tested and if they show value under the particular conditions, then the same material may be used with profit on larger areas.

In general this field experiment seems to lead to conclusions which very largely confirm those drawn from the greenhouse data and it emphasizes the need and value of manure and lime when applied to this soil and suggests the possible value which may be secured from the use of a phosphorus fertilizer.

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

The suggestions which are made in this section of the report regarding the most desirable treatments for the soils of Madison county are based upon the experimental information secured in the laboratory and greenhouse and upon the results secured in a field test carried out in another county on a soil type which is the same as the major type in this county. When the field experiments in Madison county have been under way for several years, more definite recommendations may undoubtedly be made. It should be emphasized, however, that no suggestions are offered here regarding soil treatment which have not been proven definitely to be of value by considerable practical experience among the farmers of the county and which may be put into operation under any farm conditions.

The suggestion is frequently made that farmers test the value of certain fertilizer treatments on their own farms and this is the only suggestion which
can be offered in the case of the use of phosphorus fertilizers, altho experiments indicate that they are of value. Farmers may apply a phosphorus fertilizer to small areas and thus determine for their own conditions which carrier will yield the largest effects and which will give the greatest crop growth in comparison with the cost of the material. In the case of the complete commercial fertilizer, the value of the material must be compared with that of a phosphate carrier, inasmuch as the former materials are much more expensive and it is not deemed likely that the nitrogen and potassium contained in the complete brand would be of economic significance. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid in the planning and carrying out of field tests and any farmers who are interested should communicate with the Soils Section.

**LIMING**

Many of the soils of Madison county are acid and in need of lime. Practically all of the important upland types need lime and most of the terrace soils are acid. The bottomland soils, however, all show a basic reaction throughout the soil section, except in the case of the Wabash silt loam where the subsoil shows acidity. The Lindley loam is the only upland type which is not acid and this is only true in the surface soil. The Grundy silt loam shows a basic reaction in the subsoil. There is only one instance where there is any considerable quantity of inorganic carbon present and that is in the surface soil of the Lindley loam. In all the other cases where the reaction is basic, there is only a small amount of inorganic carbon present and in most cases the content is so small that it can only be given as a trace. It is apparent, therefore, that even on those soils in the county which are not acid now, lime will be needed in the very near future and would probably prove of value when legumes are grown on these soils at the present time. In fact, the reaction of the soils is so slightly basic that the various types should undoubtedly be tested for acidity at the present time.

The figures given in table IV show the needs of the surface soils which are acid at the present time, but these figures merely suggest the needs of the soils and before lime is applied tests should be made of the individual soils. The lime requirement of soils is extremely variable and even average figures secured from a large number of tests will not show accurately the needs of a particular soil. Variations may occur even in the same field and if the proper amount of lime is to be applied in any individual case, that particular soil should be tested. The need of lime on soils is particularly evidenced when legumes are to be grown. Clover and alfalfa will not make their best growth unless lime is present in the soil. Other legumes are quite generally sensitive to lack of lime and frequently additions of lime will bring about increases in the yields of corn and small grains, altho ordinarily such crops are not expected to show any benefit from the use of this material.

The value of lime on soils is not due entirely to its direct effect on crop growth, but it is due also to an improvement in the physical and bacteriological conditions in the soil. Not only does lime supply plant food which is needed by all crops, particularly by legumes, but it also makes heavy soils more open and
porous, it makes light soils less porous and less subject to losses by leaching, and it brings about greater bacterial activities and hence greater production of available plant food. The value of applications of lime to acid soils is probably due in most cases to all these effects combined, but there are some instances where the bacteriological effects are probably the most significant. There is always a secondary effect of liming on corn and small grains if the legume crop of the rotation is increased in growth, owing to the fact that the greater legume residues would bring about greater yields of grain. The beneficial effects of liming acid soils has been demonstrated by many experiments and much farm experience.

The upland soils of Madison county will undoubtedly respond to applications of lime when they are acid and the experimental data and experience of farmers in the county confirms this conclusion. It is not an expensive proposition to apply lime to soils and the beneficial effects will more than warrant the outlay. The farmers of Madison county should test their soils for acidity or they should have their soils tested by the Soils Section of the Iowa Agricultural Experiment Station and they should then apply the amount of lime which the test shows to be necessary. In this way they may be sure that they are putting their soils in the best condition for the growth of general farm crops and that they are insuring the best growth of legumes.

Furthermore, it is very important that soils be tested for acidity and lime requirements at regular intervals. When soils are cultivated there is a constant removal of lime thru washing away in the drainage water and thru utilization by crops. If the soil is well drained, as is very necessary for good crop growth, the loss of lime in the drainage water may be considerable. Light textured soils will lose their lime more readily than heavier textured types, owing to more rapid washing away. One test for acidity and one application of lime to a soil, therefore, will not be sufficient for all time. Probably a test should be made at least once in a four-year rotation and the lime needed be applied preceding the clover or legume crop of the rotation.

Limestone is the most satisfactory material for use in remedying acidity in soils and it may be secured in various parts of the state. Lists of companies that are prepared to supply limestone for agricultural purposes are given in circular 58 of the Agricultural Experiment Station. Further information regarding the use of lime on soils, losses by leaching and other information along this line is given in bulletin 151 of the Iowa Agricultural Experiment Station.

**MANURING**

There is no excessive amount of organic matter in any of the soils of Madison county and in some instances the supply of this material is far too low to provide the best conditions for crop growth. An increase in the organic matter content of soils is brought about mainly thru the application of farm manure, one of the most important farm practices for the soils of this county. The beneficial effects of this material on crop yields are very definite and well known. There is no other fertilizing material which has proved nearly as valuable as farm manure.
The experiments reported in the previous pages and the practical experience of many farmers are in absolute agreement in showing large crop increases secured when farm manure is used. On those soils where the supply of organic carbon is low, as indicated in the tables, beneficial effects of manure are particularly evident, but even where the soil seems to be fairly well supplied with organic matter, additions of farm manure are of large value. Thus the Tama silt loam, for instance, altho not strikingly deficient in organic matter, is increased in productiveness to a considerable extent thru the application of manure. The farmers of Madison county should evidently take special precautions to be sure that the manure produced on their farms is carefully preserved and applied to the soil if satisfactory crop growth is to be secured and the soils are to be kept permanently fertile.

The beneficial effects of applying manure to soils are due to the influence on the chemical, physical and bacteriological conditions in the soil. Manure returns a large part of the plant food which has been removed from the soil by the crops grown and hence returns valuable plant food constituents, thus lengthening the life of the soil and prolonging the time before any one of the essential plant food constituents becomes deficient.

Light sandy soils are made more retentive of moisture, less open and porous and less subject to losses by leaching when manure is applied. Heavy clay soils are opened up and made less impervious and better aerated by the addition of manure.

Enormous numbers of bacteria are contained in manure and are therefore applied to the soil when this material is used as a fertilizer. The effect of the addition of these bacteria is to bring about a large increase in available plant food production. The better physical conditions of the soil also stimulate bacterial action and there is more decomposition and more soluble plant food prepared for the use of crops. There are many instances where the bacteriological effects of manuring are of main importance. On dark colored soils where the organic matter supply is not low, the bacterial effects of manuring are probably of the greatest importance.

In general, however, it is believed that increased crop yields secured by the use of manure are due probably to a combination of the bacterial, chemical and physical effects. In the case of Madison county soils, there are several instances where the bacterial effects of manure would undoubtedly be of major importance. There are other cases where the plant food addition would be of particular value, especially if permanent fertility is considered.

The fertilization of the soils of Madison county should begin with the use of manure. If other fertilizers are to be employed they should be used in addition to manure in order to give the best results. The use of manure is, of course, dependent very largely upon the system of farming and if livestock farming or general farming is not practiced, then some other material must be utilized in place of manure.

The value of manure is so great that it is of utmost importance to preserve the manure as produced on the farm and prevent losses which lessen its value when applied. If it is stored in loose heaps and exposed to the weather and the leaching action of rains, 70 to 90 percent of the valuable material in it
may be lost. When such losses occur, increases in crop yields are very much smaller. Hence improper storage may lead to actual economic loss on the farm. The farmers who are not taking precautions in handling the manure produced on their farms are actually reducing their own incomes.

Manure may be stored in various ways and no one method can be suggested as desirable under all conditions. It may be stored in a covered yard or in a pit, or it may be composted, or some other method adapted to local conditions may be followed. In general, it may be said that any method which keeps the manure moist and compact and protected from the weather will be of large value in preserving the fertility of the manure. Occasionally it may be best to apply manure as produced to the land. When this is possible there is no need of storage. There are many instances where this method cannot be followed, and then the manure should be very carefully stored until applied. When it is recalled that carefully stored manure may return to the land 75 to 80 percent of the plant food which has been taken out by the crops grown, the importance of taking care of this material and applying it to the land with a minimum loss can readily be seen.

On the average livestock farm the production of manure will not permit of any large application and the usual amount applied is 8 to 10 tons per acre once in a four-year rotation. On very light textured soils or light colored types, larger applications of manure may sometimes be made with profit, but for general farm crops it is not desirable to apply more than 16 to 20 tons per acre. The average application will undoubtedly prove of quite as large value on the soils of Madison county in most instances as if larger amounts were used. In general it may be said that the best practice is to make applications of manure at regular intervals and in reasonable amounts in order to provide for the best growth of general farm crops and to keep all the soils of the farm productive.

GREEN MANURING

On the grain farm some material must be utilized in place of farm manure to keep up the supply of organic matter in the soil and that is also true of many livestock farms where sufficient manure is not produced. In both cases green manuring is most desirable, either as a substitute for manure or as a supplement to it. Leguminous crops are the most desirable for green manures because when well inoculated they are able to take up nitrogen from the atmosphere and store it in the soil for the use of subsequent crops. Such materials, therefore, not only maintain the organic matter in the soil, but they also serve as nitrogenous fertilizers. Nonlegumes are sometimes used as green manures and they are valuable from the organic matter standpoint, but they do not add nitrogen and hence there are very few cases where their use is preferable to that of legumes. When the organic matter content of the soil is low, the nitrogen supply is usually deficient also, and if green manuring is to be practiced it is in general much more desirable to use a legume. Several legumes may be used as green manures and some particular one may be chosen to fit in with almost any rotation. Green manuring should not be followed blindly or carelessly as undesirable effects may occur if the soil conditions are not such that the green material will be readily decomposed. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.
CROP RESIDUES

It is very important in all systems of farming to utilize fully crop residues such as straw and stover. Frequently these materials are burned or otherwise destroyed with large losses of valuable material. The farmer who follows this method of disposing of his crop residues is actually wasting valuable fertility constituents. On the livestock farm the materials may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored and allowed to decompose to some extent before application. It is of particular importance, of course, to return all crop residues to the land when grain farming is practiced, as in this case there is practically no manure available for use. On the livestock farm the crop residues are a valuable supplement to the manure.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Madison county have shown that phosphorus is not present in any of the soil types in the county in any considerable amounts and in most cases the content of this element is so low that it is evident that phosphorus fertilizers will be needed if the soils are to be kept permanently fertile. Furthermore, there is evidence that the application of phosphorus might be of value on some of the soils of the county at the present time.

Where the total supply of phosphorus in soils is low, it is quite probable that there is an insufficient production of the element in an available form to keep crops supplied and hence, while the analyses of the soils do not show definitely the need of phosphorus, they do indicate that available phosphorus is probably deficient in many cases. The greenhouse tests on the soils of Madison county and the field tests in another county on one of the main soil types in Madison county indicate rather definitely the desirable effects of phosphorus. It is recommended that farmers test the need of phosphorus at the present time on small areas, thus determining the increases in crop yields which may be secured under their particular farm conditions. Until the field experiments which have been started in the county are completed, this is the most satisfactory recommendation which can be made.

Either of two phosphorus fertilizers may be used, acid phosphate or rock phosphate. Acid phosphate is the more expensive, but it contains phosphorus in an available form and this element is therefore more readily utilized by crops. Rock phosphate, while cheaper, has a low rate of availability and considerably larger applications must be made. It is not possible yet to suggest which of these materials should be employed and farmers are urged to use both materials in tests on their farms. Relative yields secured when these materials are applied would indicate which will prove the most profitable, but the yield alone is not sufficient to warrant a choice, as comparisons of the value of the two materials depend also upon the cost of the application. It should be emphasized also that yields should be secured for several years in order to arrive at satisfactory comparisons, as rock phosphate, while not rapidly available the first year after application, becomes more largely available later. Acid phosphate is immediately available and hence is applied annually in the spring. Rock phosphate is applied usually once in a four-year rotation and hence yields of
crops should be secured for that period if satisfactory comparisons are to be made. It is frequently desirable to apply acid phosphate to a small area and thus determine the need of phosphorus on a particular soil and later rock phosphate may be tested to determine its relative value in comparison with further applications of the acid phosphate.

Farmers may carry out tests with these materials on small areas with little difficulty. Directions are given in circular No. 51 of the Iowa Agricultural Experiment Station.

Most of the soils types in Madison county are fairly well supplied with nitrogen, but in any case an addition of this element must be considered in planning systems of permanent fertility. There is a constant loss of nitrogen from soils by removal in the drainage water and by utilization by the crops grown and hence there must be a return of nitrogen to soils if the proper amount of this element is to be maintained. Even altho many of the soils in the county are not strikingly in need of nitrogen at the present time, this element will be needed in the future and precautions should be taken to keep up the supply by regular additions of materials containing nitrogen.

Farm manure is the most important fertilizing material for supplying nitrogen, and it may return a large portion of the nitrogen removed by the crops grown. If the manure produced on the livestock farm is carefully preserved and applied to the soil, the decrease in nitrogen content in the soil will be rather slow, but even under livestock farming conditions with a careful utilization of the manure, the nitrogen content of the soil will not be maintained. On the grain farm where manure is not available for use, some other source of nitrogen must be employed. Under both these systems of farming the practice of green manuring will provide it. It is particularly important on the grain farm.

Legumes should be used in green manuring, as they have the ability when well inoculated to utilize the nitrogen of the atmosphere and when turned under in the soil, they increase the supply of nitrogen. Nonlegumes are not of value as nitrogenous fertilizers, but well inoculated legumes have proved the cheapest and most efficient nitrogenous materials which can be employed.

It is important to note that the mere growing of a legume will not be sufficient to build up the nitrogen content of the soil. If the crop is cut off, nitrogen is removed and while the soil will not be depleted as largely as would be the case with a grain crop, still no nitrogen will be added. Occasionally the seed only of a legume crop is removed and the remainder is turned under. This method may add considerable nitrogen. Legumes should undoubtedly be used in all rotations and it is very necessary that a part or all of the crop be turned under in the soil as a green manure if the nitrogen content of the soil is to be kept up. Occasionally legumes are employed as catch crops and when used in this way they may also serve to supply nitrogen as well as organic matter to the soil.

The proper utilization of crop residues is very important under all systems of farming to cut down the losses of nitrogen from the soil; such materials may prove of considerable value from the nitrogen standpoint, supplementing the use of farm manure or green manures. Commercial nitrogenous fertilizers are not recommended for general farm crops in this county, as it is believed that
leguminous green manures are much cheaper and quite as effective. Small amounts of commercial materials may be applied as top dressings to stimulate the early growth of crops, but they are usually too expensive. If they prove of value on small areas they may be employed, however, without any fear of injuring the soil. Farmers who are interested may test the use of such fertilizers, determining for their own conditions the economic value from the application.

Many analyses have been made of the soils of the state and in all cases large amounts of potassium have been found. There is no doubt, therefore, but that there is a large supply of potassium in all the soils of Madison county and it is not likely that potassium fertilizers will prove of value in any case for general farm crops. Such materials might prove profitable if applied in small amounts as top dressings, but their general use cannot be recommended. If the soils are well drained and cultivated, supplied with lime and organic matter, the rapid production of available potassium, sufficient for crop needs, is almost certain. Farmers who are interested in the use of potassium fertilizers may test their application to small areas and if profitable returns are secured, applications may be made to large areas without any injury to the soil.

Complete commercial fertilizers are being tested in the field experiments now under way in the county and their value is being compared with that of phosphorus carriers. Their use at the present time cannot be recommended and the indications from the experiments which have been carried out are that phosphorus fertilizers will prove more profitable. The complete brands are rather expensive and if the soils do not need potassium or nitrogen, a phosphorus carrier would undoubtedly prove more profitable. If tests prove their application of value there is no objection to their use. It is merely a question of their economic value in comparison with phosphorus. Farmers who are interested in complete materials should test their use on small areas before making any extensive application.

**DRAINAGE**

The soils of Madison county are in general quite adequately drained. The natural drainage system of the county is well developed and there are very few areas where excess water is not rather readily removed. One of the upland types, however, the Grundy silt loam, is rather poorly drained, occupying level upland areas and having a rather stiff subsoil. The areas on the map where this soil occurs are the areas which are in need of drainage. There are a few other areas where drainage is needed, but they are not at all extensive. The installation of tile frequently would prove of considerable value in making the Grundy silt loam more productive.

Where the soil is poorly drained no other treatment will prove of value and even tho the expense of tiling is considerable, it will be well warranted by the increased crop yields secured. Many of the bottomlands in the county are not well drained, but they are also subject to overflow and if they are to be brought under cultivation they must be protected from overflow as well as provided with adequate drainage. In most cases these areas are kept in pasture and no attempt is made to cultivate them.
THE ROTATION OF CROPS

It is very necessary for the continued fertility of all soils that some rotation of crops be practiced. Continuous cropping always leads to a rapid reduction in fertility and it also has proven economically undesirable. Even if a money crop is grown continuously, the reduction in crop yields will be so rapid that the value of all the crops grown over a period of years will be much greater where a rotation is practiced, in spite of the fact that less valuable crops are included. Various rotations may be used under different conditions and no one rotation should be recommended for general use. In fact, it may be said that almost any rotation may be practiced provided it includes a legume and a money crop. No specific experiments have been carried out in Madison county with rotations, but the following may be given as examples of desirable rotations which have been used throughout the state.

I. 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.)

II. 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.)

III. 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.)

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 of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not likely 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 likely 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 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 manure, 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 may 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 made more costly and inconvenient.

Erosion occurs to a considerable extent in Madison county. The Shelby loam and the Lindley loam, the two drift types, are subject to considerable washing; in fact they have been formed because of the washing away of the surface covering of loess. The Clinton silt loam of the loessial upland is frequently considerably eroded and occasionally there is some gully formation in the Tama silt loam. The Jackson silt loam of the terrace is somewhat eroded and both residual soils are badly washed. It is very necessary that care be taken in handling the soils of this county that they be protected from the injurious effect of erosion and from the methods suggested here some one may be chosen which will serve under the particular conditions.

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 to 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, how-
ever, 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 method 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 or 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 upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes 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 drainage ways 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; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"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 brushpile, 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. 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.

A modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

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 the 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 of 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 danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Diekey dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned
separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially 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 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 the prevention of 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 drainage ways 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 a 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 or Adams dam, already described, is especially applicable 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.

BOTTOMLAND EROSION

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

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

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

There are 15 individual soil types in Madison county and these are divided into five large groups according to their origin and location. These groups are known as drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Shelby and Lindley series. Together they cover almost one-fourth of the total area, 24.2 percent of the county.

SHELBY LOAM (79)

The Shelby loam is the most extensive drift soil in the county and the second largest type, covering 19.9 percent of the total area. It occurs in all parts of

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.
the county, occupying the steeper slopes between the bottomlands and the upland areas. It occurs in narrow continuous strips that extend back along the valleys of the smaller streams on the hillsides adjoining the Tama silt loam of the upland. The most extensive areas of the type are found in the southwestern part of the county and in the northeastern section.

The surface soil of the type is a brown to dark brown mellow loam 6 to 14 inches in depth. Below that point the soil is a stiff, waxy yellowish-brown to light brown gritty clay or sandy clay mottled with yellow and drab. Below 30 inches the subsoil frequently consists of a light colored coarse sand mixed with gravel. Variations in the surface soil are common. The texture varies from a fine sandy loam to a silt loam. Occasionally there are shallow layers of sand and gravel separating the soil and subsoil. Stones are of frequent occurrence and streaks of calcareous material are occasionally found. The depth of the surface soil is variable on the gentler slopes, being 12 to 14 inches deep, while on the steeper slopes the soil has been removed considerably and the yellowish-brown silty clay loam subsoil is exposed. Along some of the smaller intermittent drainageways, narrow strips of colluvial material are included with the type, as they were too small to be shown on the map. Small areas of silt loam are included, the drift material appearing at a depth of 18 to 22 inches. On the south slopes to the streams, pebbles, stones, gravel and small boulders are occasionally found. On the hillsides, ridges and knolls a fine sandy loam sometimes occurs and these areas are included with the type, owing to their small extent. They are usually characterized by pockets of coarse sand and gravel. Along the southern boundary of the county directly south of East Peru there is an area of typical Shelby fine sandy loam. Another area occurs in the northern part of the county directly east of Earlham. These are not separated owing to their small extent.

Fig. 4. Shelby loam in Madison county is used largely for pasture.
In topography the Shelby loam ranges from gently rolling to hilly or rough and the soil is well drained. It is subject to destructive erosion and may be badly washed in the more rolling areas.

About 75 percent of the smoother areas of this type are under cultivation, the remainder being in pasture. Most of the typical Shelby loam, however, is used for pasture or hay land. Originally it was partly timbered with oak, hickory, elm, hazel and underbrush. Some of the slopes are still forested. When the type is farmed, corn, oats and hay are the main crops grown. Yields of corn amount to 20 to 40 bushels per acre; oats 20 to 30 bushels and hay 1 to 1½ tons.

Fairly satisfactory crop yields are secured on cultivated portions of the type but they would be increased thru the addition of farm manure in liberal amounts, as the organic matter content of the type is not high. Phosphorus fertilizers would undoubtedly prove of value and in some instances the addition of lime would be needed, altho the soil is not always acid in reaction. The type is subject to extensive washing and when cultivated care should be taken to prevent the removal of the surface soil. There are many areas where cultivation is impracticable and the soils should undoubtedly be utilized for pasture or hay land. Excellent pastures may be maintained on much of the rougher areas of the type and this is undoubtedly the most profitable method of handling such rough areas as are of frequent occurrence.

LINDLEY LOAM (65)

The Lindley loam is a minor soil type in the county covering 4.3 percent of the total area. It occurs on the slopes to the streams separating the areas of Clinton silt loam on the upland from the bottomland types. It is found mainly along the south slopes of North river, Cedar creek, on both sides of Middle river and in extensive areas along Clanton creek. The areas of the type are all narrow and there are no extensive occurrences.

The surface soil of the Lindley loam is a light grayish-brown to brown loam extending to a depth of 6 to 12 inches. It is underlaid by a light brown or yellowish-brown tenacious, gritty sandy clay loam to sandy clay, in many places mottled with yellowish-brown and grayish-drab. Gravel and coarse sand frequently occur in the subsoil and some lime nodules are occasionally present. Variations occur in the surface soil, the texture ranging from a silt loam or silty clay loam to a fine or coarse sandy loam. One-fourth of a mile south of Hanley there is an area extending to the bottomland along Clanton creek where the soil is a fine sandy loam to fine sand of a light yellowish-brown color. In the more heavily timbered areas the surface soil may be a mellow black silt loam 2 to 5 inches in depth. In small depressed areas there are occasionally layers of silt loam or silty clay loam several inches in depth. These minor variations of the type are all too small to be mapped separately.

In topography the Lindley loam is rolling to steep and abrupt and the soil is subject to serious washing. The type is well drained, while surface drainage is excessive. In many of the rough areas much of the surface soil has been washed away, and the underlying subsoil material is exposed.

The Lindley loam is mainly utilized for pasture and only a small part of the type is under cultivation. Much of it is forested with white and black oak,
hickory, ash, hazel, sumac and red haw. On the cultivated areas the chief crops grown are corn, oats and hay. Corn yields 20 to 40 bushels per acre and oats 25 to 35 bushels.

When this type is cultivated it should receive liberal applications of farm manure and if this material is not available, leguminous green manure crops would be of value. The type is low in organic matter and needs to be built up in this constituent. It may be acid in reaction in some cases, although the particular sample analyzed in this report showed a high content of lime. The occurrence of lime in the soil is extremely variable and it should be tested before legumes are grown. Phosphorus fertilizers would undoubtedly prove of value and tests are recommended for these materials to determine their value on general farm crops. It is particularly important that the type be protected from erosion, as serious washing occurs over large areas. In the rougher areas the type should undoubtedly be kept in pasture and that method of handling it will prove the most satisfactory.

**LOESS SOILS**

There are three loess soils in the county, classified in the Tama, Clinton and Grundy series. Together they cover 63.7 percent of the total area of the county.

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Fig. 5. Valley of Clanton creek west of East Peru. The bottomland soil is Wabash loam, with Lindley loam and Soga stony silt loam on the bluffs.
The Tama silt loam is the largest individual soil type in the county as well as the largest loess soil. It covers slightly over half of the total area, 50.3 percent. It is found on the uplands in all parts of the county, the most extensive areas occurring in the northwestern quarter of the county. It is the main type on the more gently rolling uplands and is very largely separated from the bottomlands by the rolling to rough areas of Shelby loam. In the northwestern part of the county, the loess is very deep and the topography is very slightly rolling. In the remainder of the county the type is more noticeably rolling in topography and not quite so deep.

The surface soil of the Tama silt loam is a dark brown mellow silt loam 8 to 20 inches in depth, averaging about 14 inches. The subsoil is a yellowish-brown to brown, compact, friable, heavy silt loam to light silty clay loam, becoming heavier at the lower depths. In the lower subsoil there is often a grayish cast and mottlings of yellowish-brown are occasionally found. Some reddish-brown iron stains also occur. In the northeastern and southwestern parts of the county where the surface soil is shallower, varying from 8 to 14 inches in depth, the soil is somewhat lighter in color at the surface, being almost a grayish-brown and the subsoil is mottled with yellow throughout, mottlings being more pronounced at the lower depths. Rusty brown iron concretions are usually present. In the extreme southeastern corner of the county near Truro and St. Charles, the soil is more typical and resembles that found in the northwestern part of the county. The boundary lines between the Tama and the Grundy silt loam, which is usually more level in topography, are frequently very difficult to draw and in several instances are more or less arbitrary. The Tama silt loam topography is usually gently rolling but may become almost level in certain areas.

About 95 percent of the type is under cultivation and the remainder is utilized for pasture. There is very little of the type that was ever timbered. It has been developed, apparently, under prairie conditions. Corn is the most important crop grown, other crops of value including oats, wheat, timothy and clover. Corn yields 35 to 70 bushels per acre, averaging about 45 bushels. Wheat produces 20 to 30 bushels per acre, the winter varieties being grown almost entirely. Clover and timothy mixed constitute the principal hay crop and the yields range from 1 to 3 tons per acre. Rye, barley, millet, sorghum, vetch, rape and Sudan grass are other crops which are grown to some extent. Fruit and vegetables are produced for home use and excellent yields of potatoes are secured.

The Tama silt loam is naturally a rather productive type but will respond, in many cases, to applications of various fertilizing materials. Applications of farm manure are always of value and lead to increased crop yields. This material should be applied in as large amounts as practicable for this type in order not only to increase crop yields, but to keep up the supply of organic matter. Where manure is not produced, the leguminous crops should be turned under as green manures. The Tama silt loam is acid in reaction and applications of lime are necessary to permit of the best growth of legumes. The soil should be tested for acidity at regular intervals and lime applied as needed.
The phosphorus content of the soil is not high and phosphorus fertilizers will undoubtedly be needed in the future if they do not prove of value at the present time. There are indications from the greenhouse experiments which have been referred to earlier in this report, that phosphorus fertilizers may prove of value on this soil. Field tests in other counties indicate also the possible value from applications of phosphorus. It is urged that farmers test the value of rock phosphate and acid phosphate on their own farms in order to determine whether phosphorus fertilizers are of value under their particular conditions and, if so, which material should be employed.

**CLINTON SILT LOAM (80)**

The Clinton silt loam is the third largest soil type in the county and the second most extensive loess soil. It covers 9.3 percent of the total area of the county. It occurs on the tops of the higher ridges adjacent to the larger streams. It is most extensively developed along Middle and North rivers and Clanton creek. The largest area is found between Clanton creek and Middle river in the southeastern part of the county. The type occurs only rarely in the north­west and southwest sections of the county. Near the heads of the streams and along the minor tributaries of the larger rivers, the type occurs only in small patches on the tops of the ridges.

The surface soil of the Clinton silt loam is a light grayish-brown, smooth floury silt loam to a depth of 7 to 12 inches. At that point it becomes a more compact brown to yellowish-brown heavy silt loam faintly mottled with gray. Between 14 and 18 inches the subsoil becomes a very compact yellowish-brown silty clay mottled with light gray and grayish-brown.

In topography the Clinton silt loam is gently rolling to hilly and the drainage is entirely adequate. The soil is subject to considerable erosion and gullies and ditches are of rather common occurrence.

This type was originally forested with white oak, black oak, elm, hickory, hazel and other hardwood trees. Most of the land is now cleared and utilized for general farming. The principal crops grown are corn, oats, wheat, clover and timothy. Corn yields from 20 to 40 bushels per acre, oats 25 to 40 bushels per acre, hay 1 to 2 tons per acre. Small fruits and tree fruits, strawberries, blackberries, raspberries, cherries, apples and grapes grow very satisfactorily on this soil but they are not produced in sufficient quantities even to supply the local markets. Potatoes and garden vegetables are grown for home use.

The Clinton silt loam is not as highly productive a type as the Tama silt loam and will respond profitably to fertilizer treatments. It is particularly in need of organic matter and applications of farm manure are very desirable and prove extremely profitable. This material should be applied in as large amounts as practicable if the soil is to be built up in organic matter supply and made more productive. If farm manure is not available leguminous green manures should be employed. The soil is acid in reaction and applications of lime are quite necessary if legumes are to be grown. The soil should be tested for acidity and lime applied as necessary. The phosphorus content of the Clinton silt loam is low and phosphorus fertilizers will undoubtedly be needed in the future. They may be of value in many cases at the present time and farmers are urged to test the value of phosphorus on their own farms. In this way
they may determine whether phosphorus fertilizers will prove of value on their soils and they will also learn whether acid phosphate or rock phosphate will prove the most profitable.

**GRUNDY SILT LOAM (64)**

The Grundy silt loam is a minor type in the county, covering 4.1 percent of the total area. It is found in all parts of the county, but in comparatively small areas. The largest continuous area is south and east of Winterset. Other areas of considerable size are just west of Winterset and throughout the northwestern quarter of the county, especially in the vicinity of Earlham. It is found on the highest areas of upland, on the level land between the streams or drainage channels, occurring in strips from one-eighth to three-fourths of a mile in width and also in many small patches.

The surface soil of the Grundy silt loam is a dark brown to almost black friable silt loam 8 to 14 inches in depth, averaging about 10 inches. The subsoil to a depth of 18 to 22 inches is a grayish-brown to dark brown silty clay loam with faint yellowish mottlings at the lower depths. Below 22 inches the subsoil changes abruptly into a bluish-gray or grayish-brown silty clay mottled with yellow. In some areas there is a layer of gray silty material, in the subsurface layer between the depths of 8 and 12 inches. Rusty brown to black iron concretions are numerous. The soil is lighter in color and more plastic and tenacious at the lower depths and because of its dense impervious character is locally called "hardpan."

In topography the Grundy silt loam is level to very gently undulating. The drainage is quite inadequate and the installation of tile is very necessary to remove the water which accumulates on the type after each rain.

Practically all of the soil is under cultivation, general farm crops being grown. Corn is the most important crop, yielding about 55 bushels per acre on the average. Under favorable conditions this yield is very much increased.

Fig. 6. Grundy silt loam south of Earlham shows typical topography of this soil.
Oats yield from 30 to 80 bushels per acre in favorable seasons but are inclined to lodge in wet years. Wheat yields 20 to 40 bushels per acre and hay, usually clover and timothy, yields from 1 to \(2\frac{1}{2}\) tons per acre.

The chief need of the Grundy silt loam to make it more productive is adequate drainage. The installation of tile proves distinctly profitable. The soil is acid in reaction and should be limed if clover or other legumes are to be grown. Applications of farm manure are of considerable value on this soil, bringing about increases in crop yields in practically all cases. This is true in spite of the fact that the type is not particularly deficient in organic matter. The content of phosphorus is not high and there are indications that phosphorus fertilizers might prove of value. Tests on individual farms with the use of both rock phosphate and acid phosphate are very desirable in order to determine whether or not phosphorus should be applied to the soil and which particular fertilizer might be employed the most profitably.

**TERRACE SOILS**

There are four terrace soils in the county, classified in the Waukesha, Bremer, Jackson and Calhoun series. They are all minor in area and together cover only 2.1 percent of the total area of the county.

**WAUKESHA SILT LOAM (75)**

The Waukesha silt loam is the largest of the terrace types but it is small in area, covering but 1.0 percent of the total area of the county. It occurs in small areas in various parts of the county, chiefly, however, along Middle river and Clanton creek, the largest areas being found east and south of Winterset and northeast of East Peru. It is found on the terraces joining the soils of the Wabash series in narrow strips.

The surface soil of the Waukesha silt loam is a brown to dark brown mellow silt loam 12 to 20 inches in depth. Below that point it changes to a brown to grayish-brown heavy silt loam to light silty clay loam. The lower subsoil is heavier in texture and lighter in color and mottled with gray. In the more level areas there is a heavy intermediate layer at a depth of 10 to 15 inches consisting of a dark brown silty clay loam.

In topography the Waukesha silt loam is generally level to gently undulating. In some areas the surface topography has been modified somewhat by the streams from the uplands flowing thru. The type is well drained and not at all drouthy. Originally the Waukesha silt loam was forested to a small extent but very few trees remain on it at present.

Practically all of the type is in cultivation, only a few of the smaller areas being utilized for pasture. General farm crops are grown, corn being the most important. Yields of this crop average 35 to 70 bushels per acre. Oats, wheat and clover and timothy are grown to some extent and the yields are very much the same as on the Tama silt loam of the upland. Alfalfa has been grown on small areas and yields 2 to 3 tons of hay per acre.

This soil is quite productive but increases in crop yields are secured thru proper soil treatment. Applications of farm manure are of large value. The soil is acid and lime should be applied as needed, particularly for the growth
of legumes. The phosphorus content is not high and phosphorus fertilizers would probably prove of value in many cases.

**BREMER SILT LOAM (88)**

The Bremer silt loam is a minor terrace type in the county, covering 0.7 percent of the total area. It occurs in several areas in various parts of the county, chiefly, however, along Middle river, Clanton creek and North river. The largest areas are found along Middle river between Patterson and Bevington. The other areas are all small in extent.

The surface soil of the Bremer silt loam is a dark brown to black, compact, friable silt loam to a depth of 8 to 12 inches. The subsoil is a dark brown to black heavy stiff silty clay loam changing at 22 to 28 inches into a brown to dark brown plastic clay loam faintly mottled with yellowish-brown and gray. In some areas the subsoil contains reddish-brown to black iron concretions. There are small areas of Bremer silt clay loam included with this type but they have not been separated owing to their small extent.

In topography the Bremer silt loam is level to gently sloping. The surface drainage is fair but the soil is quite generally in need of tiling owing to the heavy character of the subsoil. Practically all of the type is under cultivation, only a small area being in pasture. Corn, oats, wheat and hay are the principal crops grown. Corn yields 35 to 70 bushels per acre and hay 1½ to 2 tons. Yields of wheat and clover are very much the same as on the adjacent uplands.

This type would be benefited particularly by the installation of tile where artificial drainage has not already been provided. It is high in organic matter but small applications of farm manure are of value, particularly on newly drained areas. The soil is acid and in need of lime. It is not high in phosphorus and phosphorus fertilizers might be employed to advantage.

**JACKSON SILT LOAM (81)**

The Jackson silt loam is a minor type in the county, covering only 0.3 percent of the total area. It occurs in a number of small areas, chiefly along Middle river, the most extensive areas being found in the vicinity of Webster. Smaller isolated areas occur along Clanton creek, North Branch of North river, Grand river and North river.

The surface soil of the Jackson silt loam is a light brown to grayish-brown smooth silt loam extending to a depth of 8 to 12 inches. Below this point it grades into a light brown to yellowish-brown silt loam becoming more compact at the lower depths and streaked with gray. Below 30 inches the subsoil is a very compact, brown heavy silty clay loam slightly mottled with gray. In some areas where the terrace joins the upland, there are small layers and pockets of sandy and silty material in the subsoil and occasionally some sandy material has accumulated on the surface.

In topography the soil is level to gently undulating. It occurs 10 to 30 feet above the bottomlands and drainage is usually quite adequate. It is practically all under cultivation and corn, wheat, oats, timothy and clover are the chief crops grown. Corn yields 30 to 50 bushels per acre, oats 30 to 40 bushels, wheat 15 to 30 bushels and hay 1 to 2 tons. Small fruits and vegetables grow well on this soil and some apples are produced in small orchards.
Fig. 7. A stretch of level terrace soil.—Waukesha silt loam.

This type is benefited particularly by applications of farm manure which should be made in liberal amounts. It is acid in reaction and should be limed for the best growth of all crops, particularly legumes. It is not high in phosphorus and phosphorus fertilizers would probably prove of value.

**CALHOUN SILT LOAM (42)**

The Calhoun silt loam is a very minor type in the county, covering 0.1 percent of the total area. It occurs in several small areas along Middle river, North river and the north fork of Clanton creek.

The surface soil of the Calhoun silt loam is a light brown to light brownish-gray floury silt loam 6 to 10 inches in depth. Below this point there is a layer of light gray to light yellowish-gray silt loam 8 to 10 inches in thickness. This passes abruptly into a heavy compact and impervious yellowish-gray silty clay to clay loam mottled with yellowish-brown in the lower depths.

In topography the Calhoun silt loam is nearly flat to gently undulating. It is poorly drained and the installation of tile is necessary to remove excess moisture. The type was originally forested with oak, but practically all of it has been cleared and is now in cultivation. General farm crops are grown and the yields are very much the same as on the Jackson silt loam. The type is in need of drainage particularly. It would respond to applications of farm manure, is acid in reaction and should be limed. It is not high in phosphorus and phosphorus fertilizers would probably prove of value.

**SWAMP AND BOTTOMLAND SOILS**

There are four swamp and bottomland soils in the county, all classified in the Wabash series. Together they cover 6.9 percent of the total area of the county.

**WABASH SILT LOAM (26)**

The Wabash silt loam is the largest individual bottomland soil, covering 3.3 percent of the total area of the county. It occurs along practically all of the
more important streams in the county, the largest areas being found along North river and Clanton creek. These areas range from one-fourth to one-half mile in width. There are also well developed areas along South river in the southeast corner of the county, along Jones creek and Badger creek in the northeast corner and along Cedar creek. Narrow strips are found along the smaller streams in other parts of the county.

The surface soil of the Wabash silt loam is a dark brown to nearly black compact silt loam 4 to 20 inches in depth. Below this point it becomes a dark brown to black heavy silt loam to a depth of 24 to 28 inches where it changes to a heavy tough dark brown to grayish-brown silty clay to clay loam mottled with gray or yellowish-brown. There are many variations in the surface soil within the areas of this type. Along North river the surface soil is especially heavy and shallower than typical, passing from 8 to 14 inches into a tenacious impervious black silty clay to clay loam mottled with gray. Along North river the type is associated with the Wabash silty clay loam and the boundary lines are drawn more or less arbitrarily.

In topography the Wabash silt loam is generally level, sloping slightly toward the streams. The drainage is usually poor, particularly so where the subsoil is more impervious. The surface is 4 to 12 feet above the normal water level of the streams and much of the land is subject to overflow. The type is characteristically higher along the banks of the stream than it is back from the channel. Along the uplands the type is very rarely flooded.

Along the banks of the streams there are narrow belts of forest trees and these are principally oak, hickory, ash, cottonwood, willow and soft maple. About 85 percent of the type is under cultivation, corn being the most important crop grown. Oats, wheat and hay are also grown to some extent. Corn yields from 40 to 60 bushels per acre and under favorable seasonal conditions may

Fig. 8. Wabash silt loam occurs along Jones creek, with Lindley loam on the slope beyond.
yield as high as 75 to 80 bushels per acre. Oats yield 30 to 60 bushels and wheat 18 to 35 bushels per acre. Hay crops generally yield 1 to 2 tons per acre.

The Wabash silt loam is in need of drainage to make it productive and also should be protected from overflow. When this is accomplished the type will permit of large crop yields. It is acid in reaction and will need lime when brought under intensive cultivation, especially for leguminous crops. Small applications of manure would be of value when the land is newly drained. Phosphorus fertilizers will be needed in the future and may prove of value in some cases at the present time.

WABASH FINE SANDY LOAM (62)

The Wabash fine sandy loam is a minor bottomland type covering 1.4 percent of the total area of the county. It occurs in numerous small areas along the streams of the county, being developed along Clanton creek, the tributaries of this stream in the southeastern part of the county, the West Branch of Grand river in the southwest corner of the county and along Middle river, North river and Jones creek. The largest individual area is found along Middle river south and west of Winterset.

The surface soil of the Wabash fine sandy loam is a brown to dark brown fine sandy loam 12 to 20 inches in depth. Below this point it becomes a brown to light brown fine sandy loam faintly mottled with gray. Below 30 inches the subsoil is a coarse light brown sand. Some gravel is found mixed with the soil throughout the three-foot section.

In topography the type is generally flat but owing to the loose open structure of the soil, drainage is good. It is subject to overflow regularly and hence varies considerably in character of surface material.

Only a part of this soil is under cultivation owing to the frequency of overflow. Corn is the most important crop grown and yields range from 35 to 40 bushels per acre. This soil should be protected from overflow if cultivated crops are to be grown successfully. When this is accomplished it would be benefited materially by the addition of organic matter. Liberal applications of farm manure would prove of value or leguminous crops might be used as green manures. The soil is usually acid and in need of lime for the best growth of legumes. It is not high in phosphorus and applications of phosphorus fertilizers will be needed in the future and may be of value in some cases at the present time.

WABASH LOAM (49)

The Wabash loam is a minor type in the county, covering 1.3 percent of the total area. It occurs chiefly along Grand river where it is found in narrow continuous strips covering practically all of the first bottom. Small areas are also found along Middle river, Clanton creek, North river and its tributaries.

The surface soil of the Wabash loam is a grayish-brown to dark brown mellow loam 8 to 12 inches in depth. Below this point it changes to a light brown to grayish-brown compact loam which passes at about 24 inches into a lighter brown fine sandy loam. The soil is quite variable because of the frequency of overflow. In some areas there is considerable sand and gravel in layers or pockets. There is a small area along Middle river, in sections 6 and 7
of Scott township, where the soil is a light brown to brown loam 15 to 20 inches in depth, underlaid by a yellowish-brown fine sandy loam mottled with gray. The soil on this area really belongs in the Genesee series but was not mapped separately because of its small extent.

In topography the type is level and drainage is good. It is subject to frequent overflow, however, and there are a few poorly drained spots. Only a very small part of the soil is under cultivation and the land is used almost wholly as pasture. Much of it is forested, chiefly with cottonwood, willow, box elder, ash and post oak. If it is to be brought under cultivation the type would need to be protected from overflow, liberally supplied with manure and applications of phosphorus would probably be of value.

**WABASH SILTY CLAY LOAM (48)**

The Wabash silty clay loam is a minor type in the county, covering 0.9 percent of the total area. It occurs along most of the larger streams of the county, the greater part being found along the North river. Small areas occur along Cedar creek and Clanton creek.

The surface soil of the Wabash silty clay loam is a black silty clay loam 8 to 10 inches in depth. Below this there is a black tenacious clay loam which changes at 18 to 20 inches into a dark brown to black stiff plastic clay loam mottled with dull brown or gray. Yellowish-brown mottlings and reddish-brown iron stains are found in the lower subsoil. This type is locally known as "gumbo" because of the sticky plastic character of the soil. Within the type there are included small areas of a mucky clay loam covered at a depth of 2 to 3 inches with a layer of decayed organic matter. These areas are found in depressions 5 to 100 feet in width and they remain marshy during most of the summer and support only a growth of reeds and coarse water grasses.

In topography the Wabash silty clay loam is level to flat. The drainage is poor and the type is subject to overflow. Most of it is uncultivated, growing only coarse fibered slough grass. In small areas which are under cultivation, corn, oats and hay are the principal crops. Where drainage is adequate corn may yield 40 to 65 bushels per acre. Oats produce fairly well but are likely to lodge.

If this soil is to be cultivated it is particularly in need of drainage. When this is accomplished and the type is protected from overflow, large crop yields may be secured. Small applications of farm manure might be of value on newly drained areas and applications of phosphorus will be needed in the future.

**RESIDUAL SOILS**

There are two residual soils in the county classified in the Sogn and Hagers town series. Together they cover 3.1 percent of the total area of the county.

**SOGN STONY SILT LOAM (155)**

The Sogn stony silt loam is the larger of the residual soils but it is not very extensive in occurrence in the county, covering 2.9 percent of the total area. It is found along Middle river in the central and central western parts of the county, along North river, North Branch and Cedar creek in the northern part of the county and along Jones creek and upper Clanton creek in the south-
eastern part of the county. The type is derived from the weatherings of narrow exposures of limestone and it occurs on steep slopes and in ravines.

The surface soil of the type is a black loose mellow silt loam 6 to 8 inches in depth. Here it passes abruptly into a grayish-brown to olive gray loam to clay which is tough, plastic and highly calcareous. It contains fragments of limestone and shale. The type is of little value for farming and can be used only for pasture. It supports a scant growth of hardwood trees. None of it is under cultivation.

HAGERSTOWN SILT LOAM (156)

The Hagerstown silt loam is a very minor type in the county, covering only 0.2 percent of the total area. It occurs in several small areas, the largest being found along Clanton creek northeast of East Peru, along Cedar creek northeast of Winterset and along North river north of Winterset. It also occurs in many areas which are too small to be shown on the map.

The surface soil of the Hagerstown silt loam is a light red to reddish-brown silt loam extending usually to a depth of 12 inches, averaging about 8 inches. In some places the surface soil has a purplish-red color and where it contains much organic matter the color is a dark reddish-brown. The subsoil is a reddish-brown stiff heavy clay loam to clay.

In topography the soil is sharply rolling and the type has little agricultural value. It occurs on the steep hillsides, being usually found midway up the hillside with the Sogn stony silt loam below. The type was originally covered by a sparse growth of hardwood trees. At present it is used mainly for pasture and woodlots.
APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

PLANT FOOD IN SOILS

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

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

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

Frequently a soil analysis shows the presence of such 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 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.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions. The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

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

It is evident from the table that the continuous growth of any common farm crop without returning 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 non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

Of course, if the crops 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 plant food loss.

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.
TABLE I. PLANT FOOD IN CROPS AND VALUE

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Value of Plant Food</th>
<th>Total Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lbs.</td>
<td></td>
<td></td>
<td>$12.00</td>
<td>$14.37</td>
</tr>
<tr>
<td>Corn, grain</td>
<td>75 bu.</td>
<td>75</td>
<td>12.75</td>
<td>14</td>
<td>$1.52</td>
<td></td>
</tr>
<tr>
<td>Corn, stover</td>
<td>2.25 T.</td>
<td>30</td>
<td>4.5</td>
<td>39</td>
<td>$0.54</td>
<td></td>
</tr>
<tr>
<td>Corn, crop</td>
<td>111</td>
<td>17.25</td>
<td>17.76</td>
<td>2.07</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>Wheat, grain</td>
<td>30 bu.</td>
<td>42.6</td>
<td>7.2</td>
<td>7.8</td>
<td>8.61</td>
<td></td>
</tr>
<tr>
<td>Wheat, straw</td>
<td>1.5 T.</td>
<td>35</td>
<td>2.4</td>
<td>27</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Wheat, crop</td>
<td>57.6</td>
<td>6.6</td>
<td>9.21</td>
<td>1.14</td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>Oats, grain</td>
<td>50 bu.</td>
<td>55</td>
<td>5.5</td>
<td>8</td>
<td>5.28</td>
<td></td>
</tr>
<tr>
<td>Oats, straw</td>
<td>1.5 T.</td>
<td>15.5</td>
<td>2.5</td>
<td>26</td>
<td>2.48</td>
<td></td>
</tr>
<tr>
<td>Oats, crop</td>
<td>48.5</td>
<td>8</td>
<td>7.76</td>
<td>1.92</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td>Barley, grain</td>
<td>30 bu.</td>
<td>23</td>
<td>5.5</td>
<td>3.68</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Barley, straw</td>
<td>0.75 T.</td>
<td>9.5</td>
<td>113</td>
<td>1.52</td>
<td>0.78</td>
<td></td>
</tr>
<tr>
<td>Barley, crop</td>
<td>6.3</td>
<td>3.5</td>
<td>5.20</td>
<td>0.72</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td>Rye, grain</td>
<td>30 bu.</td>
<td>20.4</td>
<td>6.3</td>
<td>4.70</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Rye, straw</td>
<td>1.5 T.</td>
<td>12</td>
<td>21</td>
<td>1.92</td>
<td>1.26</td>
<td></td>
</tr>
<tr>
<td>Rye, crop</td>
<td>41.4</td>
<td>28.8</td>
<td>6.62</td>
<td>1.08</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>Potatoeens</td>
<td>300 bu.</td>
<td>65</td>
<td>127</td>
<td>10.98</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Alfalfa, hay</td>
<td>6 T.</td>
<td>27</td>
<td>144</td>
<td>48.00</td>
<td>3.24</td>
<td></td>
</tr>
<tr>
<td>Timothy, hay</td>
<td>5 T.</td>
<td>9</td>
<td>67.5</td>
<td>11.52</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>Clover, hay</td>
<td>8 T.</td>
<td>15</td>
<td>90</td>
<td>19.20</td>
<td>1.80</td>
<td></td>
</tr>
</tbody>
</table>

that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

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

PERMANENT FERTILITY IN IOWA SOILS

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

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until 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 likely to be limiting factors in crop production.

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

CULTIVATION AND DRAINAGE

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

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their

*Bulletin 150, Iowa Agricultural Experiment Station.
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.

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.

MANURING

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

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

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common. By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of 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.

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 few very 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
Fig. 10. Map showing the principal soil areas in Iowa

tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

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 was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

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

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 eolian.
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:

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

Inorganic matter:

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

*35 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.
Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

The determinations of soil types are verified also by inspection 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.