# SOIL SURVEY OF IOWA
## GREENE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
MECHANIC ARTS

**Agronomy Section**
**Soils**



**Soil Survey Report No. 44**
**April, 1927**
**Ames, Iowa**

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April 7, 1927 Soil Survey Report No. 44

# SOIL SURVEY OF IOWA

## Report No. 44--GREENE COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of H. R. Meldrum, L. W. Forman and C. L. Orrben

IOWA AGRICULTURAL
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# GREENE COUNTY SOILS*


By W. H. Stevenson and P. E. Brown with the assistance of C. L. Orrben, L. W. Forman, and H. R. Meldrum.


GREENE County is located in western central Iowa in the central tier of counties north and south and in the fourth tier of counties east of the Missouri River. It is in the Wisconsin drift soil area and hence the soils of the county are all of glacial origin.

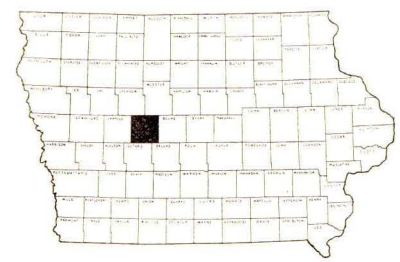


Fig. 1. A map showing the location of Greene County.

The total area of the county is 574 square miles or 367,360 acres. Of this area, 346,136 acres or 94.2 percent is in farm land. The total number of farms is 1,975 and the average size of the farms is 175 acres. The farms are operated by 637 owners, 321 relative renters, 842 renters, 170 both owning and renting, and 5 unclassified.

The following figures taken from the Iowa Yearbook of Agriculture for 1925, show the utilization of the farm land in the county:

| | |
|---|---|
| Acreage in general farm crops | 258,079 |
| Acreage in farm buildings, public highways and feed lots | 16,100 |
| Acreage in pasture | 69,158 |
| Acreage in waste land not utilized for any purpose | 1,638 |
| Acreage in farm wood lots used for timber only | 94 |
| Acreage in crop land lying idle | 692 |
| Acreage in crops not otherwise listed | 574 |

### THE TYPE OF AGRICULTURE IN GREENE COUNTY

The type of agriculture followed at the present time in the county is mainly a system of general farming, including much stock raising. On many farms, a large part of the grain produced is fed to livestock, while most farmers raise enough stock to consume the roughage and hay grown on the farm. The relative amount of grain fed on the farms to livestock or sold on the markets varies somewhat in different years, depending upon market conditions. In some seasons, there is a much greater sale of grain, while the feeding of stock is not practiced so extensively. In other seasons, when the market price of grain is low, there is more feeding.

Hog raising, cattle feeding, sheep feeding and dairying are the principal livestock industries. Hogs provide the chief source of income on most farms. In many cases considerable income is derived from the sale of cattle, sheep and dairy products. The chief crops grown are corn, oats and hay. About half of the corn crop is usually utilized for feeding purposes on the farms, the surplus being sold on the local markets. The other common farm crops

*See soil survey of Greene County, Iowa, by A. W. Goke of the U. S. Dept. of Agriculture and C. L. Orrben of the Iowa Agricultural Experiment Station. Field Operations of the Bureau of Soils, 1921.

grown are used mainly as feed for the stock. Most of the farm incomes in the county come from the sale of hogs, cattle, sheep and dairy products and from the sale of surplus corn and occasionally other crops.

The waste land acreage in the county is rather large and undoubtedly a considerable part of it might be reclaimed and made productive by the adoption of proper methods of soil treatment. The reasons why such areas are not utilized for any purpose are variable and hence general recommendations regarding their reclamation cannot be made. In a later section of this report, methods of handling unproductive areas in the various individual soil types will be suggested. These methods may vary with the individual type. Suffice it to say here, that many of these areas of unproductive land may be made productive by simple, inexpensive methods of treatment. Advice regarding the handling of soils in special cases where the conditions are more or less abnormal, may be secured from the Soils Section of the Iowa Agricultural Experiment Station, upon request.

## THE CROPS GROWN IN GREENE COUNTY

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

Corn is the leading crop. It occupies the largest acreage of any crop, being grown on over 44 percent of the total farm land. It is by far the most valuable crop produced in the county. It occupies about one-half of the total acreage in cultivation on most farms. Average yields in 1925 amounted to 44.6 bushels per acre. In many cases, larger yields than this are secured, where the conditions are particularly favorable. The chief varieties grown are Iowa Silvermine, Reids Yellow Dent and Bloody Butcher. It is estimated that in general about half of the corn crop is utilized for feeding purposes on the farms, the remainder being sold, chiefly at the local markets. Hogging down of corn is practiced rather widely. In many cases soybeans and rape are seeded between the rows of corn at the last cultivation, thus increasing the feeding value of the crop in the hogging-down operation. In some cases, the corn is fed in the form of silage.

The second crop in acreage and value is oats. In 1925, this crop was grown on 24.92 percent of the total farm land of the county. Average yields in that year were 38 bushels per acre. Under more favorable seasonal conditions, the yields are often considerably greater. The varieties most generally grown include Iowa 103, Iowa 105, and Green Russian. The early maturing varieties are the most popular and the most generally used. The seeding of these varieties insures rapid growth and the early maturing of the crop. Most of the oats crop is utilized on the farm for feeding purposes.

Tame hay is the third crop in acreage and in value. In 1925, it was grown on somewhat over four percent of the total farm land. The average yield of the crop amounted to 1.1 tons per acre in that season. The tame hay crop usually consists of clover and timothy mixed. Occasionally these crops are grown alone but only rarely, the opinion seeming to prevail that the combination permits of the production of a better hay crop. This opinion is probably based on the fact that, in many cases, the clover crop has been poor due to seasonal conditions, the lack of lime in the soil, or the lack of inoculation or some other unsatisfactory condition and when timothy is grown with the clover, a larger hay crop is produced, the timothy not being so sensitive to unfavorable conditions as the clover. From the standpoint of soil fertility it would be very much more desirable to grow clover alone as the clover has a much greater effect in building up the fertility of the soil. When timothy is grown with the clover the value of the crop as a soil builder is very largely reduced. All of the hay crop produced in the county is utilized for feeding purposes on the farms.



Some timothy is grown for seed and in 1925, 165 acres of clover were utilized for seed.

There is a small acreage still in wild hay, average yields amounting to 1.2 tons per acre. It is produced on the low, poorly drained areas and, in many cases, is rather coarse and has a low feeding value.

Alfalfa is grown to only a limited extent but average yields of this crop amounted in 1925 to 2.2 tons per acre. When attempts to raise alfalfa have been unsuccessful, in spite of favorable seasonal conditions, attention should be given to the thoro drainage of the area, to the supply of lime in case the soil is acid, as is apt to be the case, to the preparation of a proper seed bed, to the securing of good seed and to the thoro inoculation of the seed. When all these precautions are taken, there is no reason why a successful crop of alfalfa should not be secured.

Some sweet clover is grown, being utilized mainly as pasture for cattle and hogs. It makes a good forage plant of high feeding value and it has a beneficial effect on the fertility conditions in the soil. It can be grown successfully if the land is thoroly limed before the crop is seeded.

There is only a very small acreage in wheat and it is not an important crop. Yields amounted to 16 bushels per acre in 1925 in the case of the

TABLE I. AVERAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN GREENE COUNTY, IOWA*

| Crop | Acreage | Percent of total farm land of county | Bushels or tons per acre | Total bushels or tons | Average price | Total value of crop |
|---|---|---|---|---|---|---|
| Corn | 153,562 | 44.36 | 44.6 | 6,848,865 | $0.56 | $3,835,364 |
| Oats | 85,243 | 24.92 | 38.0 | 3,266,436 | 0.32 | 1,045,259 |
| Winter wheat | 131 | 0.04 | 16.0 | 2,096 | 1.36 | 2,850 |
| Spring wheat | 52 | 0.02 | 12.0 | 624 | 1.30 | 811 |
| Barley | 327 | 0.09 | 30.0 | 9,810 | 0.57 | 5,591 |
| Rye | 58 | 0.02 | 17.0 | 986 | 0.80 | 788 |
| Tame hay | 14,918 | 4.10 | 1.1 | 16,410 | 13.50 | 221,535 |
| Wild hay | 2,430 | 0.70 | 1.2 | 2,916 | 10.50 | 30,618 |
| Alfalfa | 986 | 0.29 | 2.2 | 2,169 | 17.50 | 37,957 |
| Potatoes | 180 | 0.05 | 61.0 | 10,980 | 2.35 | 25,803 |
| Pasture | 69,158 | 2.00 | ------ | -------- | ------ | -------- |

*Iowa Yearbook of Agriculture, 1925.

winter varieties and to 12 bushels per acre with the spring varieties. Turkey is the variety which is most commonly grown.

There is only a small total production of rye, barley and flax. Rye and barley are utilized mainly as supplementary feed for hogs. Flax is grown to a small extent, chiefly on certain so-called alkali and peat soils which have been newly drained. Millet is also sometimes grown on such areas. It is utilized chiefly for feeding purposes but is not considered a very satisfactory crop. Some Sudan grass is grown, chiefly, however, in an experimental way. Yields have been estimated at from 4 to 7 tons of hay per acre. Rape is occasionally grown, mostly with the corn which is to be hogged down. It provides a well balanced ration with corn, and is most useful as a feed for hogs and sheep.

Soybeans are grown on an increasing acreage. In some cases, the beans are seeded with the corn which is to be hogged down. Satisfactory yields of soy beans may be secured on most of the land in the county and the crop is quite profitable.

Fruit growing is carried on in a very limited way, and is not commercially important. Apples, grapes, strawberries, plums and cherries are grown on most farms, chiefly for home consumption.

Potatoes are grown on practically all farms, the crop being utilized almost entirely to supply the home demands.

## THE LIVESTOCK INDUSTRY IN GREENE COUNTY

The livestock industries of the county in the order of their importance are hog raising, cattle feeding, sheep feeding, and dairying. The following figures taken from the Iowa Monthly Crop Report of July 1, 1926, based on the January 1, 1926, estimates of the Division of Crop and Live Stock Estimates of the U. S. Department of Agriculture, show the extent of the live stock industry in the county:

| | |
|---|---|
| Horses | 12,800 |
| Mules | 1,200 |
| All cattle | 33,800 |
| Hogs | 81,600 |
| Sheep | 5,200 |

The raising of hogs is the principal livestock industry and on most farms, the sale of hogs provides the chief source of income. Generally the hogs are of mixed breeds, but in many cases pure bred herds are maintained. Duroc Jersey and Poland China are the most popular breeds. Other breeds of importance in the county are the Chester White and Hampshire. On January 1, 1926, there were 81,600 hogs in the county, which indicates the extent and importance of the industry.

The raising of beef cattle is not an important industry. The breeding herds are generally pure bred. The principal breeds of importance in the county are the Shorthorns, Aberdeen Angus, Herefords, and Polled Herefords. On January 1, 1926, there were 33,800 cattle in the county. This number, however, includes the dairy cattle which make up a large part of the total. Most of the cattle outside of the dairy herds are purchased in Chicago and Omaha as feeders and after a 60 or 90-day feeding period are sold on the market.



Dairying is practiced to some extent thruout the county. On most farms there is some surplus of dairy products which is sold, mainly in the form of cream, thru the local cream stations. The Holstein and Jersey are the leading dairy breeds in the county. There is no large income on the farms in general from the dairy industry, but in many cases dairying proves of considerable profit.

Horses and mules are raised to a very limited extent in the county, most of the horses being of the draft type. The Percheron is the favorite breed. Occasionally there is a farmer who specializes in raising draft horses.

On some farms where there is considerable rough land, the sheep industry has been developed. In general, however, there is not very much sheep raising in the county. Where sheep are fed, the feeders are bought on the Omaha and Sioux City markets, and after being pastured in the corn fields, are put on a fattening ration for a period of 40 to 60 days and then sold. The wool produced in the county is sold thru the County Wool Growers Association.

The raising of poultry has long been considered a side line on most farms, but in recent years the large profits which have been secured from poultry products have caused the industry to receive increased attention. The sale of poultry and eggs may add materially to the farm income. Most of the products are sold at the local markets and to local buyers.

## SOIL FERTILITY CONDITIONS IN GREENE COUNTY

In general the yields of the common farm crops grown in Greene County are quite satisfactory but, by the adoption of proper methods of soil treatment, profitable increases in the yields of these crops may frequently be secured. The needs of the various individual soil types which occur in the county are variable and they will be discussed in detail in a later section of this report. There are certain general recommendations, however, which may be mentioned here as they are of significance to the soils of Greene County as a whole.

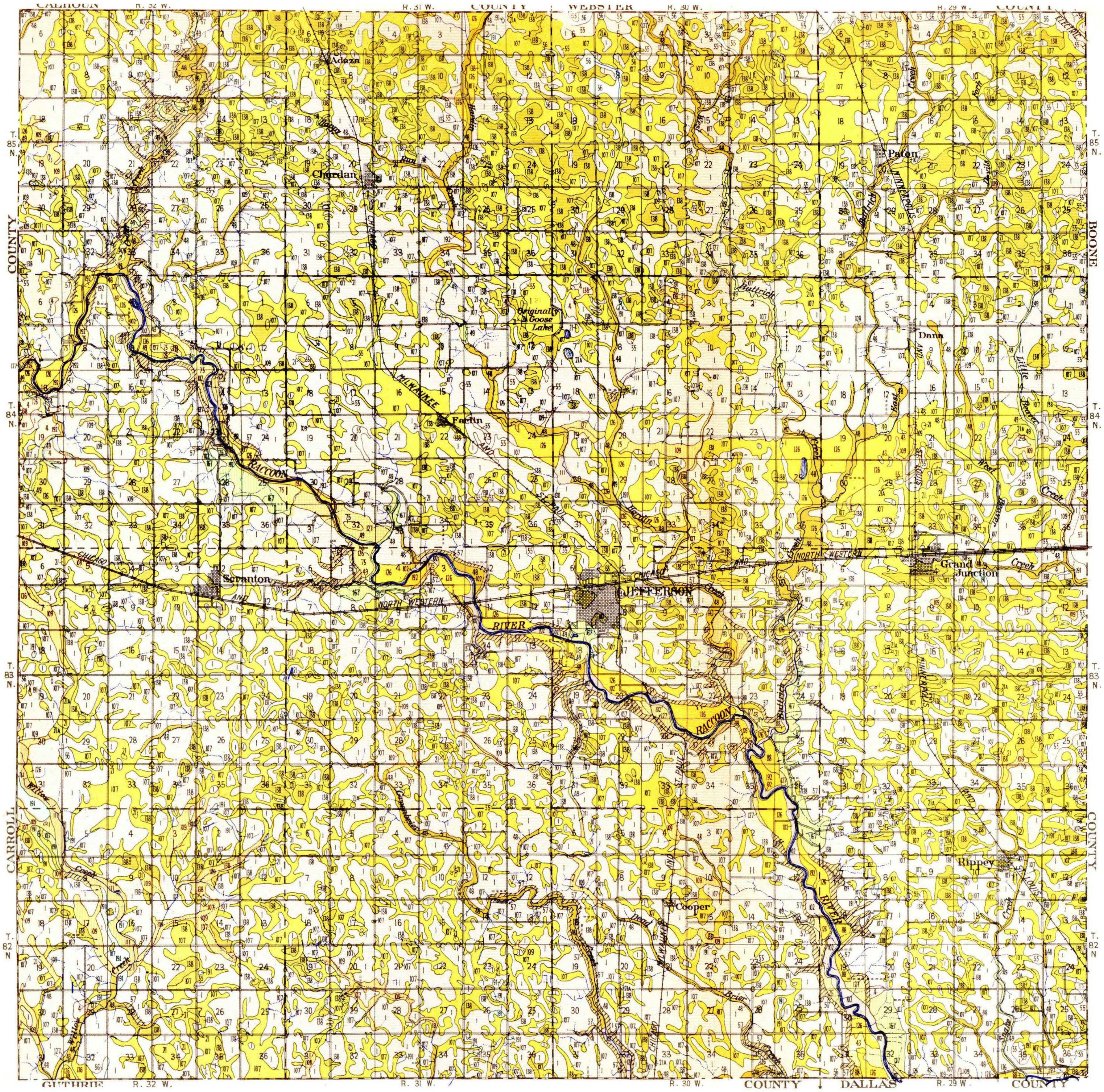
In the first place, emphasis should be placed upon the securing of adequate drainage conditions in the county. There are many areas where the soils are inadequately drained and crop yields are frequently poor because the soil is too wet. Wherever this is the case, the installation of tile would be valuable. The Webster soils on the uplands, the Fargo and Bremer soils on the terraces, and the Wabash and Lamoure soils on the bottoms, are all apt to be very seriously in need of drainage. On the upland and terrace types particularly, tiling would be very profitable. This is the first treatment needed by many of these soils, in order to secure a more satisfactory production of crops.

In common with most of the soils in the Wisconsin drift soil area, the various types in this county are very well supplied with organic matter as is indicated by their color, which, in many cases, is black. It has been found, however, by much experience and many experiments, that applications of farm manure which supplies much organic matter will bring about profitable increase in crop yields on many of these soil types. On the Carrington loam for instance, the most extensively developed upland soil in the county, additions of farm manure are particularly valuable. The same is true of the Clarion loam. On the Carrington fine sandy loam, the use of farm manure is very profitable and similarly on the Pierce sandy loam, and the Conover silt loam. Small applications are of value on the soils of the Webster series but in this case the manure should be applied in small amounts and should not be added just preceding the growing of a small grain crop, since there is danger of causing it to lodge. When the manure is applied properly, however, to these types, very profitable crop increases are often secured. On many of the terrace and bottomland soils, similar value from the application of manure has been noted.

In many cases the growing of legumes and turning them under as green manures will be of value on the soils of this county, especially when the supply of farm manure is limited. Green manuring is a substitute for the use of farm manure or as a supplement to that practice. All crop residues should, of course, be thoroly utilized on every farm in order to aid in maintaining the supply of organic matter. These various methods of supplying organic matter to the soil permit of considerable additions of plant food constituents. In the case of green manuring with legumes there may be a considerable increase in the nitrogen content of the soil and where farm manure and crop residues are thoroly utilized considerable proportions of the plant food constituents which have been removed from the soil by the crops grown, are returned to the land.

Many of the soil types in the county are acid in reaction, at least in the surface soil. In some cases the soils are well supplied with lime and where this is true, additions of lime are unnecessary. The soils should be tested regularly, however, to determine their reaction or lime requirements and lime should be applied as needed in order that the supply in the soil may be kept up. If the soil becomes acid, the most satisfactory yields of crops will not be secured and, in the case of legumes, the crop may often prove a failure. When the surface soil is strongly acid, additions of lime are very necessary for the best growth of legumes. Even when there is some lime in the subsoil, if the surface soil shows an acid reaction, it may be desirable to make a small application in order to provide for a vigorous early growth of a legume. The only way to determine the need of the soil for lime is to have it tested, and it is urged that the soils of Greene County, particularly the Carrington, Conover, Waukesha and Bremer types be tested regularly to determine whether or not lime should be added. The soil types of the Webster series on the uplands and some of the terrace and bottomland soils, while normally well supplied with lime, may sometimes be acid and additions of lime may be necessary. Tests should be carried out on these soils before legumes are grown.

None of the soil types in the county show any large content of phosphorus and it seems evident, therefore, that additions of a phosphate fertilizer would undoubtedly prove valuable in many cases. Experiments which have been carried out on some of the soil types found in this county have shown profitable effects from the application of a phosphate fertilizer. Both acid phosphate and rock phosphate have been used in many of these experiments and in some cases both of the fertilizers have shown results. In general, acid phosphate seems to be somewhat more economically profitable. While the rock phosphate often brings about as large increases in crop yields as the acid phosphate, the




# SOIL MAP OF GREENE COUNTY

Thomas D. Rice, Inspector, Northern Division. Soils Surveyed by A. W. Goke, in charge U. S. Dept. of Agriculture and C. L. Orrben, Iowa Agricultural Experiment Station.

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. C. F. Marbut, in charge Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in Charge

## LEGEND

*Drift Soils*

- 57 Carrington Loam, Steep Phase
- 1 Carrington loam
- 107 Webster silty clay loam
- 138 Clarion loam
- 55 Webster loam
- 167 Conover silt loam
- 4 Carrington fine sandy loam
- 56 Webster clay loam
- 191 Pierce sandy loam

*Terrace Soils*

- 126 O'Neill sandy loam
- 109 Fargo silty clay loam
- 75 Waukesha silt loam
- 127 Waukesha sandy loam
- 43 Bremer silty clay loam
- 88 Bremer silt loam

*Swamp and Bottomland Soils*

- 48 Wabash silty clay loam
- 102 Sarpy fine sandy loam
- 49 Wabash loam
- 21 Peat
- 192 Wabash very fine sandy loam
- 111 Lamoure silty clay loam
- 21A Muck

Scale: 1 inch 2½ Miles

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greater cost involved in applying one ton of rock phosphate in the four-year rotation compared with 600 to 800 pounds of acid phosphate per four-year rotation means that the application of the rock phosphate will be apt to show less money value. It is impossible to make a definite choice between the two phosphates for all conditions. It is urged, therefore, that both be tested on individual farms in this county to determine which will prove the more profitable under the particular conditions. For quick returns and the determination of the response of the soil to applications of phosphorus, the use of acid phosphate is recommended. When a soil has definitely been shown to be in need of a phosphate fertilizer, then rock phosphate may often be applied to advantage, it being understood that the value of the rock phosphate will not necessarily appear during the first season. In fact in most cases the increases in crop yields from rock phosphate are much greater in the second season and may persist for several seasons following.

Experiments have been carried out with complete commercial fertilizers, comparing their effect with the effect of the use of acid phosphate on some of the soils in the county and while quite as large crop increases are secured in many cases from the complete fertilizers, their greater cost means that the application has been less economically profitable. Complete fertilizers are not believed to be needed in general in Greene County, as in many instances acid phosphate seems to prove quite as valuable in increasing crop yields. The soils are generally well supplied with total potassium and if nitrogen is deficient it may be added to the soils by the proper use of farm manure and the turning under of inoculated leguminous crops as green manures. Hence it would seem that the phosphorus supplied by the complete fertilizer is the chief reason for its value and that acid phosphate would probably be more desirable for general use. Tests of complete commercial fertilizers may readily be carried out on any individual farms and farmers who are interested are urged to test these materials on a small scale in comparison with acid phosphate before purchasing in quantities for application to considerable areas.

Commercial nitrogenous fertilizers are certainly not needed on the soils of the county in general. It would seem that the use of leguminous crops as green manures would prove a cheaper and better source of nitrogen for such soils as may be deficient in this element. The thoro utilization of farm manure, the turning under of legumes as green manures, and the return of all crop residues to the soil, will permit of the maintenance of the nitrogen content of the soils of this county.

Commercial potassium fertilizers may be of value in some isolated cases in the county but their general use cannot be recommended at the present time. The soils are well supplied with potassium and, if it is made available rapidly enough, crops should be adequately provided with this element. Farmers who are interested may test these fertilizers, making the application of the potassium fertilizer along with acid phosphate and comparing with acid phosphate used alone.

Erosion occurs on some areas in the county, the Carrington loam, steep phase, occupying most of the eroded land. There is some surface washing, however, in areas of the Carrington loam, the Clarion loam, the Pierce sandy loam and the Carrington fine sandy loam. In general erosion is not a serious problem in the county, but where it does occur, methods should be adopted to prevent the further washing away of the surface soil and the formation of gullies, or to reclaim land which has already been injured by the destructive action. Suggestions are offered later in this report, for the control and prevention of erosion and some one of these suggestions may be put into operation under any particular conditions.

## THE GEOLOGY OF GREENE COUNTY

The soils of Greene County have been derived mainly from the deposits made during the glacial age. It is unnecessary, therefore, to consider the geological history of the county except as it involves the glacial period. The bedrock is so deeply buried by the debris left by the glaciers, that it has no effect upon the soils of the county.

During the glacial age at least two great ice sheets swept over the county and each, upon its retreat, left behind a vast deposit of glacial till or debris. The earlier deposits have been very largely carried away by the later glaciers. The topographic characteristics of the county which were undoubtedly established following the early glaciation were very largely obliterated by the action of the succeeding ice sheets.

The first ice sheet of which there is definite evidence is known as the Kansan. This glacier left behind a deposit of drift material consisting mainly of a mixture of blue clay, containing numerous pebbles, boulders and shale fragments, and frequently much sand and gravel. The depth of this deposit was extremely variable ranging from a few feet in certain areas to many feet in other locations where valleys or depressions had previously occurred in the uplands. Thru weathering the Kansan drift material has changed in color to a yellow or red and by the addition of organic matter it has become somewhat darker. The soils of the county are influenced to only a very small extent by this early glacial deposit. The Conover soils are sometimes considered to be derived in part at least from the Kansan drift. The Pierce soils, too, may be partly Kansan in origin but these types are mostly formed by the terminal moraine of the glacier.

The next and last ice sheet which invaded the county is known as the Wisconsin glacier. This ice sheet covered the entire county with a thick layer of glacial drift material. The deposit, in its unweathered condition, is a bluish-drab to bluish-gray in color, changing to a yellow or buff when slightly weathered. It consists of a mixture of clay, sand, gravel and boulders. During the years which have elapsed since its deposition various weathering agencies have acted upon it, there has been an accumulation of organic matter, a certain amount of leaching has occurred and the present upland soils in the county are derived practically entirely from this later drift as modified by weathering and plant growth. The upland types of the Webster series have been developed from the glacial drift under conditions of inadequate drainage. They are very dark in color and the lime content is high in the subsoil and frequently in the surface soil. There has been a particularly large accumulation of organic



matter in these soils and very little leaching. The upland types of the Carrington and Clarion series have been developed in the better drained areas. The surface soils of these types are dark brown to black in color, the drainage conditions are better than in the case of the Webster soils and there has been a smaller accumulation of organic matter and more leaching. In most cases all of the lime has been carried away in the drainage water and only in the Clarion soils is there any lime left ever in the subsoil.

The soils on the second bottomlands or terraces and those developed along the various drainageways of the county on the bottoms have been formed from the glacial drift which has been washed down by the streams, reworked and redeposited. They possess many of the characteristics of the upland types, and are uniformly dark in color, and occasionally high in lime content. This is the case with the Fargo silty clay loam on the terraces and the Lamoure silty clay loam on the bottoms. The Bremer soils on the terraces are heavy and black in color with impervious subsoils but they contain no lime. The O'Neill soils have a sandy to gravelly subsoil, and show no lime content. The Waukesha types are lighter in

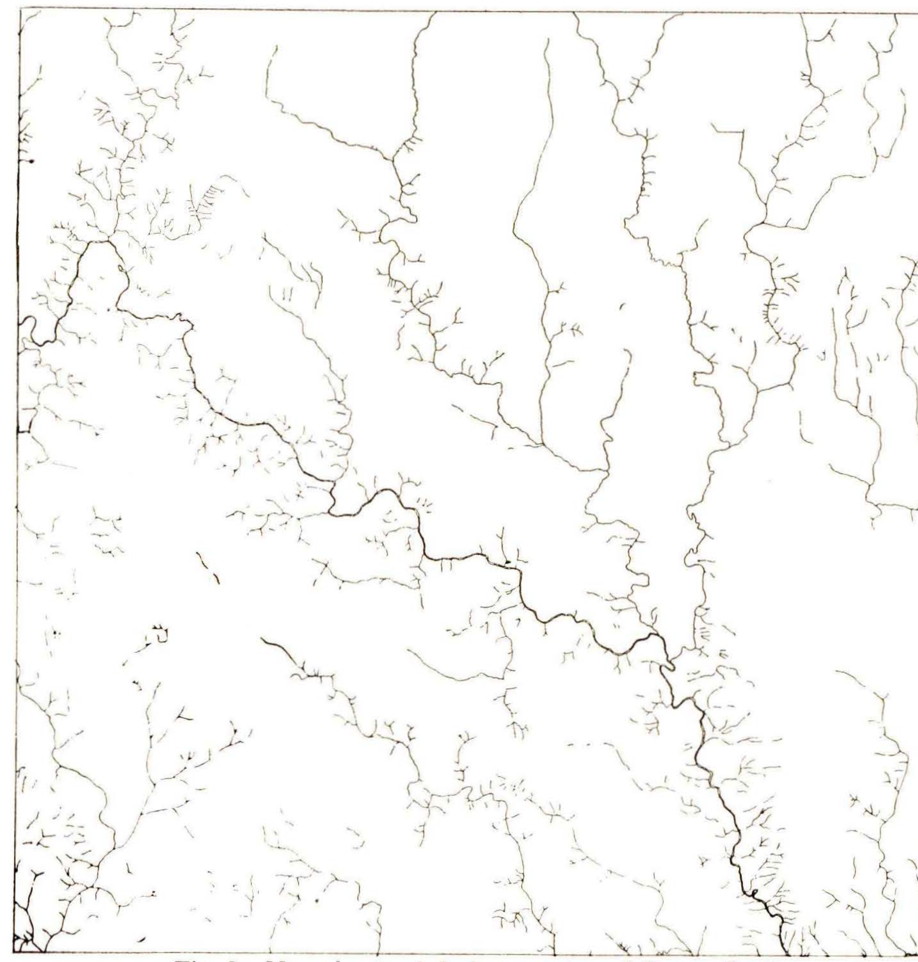

Fig. 2. Map of natural drainage system of Greene County.

texture in the subsoil than the Bremer soils and hence better drained. They do not contain lime. On the bottoms, the Wabash soils are heavy in texture and particularly heavy in the subsoil but they are poorly drained and lacking in lime content. Drainage conditions on all the heavy bottomland soils are generally very poor.

## PHYSIOGRAPHY AND DRAINAGE

In general the topographic features of Greene County are entirely characteristic of the conditions thruout the Wisconsin drift soil area. Little relief is evidenced on the uplands, the general topography being gently undulating to slightly rolling in areas of the Clarion and Carrington soils and level to flat or depressed where the Webster soils occur. The surface of the upland is dotted with these depressed areas where the Webster types are found and with some areas of peat and muck. Along some of the intermittent drainageways there are depressed areas of the Fargo silty clay loam.

Low, inconspicuous knobs and swells occur in those areas which have been formed at the edge of the glacier, in what is known as the terminal moraine. Here occur the areas of the Pierce soils. These gravelly knobs form the most conspicuous topographic features of the county.

Very little erosion has occurred and only along the larger streams has there been any cutting by the stream waters. Here, narrow, gorge-like valleys have been formed. The bottomlands are narrow and subject to overflow. Along the smaller streams the valleys are wider but they too are flooded at periods of heavy rainfall.

Terrace or second bottomlands are found along most of the streams in the county. They vary in width from one-half to one-eighth of a mile and extend for long distances along the larger streams, but they are small and irregular in distribution along the smaller creeks and tributaries.

The drainage of the county is brought about mainly by the Raccoon River and its various tributaries. This river flows diagonally across the county from northwest to southeast. With its most extensive tributaries, Hardin Creek and Buttrick Creek, and with numerous other minor tributaries, it takes care of the drainage of the central and northern parts of the county. The southwestern part of the county is drained by Willow and Green Brier Creeks, while east of the Raccoon River, Snake Creek takes care of the drainage in the southeastern corner of the county.

Over much of the county the natural drainage system is quite adequate. In rather extensive areas in many parts of the county, however, the natural drainage is not sufficient. This lack of drainage is particularly evidenced in Highland, Dawson and Paton Townships in the northern part of the county. Here there are extensive areas of the Webster silty clay loam which is naturally a poorly drained soil. Considerable areas of this type are also found in Bristol township. In the southern part of the county there are many areas of poorly drained land of this particular type and of other types of the Webster series. Much of the land on the terraces and bottoms in the county is likewise improperly drained.



The natural drainage system of the country is shown on the accompanying map. It is quite evident that there are many areas where artificial drainage is necessary. Wherever there are areas of the various types of the Webster series on the uplands, areas of the Fargo silty clay loam or of the Bremer soils on the terraces or areas of the Lamoure or Wabash series or of peat and muck on the bottomlands it is certain that artificial drainage will prove of value, if tile has not already been installed. As all these soils are naturally poorly drained, and as they occur extensively, it is quite evident that the adequate drainage of much of the land in Greene County is the first treatment that is needed for the production of satisfactory crops.

# THE SOILS OF GREENE COUNTY

The soils of Greene County are grouped into three classes according to their origin and location. These are drift soils, terrace soils, and swamp and bottomland soils. Drift soils are formed from the material carried by glaciers and deposited on the surface of the land when the glacier retreated. Such soils are quite variable in composition and usually contain pebbles and frequently boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a depression in the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The extent and occurrence of these groups of soils in Greene County are shown in table II.

Almost nine-tenths of the county, 89.6 percent, is covered by drift soils. There are comparatively small areas of terrace soils and swamp and bottomland soils. Each of these groups covers 5.2 percent of the total area of the county. They occur along the various streams and tributaries in numerous small areas varying widely in shape and size.

There are 19 individual soil types in the county and these with the steep phase of the Carrington loam and the areas of peat and muck, make a total of 22 soil areas. There are eight drift soils and with the steep phase of the Carrington loam, nine areas mapped under the heading drift soils. There are six terrace types and seven areas of swamp and bottomland soils including the areas of peat and muck. The various soil types in these groups are distinguished on the basis of certain definite characteristics which will be described later in this report. The names which are given to these soil types indicate particular characteristics. The areas covered by the individual soil types in the county are given in table III.

The Carrington loam is by far the most extensive individual soil type.

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN GREENE COUNTY

| Soil Group | Acres | Percent |
|---|---|---|
| Drift soils | 329,472 | 89.6 |
| Terrace soils | 18,944 | 5.2 |
| Swamp and bottomland soils | 18,944 | 5.2 |
| Total | 367,360 | ---- |

With the steep phase, which is of very minor importance, this type covers over half the area of the county, 53.5 percent. The Webster silty clay loam is the second most extensive soil type. It covers over one-quarter of the total area of the county, 26.2 percent. The Clarion loam is the third most extensive type, covering 7.1 percent of the county.

The remainder of the individual soil types in the county are all much smaller in extent. The Wabash silty clay loam, the most extensive bottomland soil, is next in area, covering 2.4 percent of the county. The O'Neill sandy loam, the most extensive terrace type, comes next, covering 2.2 percent of the county. Then follows the Fargo silty clay loam, the second largest terrace soil which covers 1.5 percent of the county. The Webster loam which is next in extent in the county and the fourth drift soil in area, covers 1.2 percent of the county. The remaining types all cover less than one percent of the total area of the county. There are small areas mapped of the Conover silt loam, the Carrington fine sandy loam, the Webster clay loam and the Pierce sandy loam on the uplands, areas of the Waukesha silt loam and sandy loam and of the Bremer silty clay loam and silt loam on the terraces and areas of the Sarpy fine sandy loam, Wabash loam and very fine sandy loam, Lamoure silty clay loam and peat and muck on the bottoms.

There are certain definite relationships between the topographic conditions and the occurrence of the individual soil types. On the uplands the Webster soils are found on the level to flat or depressed areas. The other upland types of the Carrington, Clarion and Conover series, are found on the more rolling

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN GREENE COUNTY

| Soil No. | Soil type | Acres | Percent of total area of county |
|---|---|---|---|
| | DRIFT SOILS | | |
| 1 | Carrington loam | 189,120 } | 53.5 |
| 57 | Carrington loam (steep phase) | 7,296 } | |
| 107 | Webster silty clay loam | 96,320 | 26.2 |
| 138 | Clarion loam | 26,240 | 7.1 |
| 55 | Webster loam | 4,288 | 1.2 |
| 167 | Conover silt loam | 2,496 | 0.7 |
| 4 | Carrington fine sandy loam | 1,344 | 0.3 |
| 56 | Webster clay loam | 1,344 | 0.3 |
| 191 | Pierce sandy loam | 1,024 | 0.3 |
| | TERRACE SOILS | | |
| 126 | O'Neill sandy loam | 7,936 | 2.2 |
| 109 | Fargo silty clay loam | 5,632 | 1.5 |
| 75 | Waukesha silt loam | 2,112 | 0.6 |
| 127 | Waukesha sandy loam | 1,920 | 0.5 |
| 43 | Bremer silty clay loam | 704 | 0.2 |
| 88 | Bremer silt loam | 640 | 0.2 |
| | SWAMP AND BOTTOMLAND SOILS | | |
| 48 | Wabash silty clay loam | 8,832 | 2.4 |
| 102 | Sarpy fine sandy loam | 2,432 | 0.7 |
| 49 | Wabash loam | 2,112 | 0.6 |
| 21 | Peat | 2,048 | 0.5 |
| 192 | Wabash very fine sandy loam | 1,728 | 0.5 |
| 111 | Lamoure silty clay loam | 960 | 0.3 |
| 21a | Muck | 832 | 0.2 |
| | Total | 367,360 | ---- |



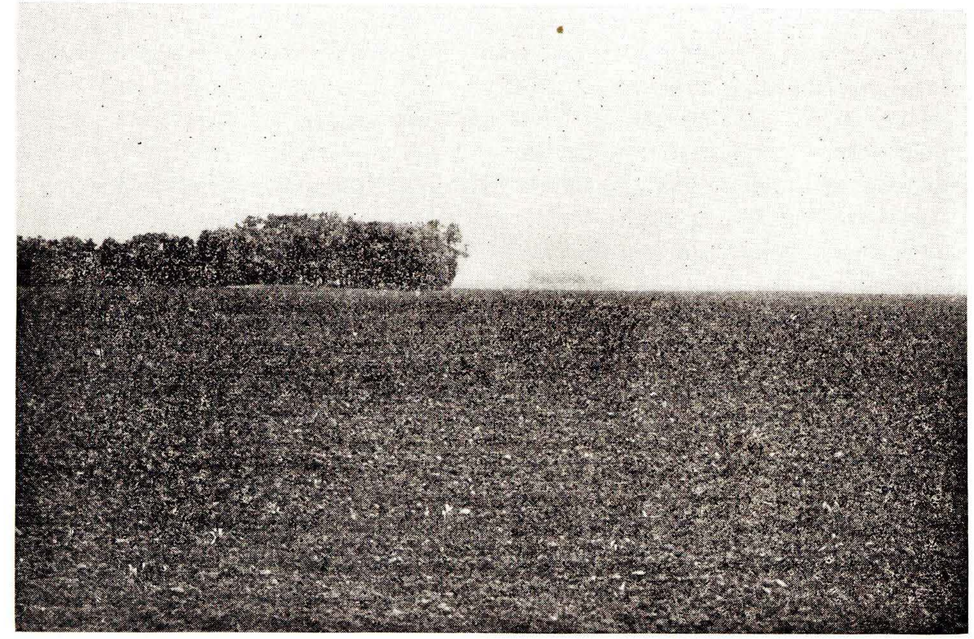

Fig. 3. Flat areas of Webster soils show knolls of Clarion loam or Carrington loam.

areas or high ridges in the uplands. The Pierce sandy loam occurs in knob-like areas in the uplands, being made up largely of gravelly material.

The steep phase of the Carrington loam as indicated in the name is rather abrupt in topography and on this type considerable erosion has occurred. On the terraces the Fargo and Bremer soils are found on the very level to depressed areas while the O'Neill and Waukesha types occur on the higher lands and are frequently slightly undulating in topography. On the bottoms the topographic features are, of course, not developed, most of the areas being level to flat in topography.

## THE FERTILITY IN GREENE COUNTY SOILS

Samples were taken for analysis from each of the soils in the county except the steep phase Carrington loam and the Pierce sandy loam on the drift uplands. These types were not sampled because of their small extent and because of the fact that they are of little importance agriculturally. Furthermore the variable character of these soils would make an analysis of questionable value. The areas of peat and muck were not sampled as many analyses have been made of these materials and there is so much variation in them with regard to depth and extent of decomposition, and the materials are so uniform in composition, that further analyses seem unnecessary.

The more extensive soil types were sampled in triplicate but only one sample was taken from each of the minor types. The greatest care was exercised in sampling to be sure that the samples would represent accurately the particular soil type. It is particularly desirable that such samples be taken from areas which have not been differentiated from the general run of the type by special methods of treatment. Samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches representing the surface soil, the subsurface soil and the subsoil respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were followed in the determination of the phosphorus, nitrogen and carbon and the Truog qualitative test was used in determining the limestone requirements. The figures given in the tables are the averages of the results of duplicate determinations of 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 two million pounds of surface soil per acre.

The various soil types in the county show considerable variation in content of total phosphorus. The amount of this element ranges from 767 pounds in the Conover silt loam up to 1,966 pounds in the Fargo silty clay loam. No relationship appears between the phosphorus content of the soils and the particular soil groups, although the averages of the various types analyzed would show that the terrace soils and the swamp and bottomland soils are somewhat better supplied with this element than the upland drift types. This might be expected from the fact that the terrace and bottomland soils have been less extensively cultivated and there has, therefore, been a smaller removal of the plant food elements thru cropping.

Some interesting correlations are shown, however, among the various soil series

TABLE IV. PLANT FOOD IN GREENE COUNTY, IOWA, SOILS
Pounds per acre of 2 million pounds of surface soil (0-6 2/3")

| Soil No. | Soil type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 1 | Carrington loam | 1,166 | 4,613 | 54,953 | ------ | 2,500 |
| 107 | Webster silty clay loam | 1,508 | 7,140 | 74,803 | 41,690 | ----- |
| 138 | Clarion loam | 1,091 | 4,120 | 49,050 | ------ | 3,000 |
| 55 | Webster loam | 781 | 4,360 | 52,226 | 2,234 | ----- |
| 167 | Conover silt loam | 767 | 2,120 | 30,520 | ------ | 5,000 |
| 4 | Carrington fine sandy loam | 929 | 2,300 | 29,975 | ------ | 2,000 |
| 56 | Webster clay loam | 1,522 | 7,880 | 96,465 | ------ | ----- |
| | TERRACE SOILS | | | | | |
| 126 | O'Neill sandy loam | 1,306 | 4,040 | 51,602 | ------ | 4,000 |
| 109 | Fargo silty clay loam | 1,966 | 8,360 | 102,124 | 13,959 | ----- |
| 75 | Waukesha silt loam | 1,616 | 3,720 | 46,325 | ------ | 2,000 |
| 127 | Waukesha sandy loam | 808 | 2,680 | 33,354 | ------ | 2,000 |
| 43 | Bremer silty clay loam | 1,549 | 6,320 | 82,295 | ------ | 1,000 |
| 88 | Bremer silt loam | 1,064 | 5,000 | 71,122 | ------ | 2,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 48 | Wabash silty clay loam | 1,495 | 6,880 | 87,775 | ------ | 1,000 |
| 102 | Sarpy fine sandy loam | 1,266 | 1,440 | 16,255 | 4,727 | ----- |
| 49 | Wabash loam | 1,239 | 3,840 | 51,775 | ------ | 2,000 |
| 192 | Wabash very fine sandy loam | 1,589 | 5,000 | 58,315 | ------ | 2,000 |
| 111 | Lamoure silty clay loam | 1,441 | 7,400 | 76,579 | 16,071 | ----- |



and soil types. Thus, on the average, the soils of the Webster series on the uplands are better supplied than the Carrington, Clarion or Conover soils. On the terraces, the Fargo soils are the best supplied with the element phosphorus. On the bottomlands, the amounts of the element present are very much the same in all the soil series. Comparing the various types in the individual series it will be noted that the Webster silty clay loam and clay loam are much better supplied with phosphorus than the Webster loam. The Carrington loam is better supplied than the Carrington fine sandy loam. The Bremer silty clay loam is much higher in the element than the Bremer silt loam. The Waukesha silt loam contains twice as much phosphorus as the Waukesha sandy loam. The Wabash silty clay loam is higher in phosphorus content than the Wabash loam. The very fine sandy loam of this series is, however, higher even than the Wabash silty clay loam, probably due to some abnormal condition in this particular soil, or the particular sample which was analyzed.

In general it seems from these analyses that there is a rather definite relationship between the phosphorus content of the soils and the characteristics which serve as a basis for distinguishing the various soil series and soil types. These characteristics include topography, color, subsoil character, and texture. It seems that those soils which are level to flat or depressed in topography, blacker in color, with heavier subsoil conditions, and heavier in texture are general-
richer in phosphorus than those which are more rolling in topography, lighter
ly richer in phosphorus than those which are more rolling in topography, lighter in color, with lighter textured or more open subsoils and lighter in texture in the surface soil. Occasionally there are some exceptions to this general rule as has been noted in the case of the Wabash very fine sandy loam. The general conclusions which have been drawn from the analyses of the soils of this county are, however, borne out by the analyses of the soils in many other counties, where comparisons have been made of the phosphorus content of various soil types.

Considering the analyses of the soils of the county in general, it is apparent that there is no large content of phosphorus and certainly the supply is inadequate to meet the needs of crops for any considerable number of years. When the supply of phosphorus in the soil goes as low as is the case in many of the types in this county, it is quite reasonable to conclude that there will be an insufficient supply of available phosphorus to meet the needs of crops. It would seem, therefore, that phosphorus fertilizers would undoubtedly prove of value on many of these soils at the present time. Indeed the evidence from the greenhouse experiments and certain field tests on some of these types in other counties points to the fact that the use of certain phosphorus fertilizers on the soils of this county may be attended with considerable profit. These experiments will be referred to later in this report.

While the nitrogen content of the soils of this county is much higher than the content of phosphorus there is quite as wide a range in the total amount present. The Sarpy fine sandy loam on the bottoms contains 1,440 pounds of total nitrogen. This is the most poorly supplied type in the country. The Fargo silty clay loam on the terraces shows a content of 8,360 pounds per acre. This is the highest content of nitrogen in any of the soil types. Again there is no relationship between the nitrogen content of the various soils and the soil groups. On the average the drift soils are a little bit lower in content of this constituent than the other soil groups. The difference is not significant and may be attributed entirely to the fact that there has been less plant growth on the terrace and bottomland soils and hence a smaller removal of nitrogen.

The relationships among the various soil series and soil types are quite definite. Thus on the drift uplands the soils of the Webster series are, on the average, higher in nitrogen than the soils of the other series represented. On the terraces, the Fargo soils are better supplied than the other types, the Bremer types coming next and the Waukesha and O'Neill soils being about the same. On the bottomlands, the Wabash and Lamoure soils are higher than the Sarpy type, the Lamoure being somewhat better supplied with nitrogen than the Wabash soils.

Textural differences in the individual types are directly related to the nitrogen content of the soil. Thus the Webster silty clay loam and the clay loam are much better supplied than the loam. The Carrington loam is very much higher than the fine sandy loam. The Waukesha silt loam is higher than the sandy loam of the same series and the Bremer silty clay loam is much higher than the Bremer silt loam. The Wabash silty clay loam is higher than the loam and very fine sandy loam. The latter is somewhat better supplied than the loam probably due to some abnormality in this particular soil type or sample.

The various characteristics which serve to determine the soil series and the variations in texture of soils within series may be correlated with the nitrogen content of the soils. Those soils which are darker in color, level to depressed in topography and with heavier textured subsoils are better supplied with nitrogen than the more rolling types, light in color with lighter textured subsoils. These correlations are very evident in the case of the Webster soils on the drift upland. They are also shown with the Fargo and Bremer types on the terraces and with the Lamoure and Wabash soils on the bottoms. Soils which have a finer texture such as the silty clay loams and clay loams are better supplied with nitrogen than the coarser textured soils such as loams and sandy loams. This effect of texture is shown upon comparing the Webster clay loam and silty clay loam with the Webster loam. Similarly in the case of the Waukesha silt loam and the sandy loam the relationship is clearly shown, as well as the comparison of the Bremer silty clay loam and the silt loam. Previous conclusions are very largely confirmed by the data presented, showing the relationship between color, topography, subsoil character, surface soil texture and the nitrogen content of soils.

While the supply of nitrogen in most of the soils in this county seems to be large enough to supply the needs of many crops, this element must be considered when systems of permanent fertility are planned for the county. It is very important that the amount of nitrogen in the soils be kept up if the supply is to be adequate for future crop growth. The large removal of this element by crop growth and by removal of the soluble nitrates in drainage water makes it evident that a return of some fertilizing material supplying nitrogen must be included as an essential part of any system of permanent agriculture. In a few cases, it would seem desirable to add nitrogen to the soils now.



The most common and most satisfactory means of adding nitrogen to the soil is by the use of farm manure. By the proper preservation and application of the manure produced on the farms, a very large part of the nitrogen removed by the crops grown may be returned to the land. Crop residues when thoroly incorporated with the soil also return a considerable amount of nitrogen and thus aid in the maintenance of the supply of this constituent. It is rarely possible, however, to keep up the content of nitrogen in the soil by the use of farm manures and crop residues alone. The use of certain legume crops as green manures is a most important farm practice from the standpoint of maintaining and increasing the nitrogen supply in the soil. When legumes are well inoculated and turned under in the soil there is a considerable addition of nitrogen to the land. Green manuring also supplies considerable amounts of organic matter and the practice is one which may be very desirable in many cases as a supplement to farm manuring or as a substitute for that practice. By the proper use of leguminous crops as green manures and the thoro utilization of all farm manure and crop residues it is possible to keep up the nitrogen content of the soils of this county without having recourse to expensive commercial nitrogenous fertilizers.

The total organic carbon present in the soils in Greene County is somewhat variable ranging from 16,255 pounds in the Sarpy fine sandy loam up to 102,124 pounds in the Fargo silty clay loam. It may be noted that these are the same types which showed the lowest and highest content of nitrogen respectively.

In general the relationship among the various soils and their content in organic carbon is very much the same as that noted in the case of nitrogen. Thus the Webster soils on the drift uplands are better supplied than the other upland types. The Fargo and Bremer soils are better supplied than the other soils on the terraces, while the Wabash and Lamoure types are the richest in organic carbon among the soils on the bottoms. The effects of differences in texture are very much the same as were noted in the case of the nitrogen content. The heavier textured soils are much better supplied with organic carbon, in general, than the light textured types. This is evidenced by comparing the various Webster soils on the uplands, the Waukesha and Bremer types on the terraces and the Wabash soils on the bottoms. The same factors which have been mentioned before seem to play a very important part in determining the total content of organic carbon in these soils. Those types which are level in topography, black in color, with heavier-textured, impervious subsoils and fine textured surface soils are the richest in organic carbon or organic matter, just as was noted in the case of nitrogen and phosphorus.

It would seem that the soils of this county are fairly well supplied with organic matter, but again, it must be emphasized that any system of permanent agriculture must provide for the return to the soil of sufficient organic matter to keep up the supply. Even where the content is considerable there may be a very rapid loss under continued cultivation and the growing of general farm crops and the addition of fertilizing materials supplying organic matter is very necessary. In those cases where the content of organic carbon is low, additions of organic matter are particularly necessary.

The means which may be employed on the farms, to build up and keep up the supply of organic matter, include the use of farm manure, properly preserved and applied, the turning under of all crop residues and the utilization of leguminous crops as green manures. By these means the soils of the county need never become deficient in organic matter.

Farmers should see to it that all the farm manure produced is properly preserved and applied to their land, that all crop residues are utilized and that legumes are turned under as green manures to supplement the use of farm manure or as a substitute for that material if their soils are to be most highly productive.

The beneficial effects of farm manure on the soils of the county are well known. Data given later in this report show how great the benefits may be. It is certainly the best and most effective fertilizing material which can be used.

The relationship between the nitrogen content in the soil and the amount of organic matter or organic carbon indicates the rapidity with which various plant food constituents in the soil are being changed into an available form for plant use. In some of the soils in Greene County there is evidence that the decomposition processes are not proceeding as rapidly as they should and often there is undoubtedly too small a production of available plant food to supply the needs of crops. This condition is particularly evident in the Webster silty clay loam and the Clarion loam on the uplands. Several of the other upland types do not permit as rapid a production of available plant food as would be desirable. Some of the terrace and bottomland types are likewise apparently deficient in the proper bacterial processes to supply available plant food.

In all such cases the application of farm manure is particularly valuable because this material introduces large numbers of micro-organisms into the soil which bring about rapid decomposition of mineral plant food and the production of a greater supply of available food materials. Crop production may then be considerably enhanced. The application of small quantities of farm manure even to those soils which are black in color and high in organic matter may often be of considerable value because of this increase in the production of available plant food. Farm manure should not be applied to such soils preceding the growing of small grain crops since there is danger that it may cause them to lodge, but small amounts applied at other places in the rotation may prove of considerable value.

Five of the soil types in the county show some total inorganic carbon in the surface soil. The Webster silty clay loam and Webster loam on the drift uplands show a high inorganic carbon content. The Fargo silty clay loam on the terraces and the Sarpy fine sandy loam and Lamoure silty clay loam on the bottoms are also well supplied with inorganic carbon. The content of mineral carbonate in these soil types is related to the characteristics which determine the particular soil series into which the soils are grouped. Thus it is characteristic of the Webster, Fargo, Sarpy and Lamoure series to show a content of lime.



TABLE V. PLANT FOOD IN GREENE COUNTY, IOWA, SOILS
Pounds per acre of 4 million pounds of subsurface soil (6 2/3″-20″)

| Soil No. | Soil type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 1 | Carrington loam | 1,678 | 6,266 | 66,671 | ------ | 3,330 |
| 107 | Webster silty clay loam | 1,979 | 4,600 | 58,254 | 63,281 | ----- |
| 138 | Clarion loam | 1,858 | 6,400 | 73,575 | ------ | ----- |
| 55 | Webster loam | 1,480 | 4,400 | 50,671 | 8,189 | ----- |
| 167 | Conover silt loam | 1,454 | 2,160 | 23,435 | ------ | 7,000 |
| 4 | Carrington fine sandy loam | 2,046 | 4,160 | 45,780 | ------ | 2,000 |
| 56 | Webster clay loam | 2,128 | 4,640 | 65,771 | 14,889 | ----- |
| | TERRACE SOILS | | | | | |
| 126 | O'Neill sandy loam | 2,612 | 4,776 | 53,464 | ------ | 2,000 |
| 109 | Fargo silty clay loam | 4,876 | 12,400 | 176,370 | 16,750 | ----- |
| 75 | Waukesha silt loam | 1,778 | 6,000 | 60,495 | ------ | 2,000 |
| 127 | Waukesha sandy loam | 1,938 | 6,800 | 84,257 | ------ | 2,000 |
| 43 | Bremer silty clay loam | 3,016 | 10,400 | 132,435 | ------ | 1,000 |
| 88 | Bremer silt loam | 1,238 | 2,760 | 51,230 | ------ | 2,000 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 48 | Wabash silty clay loam | 1,938 | 4,360 | 68,125 | ------ | 1,000 |
| 102 | Sarpy fine sandy loam | 2,262 | 2,240 | 27,540 | 1,890 | ----- |
| 49 | Wabash loam | 1,966 | 4,800 | 59,405 | ------ | 2,000 |
| 192 | Wabash very fine sandy loam | 2,478 | 5,600 | 66,490 | ------ | 2,000 |
| 111 | Lamoure silty clay loam | 2,478 | 5,600 | 73,487 | 20,798 | ----- |

These soils are usually characterized only by a high lime content in the subsoil, as is the case with the Webster clay loam and Clarion loam in this county but in

TABLE VI. PLANT FOOD IN GREENE COUNTY, IOWA, SOILS
Pounds per acre of 6 million pounds of subsoil (20″-40″)

| Soil No. | Soil type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 1 | Carrington loam | 2,261 | 4,520 | 50,139 | ------ | 1,666 |
| 107 | Webster silty clay loam | 3,070 | 2,280 | 32,587 | 140,985 | ----- |
| 138 | Clarion loam | 2,424 | 5,640 | 50,840 | 39,085 | ----- |
| 55 | Webster loam | 2,424 | 3,960 | 41,524 | 75,387 | ----- |
| 167 | Conover silt loam | 1,938 | 2,640 | 23,707 | ------ | 8,000 |
| 4 | Carrington fine sandy loam | 1,857 | 1,080 | 17,985 | ------ | 2,000 |
| 56 | Webster clay loam | 3,150 | 1,860 | 30,052 | 133,448 | ----- |
| | TERRACE SOILS | | | | | |
| 126 | O'Neill sandy loam | 3,798 | 1,920 | 23,707 | ------ | 500 |
| 109 | Fargo silty clay loam | 4,566 | 4,680 | 107,910 | ------ | ----- |
| 75 | Waukesha silt loam | 2,586 | 4,812 | 49,050 | ------ | 500 |
| 127 | Waukesha sandy loam | 2,424 | 6,600 | 89,925 | ------ | 500 |
| 43 | Bremer silty clay loam | 3,636 | 8,100 | 108,727 | ------ | 1,000 |
| 88 | Bremer silt loam | 1,656 | 2,040 | 29,430 | ------ | 500 |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 48 | Wabash silty clay loam | 2,463 | 3,240 | 58,860 | ------ | 1,000 |
| 102 | Sarpy fine sandy loam | 2,826 | 960 | 24,203 | 3,592 | ----- |
| 49 | Wabash loam | 2,139 | 3,000 | 44,145 | ------ | 1,000 |
| 192 | Wabash very fine sandy loam | 3,837 | 6,600 | 77,489 | ------ | 1,000 |
| 111 | Lamoure silty clay loam | 2,706 | 3,960 | 51,219 | 14,181 | ----- |

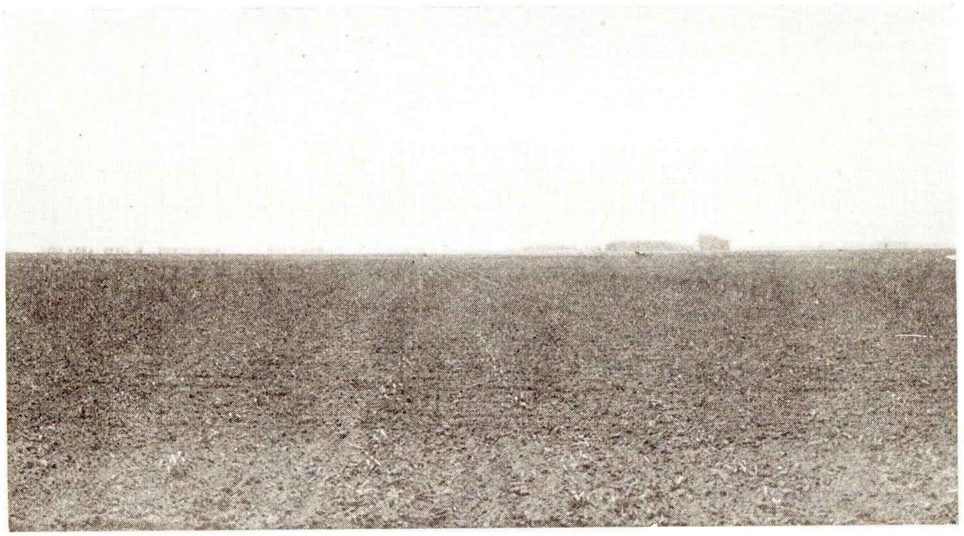

Fig. 4. Level areas of Webster silty clay loam.

all the other types of the series mentioned, the lime content is present also in the surface soil.

In all the other types in the county there is no content of inorganic carbon in the surface soil and they are acid in reaction as shown by the lime requirement test and are, therefore, in need of applications of lime. Even the Clarion loam and Webster types might possibly respond to an application of lime as the surface soils are usually acid. Especially would this be true in case a legume were to be seeded on these soils.

The amount of lime which is needed for the various soil types in the county is indicated in the table but the figures should be considered to show only roughly the needs of the particular soils. There is such a wide variation in the lime content of various soils even within the same type that it is necessary to test every soil or the soil in every field for acidity before an application of lime is made. It is important from the standpoint of the best crop production and the permanent fertility of the soils of Greene County, that all the types except the Fargo, Sarpy and Lamoure, be tested for acidity or lime requirement and that lime be applied as needed.

### 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 lbs. of subsurface soil and 6,000,000 lbs. of subsoil per acre.

The results of these analyses will not be considered in detail, because of the fact that there is little influence upon the fertility of the soil from the plant food contained in the lower soil layers unless there is a very large amount of some constituent present or a striking deficiency of a plant food element.

In the soils of Greene County the subsoils are not particularly high in any plant food nor is there any large deficiency. It seems, therefore, that the analyses of the surface soils indicate fairly accurately the plant food content of the soil section as a whole and in general the crop producing power of the land.



Considering the analyses of the subsurface soils and the subsoils it may merely be emphasized, therefore, that they serve to confirm in a very definite way the conclusions drawn from the analyses of the surface soils.

It is apparent that the phosphorus content of these soils is low and that the addition of phosphorus fertilizers is necessary for the best production of crops at the present time on many of the soils. They certainly will be needed on practically all of the types at some time in the near future. The indications are that these materials might prove of large value in many cases at present.

In general the content of organic matter and nitrogen is fairly adequate but the supply of these constituents must be maintained through regular methods of soil treatment if the content in the soil is to be kept up and if a high productivity is to be maintained. The proper use of farm manure, crop residues and leguminous green manures is very important as a means of supplying organic matter to the soil and as a means of keeping up the total content of nitrogen. The use of inoculated legumes as green manures is particularly valuable in maintaining the supply of nitrogen in the soil.

There is some lime content shown in the lower soil layers of the Clarion loam and the Webster clay loam, but with these exceptions, wherever the surface soil shows an acidity, the lower soil layers are likewise acid, and the need for lime is evidenced thruout the entire three foot section of the soil. The conclusion may merely be emphasized, therefore, that on all the types in the county except those of the Fargo, Sarpy and Lamoure series, the soils should be tested regularly for lime requirement and the amount of lime which the test shows to be necessary should be applied if the best growth of farm crops and particularly of legumes is to be secured.

## GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Greene County in an attempt to secure some indications regarding the fertilizer needs, and the possible value of the application of certain fertilizing materials to two of the most extensive soil types in the county. The experiments were carried out with the Carrington loam and the Webster silty clay loam, the two largest types in the area.

In addition to these experiments, the results of similar tests on the Webster loam from Hamilton County, the Clarion loam from Palo Alto County, the Webster silty clay loam from Wright County and the Carrington loam from Dallas County are included inasmuch as these soils are very similar to those which occur extensively in Greene County. The results are, therefore, undoubtedly applicable to the conditions in the latter county.

The treatments used in these tests include manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These materials were employed in the same amounts in which they are applied in the field experiments and in practice and hence the results secured may be considered quite definitely indicative of what may occur in the field.


Fig. 5. Greenhouse experiment on Carrington loam, Greene County, in 1921 with wheat and clover.

The manure was added at the rate of 8 tons per acre and lime in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was added 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 all the pots, the clover being seeded about one month after the wheat was up. In some of the experiments only the wheat yields are given, the clover yields not being secured.

### RESULTS ON CARRINGTON LOAM

The results obtained in the experiment on Carrington loam from Greene County are given in table VII, only the average yields from duplicate pots being shown.

The application of manure brought about a large increase in the yield of wheat and more than doubled the yield of clover. The application of lime along with manure increased the wheat yields and showed an increase also on the clover. Rock phosphate with the manure and lime showed no effect on the wheat

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, GREENE COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 7.4 | 12.4 |
| 2 | Manure | 9.0 | 27.1 |
| 3 | Manure+lime | 10.1 | 29.3 |
| 4 | Manure+lime+rock phosphate | 10.2 | 28.3 |
| 5 | Manure+lime+acid phosphate | 11.9 | 34.0 |
| 6 | Manure+lime+complete commercial fertilizer | 11.0 | 30.8 |



and no influence in the case of the clover. Acid phosphate, however, when applied with manure and lime, gave an increase in the yield of wheat and a very considerable increase in the clover yield.

The complete commercial fertilizer with the manure and lime showed less effect than the acid phosphate in the case of both the wheat and the clover crop.

It seems evident that manure is of particular value for use on this soil. Applications of lime are also valuable when used in addition to manure and the application of a phosphate fertilizer may prove distinctly profitable. The rock phosphate in this particular test did not show any increase in the crop yields while the acid phosphate showed up to good advantage. In other cases, in field tests, the rock phosphate has given considerable increases in crop yields on this same soil type, so that definite conclusions should not be drawn from this one experiment. It would seem, however, that acid phosphate would probably be more desirable for use. The complete commercial fertilizer was slightly less effective than the acid phosphate, hence it would not appear as desirable to use this particular complete fertilizer as acid phosphate is somewhat cheaper and apparently gives quite as satisfactory, if not more satisfactory, crop increases.

### RESULTS ON WEBSTER SILTY CLAY LOAM

Table VIII gives the results secured on the Webster silty clay loam from Greene County. Only the wheat yields are given in this table. The application of manure increased considerably the yield of wheat on this soil. Lime applied with manure showed a slight effect. Rock phosphate with lime and manure considerably increased the yield of the crop. Acid phosphate, however, with manure and lime did not show a similarly large increase. The complete commercial fertilizer with the manure and lime showed less effect than the rock phosphate but did give a significant increase.

It would seem that on this soil which is high in organic matter and black in color, an application of a small amount of manure would be of value in increasing crop yields, probably because of its effect in stimulating the production of


Fig. 6. Greenhouse experiment on Carrington loam, Greene County, with clover.

TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, GREENE COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams |
|---|---|---|
| 1 | Check | 7.5 |
| 2 | Manure | 9.4 |
| 3 | Manure+lime | 9.7 |
| 4 | Manure+lime+rock phosphate | 12.1 |
| 5 | Manure+lime+acid phosphate | 9.9 |
| 6 | Manure+lime+complete commercial fertilizer | 10.1 |

available plant food. It should be emphasized that manure should not be applied to this type preceding the growing of a small grain crop since it may cause the crop to lodge. Small applications of manure at other places in the rotation will, however, prove of value. When the type is acid, a small application of lime should be made in order to provide for the best growth of legumes. The use of a phosphate fertilizer would seem to be valuable on this type. In this particular test rock phosphate gave better results than acid phosphate. However, the results should not be considered final as other tests on the same type have indicated the reverse. It may safely be concluded that a phosphate fertilizer will prove of value on this soil but tests on individual soils should be carried out before definite conclusions are drawn regarding the relative value of rock phosphate and acid phosphate. In some instances the one may be more profitable while, in other cases, the other will be the material to use. The complete commercial fertilizer did not show up as well as the rock phosphate in this test and unless very much


Fig. 7. Greenhouse experiment on Webster silty clay loam, Greene County, with wheat and clover.



TABLE IX. GREENHOUSE EXPERIMENT, WEBSTER LOAM, HAMILTON COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 13.15 | 59.5 |
| 2 | Manure | 13.77 | ---- |
| 3 | Manure+lime | 17.61 | 70.0 |
| 4 | Manure+lime+rock phosphate | 13.94 | 74.5 |
| 5 | Manure+lime+acid phosphate | 18.01 | 80.0 |
| 6 | Manure+lime+complete commercial fertilizer | 20.31 | 82.0 |

larger results are secured with the complete fertilizer, it will not prove as profitable as a phosphorus carrier.

### RESULTS ON WEBSTER LOAM—HAMILTON COUNTY

The results secured on the Webster loam from Hamilton County are given in table IX. The yield of clover on the manure treated pots is not given as the results were evidently abnormal for some reason. The effect of manure is evidenced by a slight increase in the yield of wheat. Lime in addition to manure brought about a considerable increase in the wheat yield. The combination of lime and manure showed an increase on the clover. Rock phosphate had no effect on the wheat but brought about a slight increase in the case of the clover. Acid phosphate increased both the wheat and the clover yields quite definitely. The complete commercial fertilizer brought about a still larger increase in the case of both crops.

It is apparent from this experiment that the addition of lime to the Webster loam when it is acid, will lead to increases in crop growth. The test also indicates the desirability of determining the value of phosphorus fertilizers on this type by field experiments as a rather distinct crop increase from the use of the phosphate carriers is shown. Small applications of manure would also undoubtedly be of value in many cases on this type.

### RESULTS ON CLARION LOAM—PALO ALTO COUNTY

The results secured on the Clarion loam from Palo Alto County are given in table X. In this test manure brought large increases in both the wheat and clover crops. Lime showed no additional effects. Rock phosphate increased both crops giving a rather distinct gain in the case of the clover. Acid phosphate gave the same yield as the rock phosphate in the case of wheat but had a much larger influence on the clover. The complete commercial fertilizer was not

TABLE X. GREENHOUSE EXPERIMENT, CLARION LOAM, PALO ALTO COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 9.5 | 56.69 |
| 2 | Manure | 14.5 | 68.04 |
| 3 | Manure+lime | 14.0 | 68.04 |
| 4 | Manure+lime+rock phosphate | 16.0 | 74.84 |
| 5 | Manure+lime+acid phosphate | 16.0 | 86.18 |
| 6 | Manure+lime+complete commercial fertilizer | 16.3 | 70.25 |

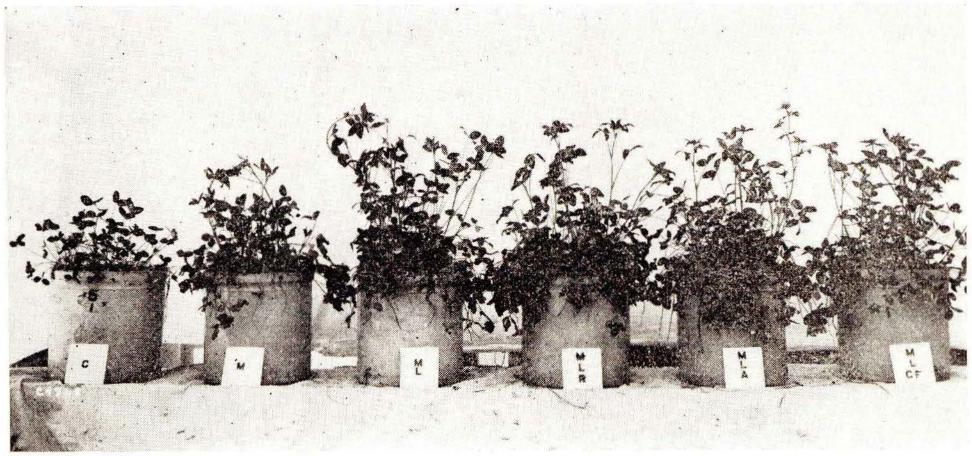

Fig. 8. Greenhouse experiment on Webster silty clay loam, Greene County, with clover.

of any more value on the wheat than were the phosphates. It showed even less effect on the clover.

Evidently on this soil type manure is a particularly valuable fertilizer and should be used quite generally. Lime may be necessary in some cases altho it did not show any effect in this experiment. There are indications of profit from the use of a phosphate. Acid phosphate seems somewhat preferable to rock phosphate, especially for clover. The complete commercial fertilizer did not show larger effects than the phosphates and hence could not be considered as desirable for use unless special tests are carried out which definitely indicate a superior value.

### RESULTS ON WEBSTER SILTY CLAY LOAM—WRIGHT COUNTY

In table XI the results secured on the Webster silty clay loam from Wright County are given. In this test only the green weights of the clover were secured. Manure brought about a large increase in the clover crop and lime in addition to manure gave a further increase. Both the rock phosphate and acid phosphate when added with lime and manure increased the clover yields, the rock phosphate showing up somewhat better than the acid phosphate. The complete commercial fertilizer had less effect than either of the phosphates.

Apparently this soil will respond to light applications of manure and should

TABLE XI. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, WRIGHT COUNTY

| Pot No. | Treatment | Weight of green clover in grams |
|---|---|---|
| 1 | Check | 61.23 |
| 2 | Manure | 108.86 |
| 3 | Manure+lime | 127.00 |
| 4 | Manure+lime+rock phosphate | 140.61 |
| 5 | Manure+lime+acid phosphate | 131.54 |
| 6 | Manure+lime+complete commercial fertilizer | 124.74 |



TABLE XII. GREENHOUSE EXPERIMENTS, CARRINGTON LOAM, DALLAS COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams |
|---|---|---|
| 1 | Check | 6.372 |
| 2 | Manure | 6.848 |
| 3 | Manure+lime | 8.306 |
| 4 | Manure+lime+rock phosphate | 9.386 |
| 5 | Manure+lime+acid phosphate | 8.760 |
| 6 | Manure+lime+complete commercial fertilizer | 9.777 |

be limed when acid in the surface soil, especially if clover is to be grown. The use of a phosphorus fertilizer is very desirable and may prove distinctly profitable on this type. Whether rock phosphate or acid phosphate should be used must be determined for the individual farm conditions. The results of this experiment very largely confirm those previously discussed on the same soil type from Greene County.

### RESULTS ON CARRINGTON LOAM—DALLAS COUNTY

The results secured on the Carrington loam from Dallas County are given in table XII. Only the yields of wheat were secured in this test. The application of manure brought about a distinct increase in the wheat crop and the application of lime along with the manure showed a very large effect. Ordinarily lime would not be expected to have a large effect on a crop like wheat but in some cases increases, such as have been noted in this experiment, are secured. Applications of the rock phosphate, acid phosphate and complete commercial fertilizer all gave increases in the wheat crop, the complete commercial fertilizer giving slightly larger increases than the two phosphates. The rock phosphate was slightly more effective than the acid phosphate. The differences, however, between the effects of these three materials were not large.

The results indicate that this soil is in need of phosphorus and that tests of the value of phosphorus fertilizers on the farm are very desirable. It is further evidenced that applications of manure and lime are very desirable on the type thus confirming the observations made on this same soil type from Greene County.

## FIELD EXPERIMENTS

There is a cooperative field experiment in Greene County but the work has not been under way on this field for a long enough period of time, for the results to be of significance. A number of experiments have been carried out, however, in adjacent counties, on soil types which are the same as those occurring extensively in Greene County, and the results secured from some of these field experiments will be given here inasmuch as they indicate quite definitely the needs of the same soil types in this county. Experiments are included here on the Carrington loam from Buena Vista County, on the Webster silty clay loam from Buena Vista County, on the Lamoure silty clay loam from Clay County, and on the Carrington loam from Hardin County.

These field experiments have all been planned with the object in mind of determining the value of various fertilizing materials when applied to the soil. The tests are laid out on land which is representative of the particular soil type. The fields all include 13 plots, 155′ 7″ by 28′, or one-tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of crops, to insure the securing of accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former, manure is applied while in the latter, crop residues are employed. The other fertilizing materials tested 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. The crop residues treatment consists of the plowing under of the corn stalks which have been cut with a disk or stalk cutter, and the turning under of at least the second crop of clover. Occasionally the first crop of clover is cut and allowed to remain on the land to be plowed under with the second crop. Lime is added in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 2,000 pounds per acre once in a four-year rotation. Since 1925 the rock phosphate is being applied at the rate of 1,000 pounds per acre once in four years. Acid phosphate is applied at the rate of 150 pounds per acre annually. Until 1923, the old standard 2-8-2 complete commercial fertilizer was used at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being applied at the rate of 202 pounds per acre, thus providing the same amount of phosphorus as that contained in the 150 pounds of acid phosphate.

### THE TRUESDALE FIELD

The results secured on Series I on the Truesdale Field located on the Carrington loam in Buena Vista County are given in table XIII. Manure brought about an increase in all the crops except the clover in 1921, the largest increase being evidenced on the corn in 1922. Lime increased the yields in all cases, showing the best results with the clover, as would be expected. Rock phosphate with the manure and lime gave increases in most years, the largest effects being shown on the clover. The effect on the oats and corn was smaller and, in the case of the corn in 1922 and the oats in 1923, no increases at all were secured. Acid phosphate gave very similar increases to the rock phosphate in some seasons. With the clover in 1921, however, there was a much larger effect from the acid phosphate, while on the same crop in 1926 there was a smaller effect. The oats in 1925 were increased to a greater extent by the acid phosphate than by the rock phosphate. In most of the other seasons the variations between the effects of the two phosphates were insignificant. The complete commercial fertilizer showed gains which were very similar to those brought about by the phosphates, giving slightly smaller effects than the acid phosphate in some instances and slightly larger effects in other cases.

The crop residues showed little effect on the yields of the succeeding crops, except in one or two instances. Lime with the crop residues brought about increases in crop yields in most cases, the effect being most evident on the clover



in 1926 and on some of the oats crops. The rock phosphate with the lime and crop residues increased the yields in practically all cases. Only with the clover in 1926 was no increase evidenced. In some seasons the increases were quite large while in other cases they were small and insignificant. Clover in 1921 showed a large increase. The oats in 1923 were increased considerably and also in 1925. Acid phosphate showed larger effects than the rock phosphate in some instances, particularly on the oats in 1920 and on the same crop in 1925, very large differences being shown in the latter year. In several other cases, however, the rock phosphate seemed to give quite as large effects as the acid phosphate and in the case of the clover crop the rock phosphate gave a slightly larger influence than the acid phosphate. The complete commercial fertilizer had about the same effect as the acid phosphate in most cases. In a few instances it gave larger effects and in one or two cases it had a smaller influence. The differences, however, were not large enough in most cases to be of significance. Only on the oats in 1923 and the corn in 1924 were the differences of very large import.

It would seem from this experiment that the application of manure is particularly valuable on this soil type and that lime in addition to manure may prove of large effect especially on the legume crop grown in the rotation. The use of a phosphate fertilizer is certainly very desirable. Increases were secured when the phosphates were applied with the manure and lime and also when they were applied with the crop residues, representing the grain system of farming.

TABLE XIII. FIELD EXPERIMENT—CARRINGTON LOAM—BUENA VISTA COUNTY. TRUESDALE FIELD—SERIES I.

| Plot No. | Treatment | 1918 corn bu. per A (1) | 1919 corn bu. per A. (2) | 1920 oats bu. per A. (3) | 1921 clover tons per A. | 1922 corn bu. per A. (4) | 1923 oats bu. per A. (5) | 1924 corn bu. per A. (6) | 1925 oats bu. per A. | 1926 clover tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 38.9 | 56.5 | 57.2 | 1.40 | 48.6 | 44.2 | 13.0 | 48.3 | 1.12 |
| 2 | Manure | 44.3 | 57.1 | 57.9 | 1.20 | 61.6 | 57.7 | 24.2 | 57.0 | 1.45 |
| 3 | Manure+lime | 46.4 | 58.1 | 59.2 | 1.60 | 64.0 | 61.2 | 32.7 | 63.2 | 1.64 |
| 4 | Manure+lime+rock phosphate | 54.4 | 58.7 | 64.7 | 2.45 | 63.2 | 60.0 | 34.1 | 64.6 | 1.77 |
| 5 | Manure+lime+acid phosphate | 49.6 | 58.7 | 64.9 | 3.30 | 61.6 | 61.2 | 32.8 | 73.1 | 1.60 |
| 6 | Manure+lime+complete commercial fertilizer | 49.6 | 58.7 | 64.7 | 3.10 | 63.7 | 68.0 | 37.5 | 71.0 | 1.79 |
| 7 | Check | 38.4 | 58.1 | 56.4 | 2.20 | 51.0 | 54.8 | 30.2 | 50.4 | 1.13 |
| 8 | Crop residues | 49.1 | 61.9 | 67.7 | 2.20 | 49.7 | 55.5 | 27.1 | 44.3 | 1.52 |
| 9 | Crop residues+lime | 51.2 | 66.6 | 66.0 | 2.20 | 50.6 | 54.5 | 31.0 | 51.7 | 1.68 |
| 10 | Crop residues+lime+rock phosphate | 58.9 | 68.8 | 68.1 | 3.10 | 61.6 | 60.0 | 31.4 | 57.6 | 1.50 |
| 11 | Crop residues+lime+acid phosphate | 57.6 | 67.2 | 76.8 | 2.90 | 64.1 | 64.5 | 24.5 | 71.0 | 1.44 |
| 12 | Crop residues+lime+complete commercial fertilizer | 62.9 | 66.1 | 77.6 | 3.00 | 60.4 | 77.0 | 34.4 | 71.6 | 1.29 |
| 13 | Check | 47.5 | 64.0 | 56.5 | 2.10 | 49.0 | 48.7 | 29.6 | 54.4 | 0.92 |

(1) Three tons lime applied in the fall of 1917.
(2) Plots 8-13 more moisture; slopes into heavier soil.
(3) Three tons lime applied in October.
(4) Dry season cut yields.
(5) Phosphate plots blown down at harvest.
(6) Plots 1 and 2 injured by squirrels. Corn green when husked due to killing frost.

TABLE XIV. FIELD EXPERIMENT—CARRINGTON LOAM—BUENA VISTA COUNTY. TRUESDALE FIELD—SERIES II

| Plot No. | Treatment | 1918 oats bu. per A. (1) | 1919 clover tons per A. (2) | 1920 corn bu. per A. | 1921 corn bu. per A. (3) | 1922 oats bu. per A. (4) | 1923 clover tons per A. | 1924 corn bu. per A. (5) | 1925 corn bu. per A. | 1926 oats bu. per A. (6) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 69.9 | ---- | 47.5 | 32.8 | 18.5 | 1.72 | 38.0 | 40.0 | 29.9 |
| 2 | Manure | 94.2 | ---- | 57.0 | 39.7 | 24.6 | 1.90 | 52.7 | 50.4 | 38.1 |
| 3 | Manure+lime | 91.2 | ---- | 59.0 | 41.8 | 27.2 | 1.86 | 46.9 | 51.8 | 37.0 |
| 4 | Manure+lime+rock phosphate | 88.2 | ---- | 61.2 | 38.1 | 32.4 | 2.26 | 44.4 | 51.7 | 37.3 |
| 5 | Manure+lime+acid phosphate | 91.2 | 1.89 | 62.1 | 40.2 | 31.0 | 2.24 | ---- | 54.8 | 43.3 |
| 6 | Manure+lime+complete commercial fertilizer | 88.2 | 2.00 | 64.0 | 44.5 | 31.9 | 2.42 | 45.0 | 58.6 | 43.6 |
| 7 | Check | 85.1 | 1.59 | 57.1 | 36.3 | 23.6 | 1.93 | 42.9 | 51.6 | 34.3 |
| 8 | Crop residues | 89.7 | 1.98 | 58.5 | 32.9 | 31.2 | 1.98 | 40.7 | 59.2 | 35.4 |
| 9 | Crop residues+lime | 97.3 | 2.07 | 59.2 | 40.1 | 29.8 | 2.03 | 41.8 | 52.2 | 32.7 |
| 10 | Crop residues+lime+rock phosphate | 91.2 | 2.19 | 60.0 | 35.6 | 34.4 | 2.39 | 46.0 | 51.1 | 38.7 |
| 11 | Crop residues+lime+acid phosphate | 92.7 | 2.22 | 60.4 | 33.6 | 36.8 | 2.11 | 40.7 | 60.4 | 47.4 |
| 12 | Crop residues+lime+complete commercial fertilizer | 95.8 | 2.37 | 61.9 | 35.5 | 37.3 | 2.39 | 39.3 | 55.2 | 40.3 |
| 13 | Check | 85.1 | 1.91 | 60.9 | 34.9 | 28.4 | 2.03 | 39.5 | 49.8 | 29.9 |

(1) Two and one-half tons lime in March.
(2) Plots 1, 2, 3 and 4 disced and seeded to oats. Clover winter-killed.
(3) Poor stand of corn.
(4) Two tons lime in April.
(5) Plot 5 injured by squirrels.
(6) Dry season—low yields.

Whether rock phosphate or acid phosphate should be applied cannot be definitely stated from the experiment as the results are somewhat variable. Tests on individual farms of the two materials are necessary before definite conclusions should be reached. The use of a complete commercial fertilizer does not seem to be any more desirable than the application of acid phosphate. Owing largely to its greater cost, tests of this material in comparison with acid phosphate should be carried out before any extensive application is made.

Table XIV gives the results secured on series II of the Truesdale Field in Buena Vista County, on the same soil type, the Carrington loam. Again the application of manure increased the yields of the various crops, showing very large effects in practically all cases. The corn and oats crops were very largely benefited by the use of the manure and there was a large effect on the clover crop as shown by the increased yield in 1923. Lime brought about further increases in the crop yields in most cases. In one or two instances the application of the lime did not prove of significance. In general, however, the application of lime to this soil when it is acid, is very desirable for the best growth of legume crops.

Rock phosphate, acid phosphate and the complete commercial fertilizer increased the yields of crops in practically all cases, when applied with the manure and lime. In one or two seasons the rock phosphate did not appear to be of value but the acid phosphate and complete commercial fertilizer always brought about considerable increases in yields, the effects being particularly noted on the clover in 1923. It would seem that the acid phosphate was the most desirable of these three materials, owing to the fact that it brought about slightly larger effects than the rock phosphate in most cases and the increases for the complete commercial fertilizer were not sufficiently greater to warrant the larger expense of the use of this material.



The crop residues exerted slight effect on the crop yields in several instances. The application of lime with the crop residues brought about increases in the yields in most cases. The effects were not large except in one or two cases, however, and in 1925 and 1926, no value from the application of lime was evidenced on the corn and oats. Rock phosphate, acid phosphate and the complete commercial fertilizer increased the crop yields in practically all cases. The acid phosphate seemed to be slightly superior to the rock phosphate in some seasons while in other cases the rock phosphate gave slightly larger effects. The greater influence from the latter material was shown on the clover in 1923 and on the corn in 1924. The acid phosphate, however, gave much larger effects on the corn in 1925 and on the oats in 1926. The complete commercial fertilizer had much the same effect as the acid phosphate in most seasons, having less influence, however, than the latter material in 1925 and in 1926 and showing slightly larger effects in some other seasons.

TABLE XV. FIELD EXPERIMENT—WEBSTER SILTY CLAY LOAM—BUENA VISTA COUNTY. NEWELL FIELD.

| Plot No. | Treatment | 1918 corn bu. per A. | 1919 corn bu. per A. | 1920 oats bu. per A. (1) | 1921 clover tons per A. (2) | 1922 corn bu. per A. (3) | 1924 oats bu. per A. (4) | (4) 1924 oats bu. per A. | 1925 clover tons per A. | 1926 corn bu. per A. (5) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 69.0 | 44.8 | 56.7 | 0.52 | 68.7 | 59.2 | ---- | 1.70 | 51.2 |
| 2 | Manure | 70.9 | 49.1 | 64.1 | 0.60 | 70.5 | 65.6 | ---- | 1.97 | 31.4 |
| 3 | Manure+lime | 71.4 | 54.4 | 63.5 | 0.70 | 69.9 | 68.3 | 59.8 | 1.95 | 23.5 |
| 4 | Manure+lime+rock phosphate | 74.1 | 61.4 | 69.7 | 0.70 | 74.1 | 69.3 | 63.5 | 2.04 | 46.4 |
| 5 | Manure+lime+acid phosphate | 66.9 | 65.1 | 76.3 | 1.12 | 80.0 | 63.4 | 63.5 | 2.36 | 36.3 |
| 6 | Manure+lime+complete commercial fertilizer | 66.4 | 70.9 | 68.9 | 1.20 | 74.4 | 67.7 | 72.2 | 2.22 | 28.3 |
| 7 | Check | 60.9 | 62.4 | 59.4 | 0.57 | 66.9 | 55.0 | 62.3 | 1.35 | 45.9 |
| 8 | Crop residues | 62.9 | 56.1 | 59.4 | 0.50 | 63.6 | 56.4 | 66.5 | 1.10 | 52.3 |
| 9 | Crop residues+lime | 64.6 | 59.2 | 61.4 | 0.42 | 64.2 | 59.5 | 71.8 | 1.21 | 57.6 |
| 10 | Crop residues+lime+rock phosphate | 63.4 | 60.8 | 56.7 | 0.52 | 67.3 | 65.9 | 66.9 | 1.88 | 50.1 |
| 11 | Crop residues+lime+acid phosphate | 62.4 | 68.5 | 72.0 | 0.90 | 67.3 | 64.1 | 69.3 | 2.08 | 58.6 |
| 12 | Crop residues+lime+complete commercial fertilizer | 61.3 | 65.3 | 71.3 | 0.92 | 67.0 | 65.8 | ---- | 2.29 | 47.5 |
| 13 | Check | 59.4 | 65.3 | 60.1 | 0.57 | 66.2 | 60.9 | ---- | 1.78 | 54.9 |

(1) Limestone applied October 11, 1920, 3½ tons. Oats down.
(2) Second cutting only.
(3) Some plots down.
(4) Four plots cut before field man arrived.
(5) Corn badly damaged by hot weather and cut early for fodder. High moisture content at cutting.

These results very largely confirm those secured on series I on the same soil type. They indicate how valuable manure is on this soil. The use of lime is desirable with manure in the livestock system of farming or with crop residues in the grain system. The application of a phosphate fertilizer will certainly prove of value on this type whether used on the livestock farm with manure and lime or on the grain farm with crop residues and lime. Whether rock phosphate or acid phosphate should be employed must be determined for individual soil conditions. The use of a complete commercial fertilizer has not been shown to be valuable enough to make the application economical. Acid phosphate would seem to be more desirable for use because it gives quite as large increases in yields and is less expensive for application.

## THE NEWELL FIELD

Table XV gives the results secured on the Webster silty clay loam on the Newell Field in Buena Vista County. In spite of the fact that this soil is very well supplied with organic matter and black in color, applications of manure brought about large crop increases in all but one season, and this was in 1926 when the yields were abnormal, due to hot, dry weather. The effects of the manure were evidenced on the corn and oats but particularly on the clover. Lime with manure gave slight increases in crop yields in several cases. The effects were not large, however, and as this soil is only slightly acid and the acidity is confined to the surface soil, no large effect from the use of lime would be expected.

The rock phosphate and acid phosphate brought about increases in crop yields in practically all seasons and on practically all crops. There were one or two exceptions but in these cases the differences were slight. The effects of the two materials showed up particularly well on the clover in 1925 and on the corn in 1926. The acid phosphate had a large effect on the clover in 1921. The influence on the corn in 1922 and on the oats in 1920 was quite evident. In most cases the acid phosphate seemed to be somewhat preferable to the rock phosphate. However, there were one or two exceptions. In 1918, in 1923 and in 1926, the rock phosphate gave better yields than the acid phosphate. The complete commercial fertilizer showed slightly larger effects than the acid phosphate in one or two cases but in general the acid phosphate gave quite as large or even larger increases in yields when used with the manure and lime and hence it should be considered preferable for application to this soil.

The crop residues have little effect on the yields on this soil as would be expected. Lime with the crop residues gave slight increases in crop yields in several cases. The differences were not large, however, but were sufficient to show the desirability of applying lime to this soil when it is acid. The rock phosphate, acid phosphate and complete commercial fertilizer showed beneficial effects in some cases on the various crops grown. In other instances, however, no effects were evidenced. The clover in 1925 showed particularly large value from the use of the phosphate materials. Similarly, in 1921, the clover was increased to a large extent by the acid phosphate and the complete commercial fertilizer. The two latter materials increased the oat yields to a large extent in 1920 and had a beneficial effect on the corn in 1919. In some of the other seasons, as in 1922 and 1923, the three materials gave practically identical effects, all showing increases, however, over the crop residues and lime alone.



It seems from these results that applications of small amounts of farm manure on the Webster silty clay loam would be of considerable value. It should be emphasized that manure should not be added to this soil prior to the growing of a small grain crop owing to the danger of causing the grain to lodge. Small amounts applied at other points in the rotation are, however, of considerable value. When the type is acid in the surface soil, applications of lime should be made. The use of a phosphate fertilizer is very desirable. The selection of the particular phosphate fertilizer which should be employed must, however, be determined by special tests on the farm. In some cases acid phosphate seems preferable while in other instances rock phosphate gives quite as good returns. Either of these materials would seem to be more desirable than a complete commercial fertilizer, owing to the greater cost of the latter and to the fact that it does not bring about sufficiently larger increases in crop yields.

## THE STORM LAKE FIELD

The results secured on the Webster silty clay loam on the Storm Lake Field in Buena Vista County are given in table XVI. Again manure brought about beneficial effects on the various crops grown, showing up particularly well on

TABLE XVI. FIELD EXPERIMENT—WEBSTER SILTY CLAY LOAM—BUENA VISTA COUNTY. STORM LAKE FIELD

| Plot No. | Treatment | 1918 oats bu. per A. (1) | 1919 corn bu. per A. | 1920 corn bu. per A. | 1921 oats bu. per A. | 1922 clover tons per A. (2) | 1923 corn bu. per A. (3) | 1924 corn bu. per A. (4) | 1925 barley bu. per A. | 1926 corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 73.0 | 54.7 | 48.2 | 45.1 | 0.75 | 51.0 | 22.7 | 40.9 | 50.4 |
| 2 | Manure | 73.0 | 54.1 | 57.3 | 42.2 | 1.01 | 60.7 | 27.5 | 47.8 | 50.1 |
| 3 | Manure+acid phosphate+potassium chloride | 73.0 | 57.6 | 58.1 | 36.3 | 1.29 | 65.1 | 29.2 | 56.9 | 53.6 |
| 4 | Manure+rock phosphate | 80.6 | 61.1 | 64.2 | 43.8 | 1.26 | 66.4 | 31.0 | 61.8 | 48.5 |
| 5 | Manure+acid phosphate | 74.5 | 66.4 | 76.5 | 51.8 | 1.42 | 68.5 | 31.8 | 57.6 | 58.4 |
| 6 | Manure+complete commercial fertilizer | 82.0 | 61.1 | 80.0 | 43.8 | 1.43 | 66.8 | 33.9 | 60.7 | 52.8 |
| 7 | Check | 70.0 | 71.5 | 66.6 | 40.9 | 1.10 | 55.8 | 34.0 | 44.5 | 48.5 |
| 8 | Crop residues | 85.1 | 75.7 | 67.7 | 49.1 | 1.08 | 63.3 | 37.3 | 44.5 | 51.2 |
| 9 | Crop residues+acid phosphate+potassium chloride | 76.0 | 70.1 | 67.2 | 41.1 | 1.25 | 70.7 | 35.7 | 64.4 | 52.8 |
| 10 | Crop residues+rock phosphate | 79.0 | 70.4 | 76.2 | 41.6 | 1.20 | 63.2 | 27.4 | 52.8 | 50.1 |
| 11 | Crop residues+acid phosphate | 73.0 | 64.0 | 76.2 | 45.5 | 1.23 | 63.1 | 31.1 | 58.2 | 49.6 |
| 12 | Crop residues+complete commercial fertilizer | 85.1 | 67.5 | 76.2 | 43.8 | 1.13 | 61.3 | 27.2 | 58.1 | 43.5 |
| 13 | Check | 79.0 | 67.5 | 67.7 | 39.7 | 0.86 | 51.9 | 23.1 | 41.6 | 34.9 |

(1) Soil basic, no manure added, oats badly lodged.
(2) Acid phosphate and potassium chloride (50 pounds per acre) applied to 3 and 9 in 1922. 1st crop only.
(3) Hogs in corn damaged yield.
(4) Early frost left corn very chaffy and light and practically none was marketable.

the clover. Considerable gains were noted also in the case of some of the corn crops and in the case of barley in 1925. The soil was not acid in reaction and hence no lime was employed. The use of rock phosphate and acid phosphate with the manure brought about increases in crop yields in all cases, the effect being particularly large with the acid phosphate on the corn in 1920, on the clover in 1922, and on the corn in 1926. The rock phosphate generally showed less effect than the acid phosphate. The reverse was true, however, in the case of the barley in 1925 and the oats in 1918. The complete commercial fertilizer gave slightly larger increases than the acid phosphate in several seasons but in other cases the beneficial effects were not so large. In no case was there any considerable difference between the effects of these two materials. The potash applied with acid phosphate to plot 3 in 1922 and in later years did not show any beneficial effect.

The crop residues had little effect on the yields on this soil. The rock phosphate and acid phosphate applied with the crop residues brought about increases in yields which were quite definite in some cases, particularly on the corn in 1920. In several cases, however, the phosphates did not seem to show any particularly large effect when applied without manure. The complete commercial fertilizer brought about larger effects than the acid phosphate in several cases but in other instances it had less value. The potash added with acid phosphate to plot 9 in 1922 and in subsequent years showed small crop increases in every season.

The results as a whole indicate the desirability of the application of small

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

| Plot No. | Treatment | 1919 clover tons per A. (1) | 1920 corn bu. per A. (2) | 1921 corn bu. per A. (3) | 1922 oats bu. per A. | 1923 clover tons per A. (4) | 1924 corn bu. per A. | 1925 corn bu. per A. | 1926 oats bu. per A. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 1.45 | 74.6 | 65.8 | 35.6 | 0.57 | 31.8 | 57.9 | 47.4 |
| 2 | Manure | 1.45 | ---- | 75.3 | 54.1 | 0.71 | 58.2 | 68.6 | 62.9 |
| 3 | Manure+acid phosphate+potassium chloride | 1.60 | 83.2 | 75.8 | 70.4 | 1.83 | 69.4 | 58.8 | 76.8 |
| 4 | Manure+rock phosphate | 1.67 | 83.2 | 70.0 | 64.1 | 1.25 | 61.7 | 55.1 | 76.8 |
| 5 | Manure+acid phosphate | 2.03 | 80.8 | 68.1 | 70.2 | 1.75 | 67.2 | 55.8 | 83.0 |
| 6 | Manure+complete commercial fertilizer | 1.79 | 80.8 | 63.2 | 68.4 | 1.26 | 60.8 | 54.0 | 71.1 |
| 7 | Check | 1.68 | 66.9 | 54.5 | 58.3 | 0.77 | 43.2 | 44.0 | 54.7 |
| 8 | Crop residues | 1.56 | ---- | 54.7 | 52.8 | 0.87 | 39.6 | 43.4 | 53.4 |
| 9 | Crop residues+acid phosphate +potassium chloride | 1.56 | 70.4 | 61.9 | 61.1 | 1.47 | 56.5 | 44.2 | 71.6 |
| 10 | Crop residues+rock phosphate | 1.68 | 73.6 | 60.4 | 57.7 | 1.14 | 61.2 | 42.2 | 72.4 |
| 11 | Crop residues+acid phosphate | 1.56 | 83.4 | 60.8 | 62.8 | 1.59 | 57.7 | 44.7 | 77.6 |
| 12 | Crop residues+complete commercial fertilizer | 2.03 | 77.8 | 64.7 | 78.4 | 1.73 | 56.4 | 57.7 | 76.5 |
| 13 | Check | 1.68 | 61.2 | 54.0 | 48.5 | 0.83 | 35.7 | 53.5 | 50.4 |

(1) Clover killed out in spots.
(2) Soil basic and no lime applied. Corn on plots 2 and 8 not husked.
(3) Acid phosphate and potassium chloride (50 pounds per acre) applied to plots 3 and 9.
(4) First cutting only.



amounts of manure to this soil, applying the manure at some place in the rotation other than just preceding the small grain crop. The use of a phosphate fertilizer would seem to be desirable. Whether acid phosphate or rock phosphate should be used must be determined by special tests. The use of a complete commercial fertilizer cannot be recommended as it would not seem to be as profitable to apply as a phosphate. The use of a potassium fertilizer cannot be recommended until tests have been carried out on individual farms and it has been shown to be of value.

## THE EVERLY FIELD

In table XVII are given the results secured on the Lamoure silty clay loam on the Everly Field, series II in Clay County.

The application of manure increased the crop yields on this soil type to a considerable extent in most cases. The effect was shown on the oats in 1922, on the corn in 1924 and on the oats in 1926 in a particularly large yield. The other crops were likewise increased by the use of manure. This soil was basic and no lime was applied. The use of rock phosphate and acid phosphate increased the crop yields to a very considerable extent in most cases, the effect being particularly evidenced on the oats in 1923, on the clover in 1924, and on the oats in 1926. No influence was shown, however, from either material on the corn in 1925. The application of potassium in the form of muriate of potash with the acid phosphate and manure which was begun in 1921 on plot 3 gave slight increases in some cases, but the results were not sufficiently greater than those secured from the application of acid phosphate alone to warrant the addition of the potassium. Similarly in the case of the complete commercial fertilizers, the increases secured were not sufficiently greater than those brought about by the acid phosphate to warrant the use of the material. In fact in several cases the complete commercial fertilizer showed smaller effects on crop yields than did the acid phosphate, and in some instances it had less effect even than the rock phosphate.

The crop residues exerted little effect on the crop yields, in general showing no increases at all. The application of rock phosphate and acid phosphate brought about increases which were quite definite particularly in the case of the acid phosphate on the clover in 1923, on the corn in 1921 and on the oats in 1922. The corn in 1924 showed a particularly large effect from both phosphates. In one or two cases the rock phosphate gave slightly larger effects than the acid phosphate, but in general the reverse was the case. The addition of potassium chloride and acid phosphate to the soil which was begun in 1921 on plot 9 increased the crop yields but no larger effects were secured than with the acid phosphate alone. The differences in most cases were too slight to be significant. It would not seem that the addition of the potassium has proven of value on this particular soil. The complete commercial fertilizer used with the crop residues gave larger effects than the acid phosphate in several seasons. The differences were not large, however, except in the case of the clover in 1919, the corn in 1925, and the oats in 1922. In general the differences were not sufficiently greater with the complete fertilizer to warrant the greater

TABLE XVIII. FIELD EXPERIMENT—CARRINGTON LOAM—HARDIN COUNTY. ELDORA FIELD—SERIES 100

| Plot No. | Treatment | 1915 corn bu. per A. (1) | 1916 oats bu. per A. | 1917 clover tons per A. | 1918 corn bu. per A. | 1919 corn bu. per A. (2) | 1920 oats bu. per A. (3) | 1921 clover tons per A. | 1922 corn bu. per A. | 1923 corn bu. per A. (5) | 1924 oats bu. per A. | 1925 clover tons per A. | 1926 corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 47.5 | 40.0 | 1.19 | 46.4 | 33.9 | 42.8 | 1.75 | 64.3 | 41.5 | 59.6 | 0.89 | 59.8 |
| 2 | Manure | 38.5 | 50.0 | 1.36 | 55.8 | 52.5 | 49.6 | 1.65 | 67.2 | 40.0 | 69.1 | 1.05 | 69.4 |
| 3 | Manure+lime | 40.8 | 40.0 | 1.53 | 52.2 | 50.6 | 56.9 | 1.50 | 69.9 | 38.2 | 70.4 | 1.14 | 63.1 |
| 4 | Manure+lime+rock phosphate | 53.3 | 46.0 | 1.78 | 48.9 | 58.8 | 57.7 | 2.30 | 66.4 | 41.8 | 71.5 | 1.18 | 52.2 |
| 5 | Manure+lime+acid phosphate | 53.9 | 53.0 | 1.87 | 68.8 | 61.1 | 60.3 | 2.55 | 73.6 | 44.8 | 79.4 | 1.32 | 58.8 |
| 6 | Manure+lime+complete commercial fertilizer | 52.2 | 53.6 | 2.04 | 60.7 | 57.9 | 59.8 | 2.65 | 70.7 | 50.4 | 78.0 | 1.46 | 60.1 |
| 7 | Check | 35.3 | 33.8 | 1.44 | 56.8 | 35.4 | 43.1 | 1.40 | 61.7 | 34.9 | 52.6 | 0.75 | 53.5 |
| 8 | Crop residues | 37.2 | 33.9 | 1.36 | 53.3 | 39.6 | 38.7 | 1.40 | 62.2 | 33.0 | 55.9 | 0.63 | 50.2 |
| 9 | Crop residues+lime | 37.3 | 30.0 | 1.28 | 60.3 | 39.2 | 50.2 | 1.55 | 64.3 | 41.5 | 71.6 | 1.18 | 52.9 |
| 10 | Crop residues+lime+rock phosphate | 38.7 | 33.3 | 1.70 | 62.2 | 44.0 | 52.2 | 2.40 | 73.6 | 45.6 | 79.5 | 1.32 | 63.1 |
| 11 | Crop residues+lime+acid phosphate | 46.8 | 46.6 | 1.87 | 65.3 | 46.0 | 55.7 | 3.00 | 82.2 | 43.9 | 83.4 | 1.25 | 63.8 |
| 12 | Crop residues+lime+complete commercial fertilizer | 35.0 | 50.0 | 1.70 | 63.7 | 41.6 | 67.2 | 2.85 | 70.0 | 45.9 | 74.2 | 1.25 | 61.8 |
| 13 | Check | 28.8 | 33.8 | 1.23 | 58.3 | 35.0 | 39.4 | 2.00 | 65.0 | 38.2 | 58.0 | 0.82 | 57.8 |

(1) Limed—3 tons per acre, fall, 1914.
(2) Dry season—yields low.
(3) Plots limed in spring.
(4) Much sweet clover on plot 13.
(5) Corn down badly, dry season.
(6) Extreme dry spring—low yield.

cost of the application, and it would seem that a phosphate fertilizer would be more desirable for use on this soil.

In general the results indicate that the application of manure may be of considerable use on this soil, in spite of the fact that it is black in color and high in organic matter content. The use of a phosphate fertilizer is recommended, tests on the indivdual farm being carried out to determine which material would be most desirable, acid phosphate or rock phosphate.

### THE ELDORA FIELD

The results secured on the Carrington loam on the Eldora Field, Series 100 in Hardin County are given in table XVIII. This experiment was begun in 1915 and the results have been secured over a period of eleven years, yields of 12 crops having been secured.

The beneficial effects of manure when applied to this soil type are shown by the increased crop yields which were secured in practically all cases. Lime with the manure brought about increases in crops in most cases. Increases were not noted in all cases, however, and in some instances the differences in the yields were small. In practice, however, it is definitely known that lime will generally bring about considerable beneficial effects on crops on this soil when it is acid. The use of rock phosphate and acid phosphate proved to be of very large value in increasing crop yields. The increases were particularly noteworthy in the case of the clover crop altho very large effects were also indicated in some cases on the corn and oats crops. Acid phosphate generally brought about somewhat larger effects than the rock phosphate. In some cases the differences were considerable, as for example on the corn in 1918. In other cases, however, there seems to be very little choice between the two materials. The complete commercial fertilizer occasionally showed larger effects than the acid phosphate but in several cases it had less influence. Differences were not strikingly large in any of the seasons, however, and hence it would not seem that this fertilizer would be as desirable for use as the acid phosphate.



Crop residues had little effect on this soil as would be expected. The use of lime with the crop residues brought about slight increases in crop yields in most cases. In one or two instances the use of lime proved very valuable. The effect was noted particularly on the oats in 1920, on the clover in 1921, and on the corn, oats and clover in 1923, 1924 and 1925. The value of lime on this soil when it is acid is shown up very definitely by these figures. The use of rock phosphate and acid phosphate was of very considerable value, the acid phosphate showing up to particular advantage when applied with the lime and crop residues. Larger increases were secured in many cases than those brought about by the rock phosphate when used with the lime and crop residues. The greater beneficial effect of the acid phosphate was noted particularly on the oats in 1916, on the clover in 1917, on the clover in 1921 and on the corn in 1922. In several other cases the rock phosphate was quite as beneficial in effect, sometimes having slightly larger influence on the crop yields. The complete commercial fertilizer frequently had less beneficial effects than the acid phosphate. In one or two cases it gave a larger influence but the differences were not large and in general it would seem that the acid phosphate is preferable for use.

The results confirm those previously secured on the same soil type, indicating that the Carrington loam will respond in a large way to applications of manure, lime and a phosphate fertilizer. Whether acid phosphate or rock phosphate should be employed must be determined under individual farm conditions.

## PEAT SOILS

Peat is partially rotted vegetable matter, which consists either of swamp grasses, sedges, rushes and flags, or of sphagnum moss, the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits only very incomplete decomposition. Deposits of peat thus formed increase from year to year and with the long continuance of swampy conditions may become of considerable depth. When the glacier which once covered north central Iowa, retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places lakes, ponds and marshes were formed because of the heavy, impervious character of the subsoil, and the formation of peat followed. It is mainly in the Wisconsin drift soil area, therefore, that peat occurs in Iowa. Greene County is located in this soil area and has several peat areas, aggregating 2,048 acres or 0.5 percent of the county's area.

There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out.[1] They are composed of fibrous, fairly dry vegetable matter, extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer, therefore, only to the shallow peats and are not at all applicable to deep peats.

The peat in Greene County is generally from 6 to 20 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Hence, practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

The analyses which have been made of numerous samples of peat soils have shown that they contain not only an abundance of nitrogen and organic matter but also considerable amounts of lime. Their phosphorus and potassium content was rather low but these elements were abundant in the muck or clay which forms the subsoils of practically all the shallow peats in Iowa. In Greene County there are only a few extremely small areas where the subsoil under the peat is not a black or drab plastic clay. The character of the subsoil plays a very important part, as will be seen in the treatments which are advised for the reclamation of peat soils. On this account the heavy character of the subsoils underlying the peats in this county is emphasized.

### FIELD EXPERIMENTS ON PEAT SOILS

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story Counties, respectively. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination in the amounts in which such materials are generally applied to soils. In no case was there any profitable increase in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and untreated soils were only such as might occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Greene County do not need the addition of commercial fertilizing materials to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be profitable. The crop seems to be able to secure a sufficient amount of these plant foods from the subsoil, which is well supplied with them. Furthermore, peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria and increase the speed of decomposition. In general, manure should not be used on peat soils, but should be utilized on land in greater need of organic matter and nitrogen.

[1]Iowa Geological Survey 19:168, 1908.



### DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Greene County need to make them productive is physical improvement thru drainage, cultivation and the growing of proper crops.

Drainage is the most important step. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential. The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case, the compacting of the peat would bring the tile too close to the surface and re-laying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is quite impervious. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will allow for the ready passage of water into the drains.

Fall plowing is desirable in order to expose the peat soil to the action of the frost, rain and snow during the winter and hasten decay. Fall-plowed peats may be worked earlier in the spring, hence, the seed bed may be more thoroly prepared. Deep plowing is also valuable, especially when the peat is very shallow and some of the underlying, heavy clay, rich in phosphorus and potassium, may be mixed with the peat. The physical and chemical conditions of the peat are both much improved by such a mixing and crop production is increased. Even in the case of deeper peats, where the subsoil is not reached by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of the air and thus hasten decomposition.

Iowa peat soils which are not over 16 inches in depth should not be rolled, as such an operation may compact them too much and check decomposition. Where the peat is deeper than this, careful rolling may be of value in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivation, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be luxuriant and interfere seriously with the production of crops.

Corn and small grain crops, as a rule, do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore, it is not advisable to seed these crops on peat soils until several years after their reclamation, when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat and thus aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit a successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Greene County. With proper treatment and crop growth, they can be reclaimed.

### "ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

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

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots while other crops are less affected.

These spots occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in detail in another publication,[1] and it is apparent from the studies which have been carried out that the salts which occur are variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amounts of these latter salts which make up the "alkali" content of Greene County "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium bicarbonate which always occurs, may prove injurious.

The "alkali" problem in Greene County and in Iowa in general is, therefore, less serious than in the West, and reclamation is more readily accomplished.

#### TREATMENT FOR "ALKALI" SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained, but this does not mean that the drainage produces the "alkali" condition.

[1]Bulletin 177, Iowa Agricultural Experiment Station—The Alkali Soils of Iowa.



A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of "alkali" salts from the soil and in draining a slough or pond, lines of tile should be laid around the low area as well as thru the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be much more rapid. The lines of tile may be brought together again below the slough and, if the area is rather wide, a third line of tile thru the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully developed, as is frequently the case in Greene County, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available. In other cases, green manures or straw may serve for the purpose, but where such materials are used a small application of manure should be made along with them, in order to hasten the decomposition processes, which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming "alkali" soils, as far is is known. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

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

Some general recommendations which are applicable to the soils of the county as a whole, based on the results of the laboratory, greenhouse and field experiments which have been discussed in previous pages, may be given here. While the field tests reported have been carried out in other counties the soil types are the same as those occurring in Greene County and it is believed that the results will indicate quite accurately the effects of the same fertilizer treatments in this county. While the recommendations given here are based primarily on the results of these experiments, they also reflect to a great extent the general experience of many farmers. No suggestions are made except such as have been proven to be of value by practical experience. The recommendations made are such as may be put into effect on any farm.

Many farmers are already carrying out simple tests with various fertilizing materials and are securing valuable data for themselves and for others who are farming the same types of soil. Such tests may be carried out readily and they are recommended in the case of several of the fertilizing materials which are discussed in this report. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid any farmer who may be interested in conducting fertilizer tests on his own soil.

## LIMING

Except for some of the Webster soils on the uplands, the Fargo soils on the terraces and the Sarpy and Lamoure types on the bottoms the surface soils in Greene County are all acid in reaction. One soil type, the Clarion loam on the uplands shows a lime content in the subsoil. The Webster soils, when acid at the surface, contain lime in the lower soil layers. With these exceptions all the types which are acid in the surface soil show an acidity extending down through the subsoil. Those types which are basic in the surface and subsurface soils show a lime content extending down thru the three-foot section, except in the case of the Fargo silty clay loam. It would seem, therefore, that except for the Fargo, Sarpy and Lamoure types the soils of Greene County should all be tested for lime requirement especially if legumes are to be grown, and the amount of lime shown to be necessary by such tests should be applied if the best legume growth is to be secured.

The needs of the surface soil indicate quite definitely the lime requirement of the particular type. Thus if the surface soil shows an acidity it may be confidently concluded that lime is needed on that soil. Even if there is some lime in the subsoil, as has been noted in the case of the Clarion loam, there is little effect on the requirement of the surface soil. Lime rarely moves upward in soils but, on the other hand, there is a tendency for it to be removed to the deeper soil layers with considerable rapidity, thru the action of drainage waters and to be removed from the soils by utilization by crops. On the Clarion loam, therefore, along with all the other types, even those of the Webster series, applications of lime are needed when the soil is acid. The only way to determine the need for lime is to have the soil tested. This should be done at regular intervals in the rotation preferably just preceding the growing of legume crops.

Soils vary considerably in acidity and lime requirement and even different samples of the same type and from the same area may show a wide difference in acidity. The figures given earlier in this report should be considered, therefore, to indicate only roughly the lime requirements in the various soil types. It is important that the soil in any field be tested for lime needs before an addition is made. In this way the proper application of lime may be made and the best results may be secured. Farmers may test their own soils for lime needs but it will usually be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. Recommendations will then be made regarding treatment.

The greenhouse and field experiments which have been described earlier in this report have shown the increases in crops which may be secured from the application of lime to the various soils when they are acid. The evidence of the beneficial effects of lime are particularly definite on the Carrington loam. The effect is also shown on the Webster silty clay loam when the surface soil is acid, and on some of the other types. Much farm experience with the use of lime has indicated the beneficial effect of this material when applied to acid soils. It is certain, therefore, that the acid soils in Greene County will show noticeable crop increases after applications of lime. Increases may be secured not only in the case of leguminous crops but often with other general farm crops.



Further information regarding the use of lime on soils, losses by leaching and other points connected with liming are given in Extension Bulletin 105 of the Iowa Agricultural Experiment Station. A list of companies prepared to furnish this material is also given in this bulletin.

## MANURING

Most of the soil types in Greene County seem to be fairly well supplied with organic matter. Only in the case of the Conover silt loam and the Pierce sandy loam on the uplands and some of the sandy terrace and bottomland types is there any deficiency in organic matter supply. From the experimental data which has been given earlier, however, and from extensive farm experience, it has been shown that practically all of the soil types in this county will respond to the application of farm manure. This is particularly true in the case of the Carrington and Clarion soils on the uplands. Even the Webster types which are black in color and high in organic matter show a response to the application of manure. Similarly on the Lamoure silty clay loam on the bottomlands, a type which is very well supplied with organic matter, the application of manure proves of value, when properly used. On these heavier textured, darker colored soils, the manure should not be applied preceding the small grain crop in the rotation, as it may cause the grain to lodge. In such cases manure should be applied in small amounts and at some other point in the rotation. When these precautions are observed, the beneficial effects of the manure is large.

Too much emphasis cannot be placed upon the importance of utilizing all the farm manure produced on every farm, in order that the largest and most profitable crop yields may be secured on the various soils. Farm manure not only keeps up the supply of organic matter in the soils but it also returns to the land large amounts of the various plant food constituents which have been removed by the crops grown. Its beneficial effects may be due to the addition of organic matter, to the supplying of microorganisms or to the return of plant food constituents. It may bring about greater availability of the various plant food elements in the soils thru the addition of the microorganisms. It may improve the physical condition of the soil by the organic matter it adds and it may have a significant effect on the chemical condition of the soil thru its content of plant food constituents.

The ordinary application of manure is about 8 to 10 tons per acre once in a four-year rotation. Rarely is it desirable to make larger applications than this and for general farm crops the largest increases per ton of manure are secured with this amount. With the heavier textured soils, as the Webster and Lamoure types, smaller applications will prove of equal value.

On grain farms where farm manure is not produced, the use of leguminous crops as green manures is a valuable practice. On many livestock farms also green manuring may be a desirable practice because of the fact that there is insufficient manure produced to keep all the soils supplied regularly. Green manuring may be considered as an important supplement to farm manure or a substitute for that material. When well inoculated, leguminous crops have the ability of taking nitrogen from the atmosphere and hence, when they are turned under as green manures, they supply nitrogen to the soil. Thus the practice of green manuring has a double value in keeping up the content of organic matter of the soil and in adding nitrogen. This practice cannot be followed blindly and carelessly, however, as undesirable results may occur if conditions are not satisfactory for the best decomposition of the green material. There are many cases where green manuring would be a very desirable practice in Greene County.

Crop residues contain considerable amounts of plant food and much organic matter and hence they should always be returned to the land in order that they may aid in maintaining the supply of organic matter and plant food constituents in the soil. On the livestock farm the residues may be used for feed or bedding and returned to the land with the manure. On the grain farm they may be stored and allowed to decompose partially before being used or they may be applied directly to the land. They play a large part in keeping up the fertility of the soil and they should never be burned or otherwise destroyed because of the actual destruction of valuable fertilizer constituents.

## THE USE OF COMPLETE COMMERCIAL FERTILIZERS

The supply of total phosphorus in the soils of Greene County is not large and it seems certain that some phosphorus fertilizer will be required on the soils in the very near future if crop yields are to be satisfactory. The data from the greenhouse and field experiments which have been discussed earlier in this report indicate that many of the soils in this county will respond very largely at the present time to the application of a phosphate fertilizer. Considerable increase in yields of general farm crops have been noted from the use of acid phosphate or rock phosphate. In many cases the acid phosphate has shown a larger effect than the rock phosphate but in other instances the rock phosphate has apparently proven quite as desirable for use.

Acid phosphate provides the element phosphorus in an immediately available form. Rock phosphate, on the other hand, must be acted upon by various agents in the soil before the phosphorus is changed into a form in which it can be utilized by the crops. This action on rock phosphate may go on rather slowly in some soils under certain conditions. Acid phosphate costs more than rock phosphate but it is applied in smaller amounts, usually at the rate of 150 to 200 pounds per acre annually. The rock phosphate is applied at the rate of one-half to one ton per acre once in the four-year rotation. The relative value of the two phosphates can be determined only by carrying comparative experiments over a period of years, and taking into account the total cost of the application of the two materials.

Insufficient data have been secured as yet to warrant the drawing of definite conclusions regarding the value of the two phosphorus carriers when applied to the soils of this county. It is recommended, therefore, that farmers test both phosphate fertilizers on their own soils, and thus determine for their particular conditions which material will prove the more profitable. Simple tests may be readily carried out on any farm. Directions which may be followed in carrying out such tests are given in Circular 97 of the Iowa Agricultural Experiment Station.



While the supply of nitrogen in the soils of Greene County is generally quite large, this element should not be overlooked in planning systems of permanent fertility for the soils of the county. Some fertilizing material containing nitrogen must be applied regularly to keep up the content of this constituent.

Farm manure is the most important and the most economic nitrogenous fertilizer which can be employed. The proper preservation and return to the land of all the manure produced on the livestock farm will aid materially in keeping up the nitrogen supply. On the grain farm some other means of keeping up the nitrogen content must be employed and in this case the turning under of a well inoculated legume as a green manure is very desirable. When the legume is well inoculated a large part of the nitrogen in the crop comes from the atmosphere and when the crop is turned under as a green manure there will be a corresponding increase in the nitrogen content of the soil. The practice of green manuring will be of value, therefore, in keeping up the nitrogen content of the soils of the grain farm and will aid on the live stock farm to keep up the content of nitrogen, supplying also large amounts of organic matter.

Earlier analyses have indicated that there is a large content of potassium in all the soils of the state and this is true in the case of the soils of Greene County. It seems hardly likely that potassium fertilizers will be of any particular value on these soils at the present time. There is enough present to supply the needs of crops for many years, provided that proper conditions are maintained in the soils to lead to the production of available potassium in sufficient amounts. The experiments where potassium has been applied to one of the soils in the county have not indicated any considerable value from the use of potassium at the present time. Tests, however, should be carried out on individual farms before definite conclusions regarding the need of potassium fertilizers are drawn. Small amounts may be valuable in individual cases.

The use of complete commercial fertilizers cannot be generally recommended on the soils of Greene County. The tests which have been carried out have shown in most instances quite as large a beneficial effect from the use of acid phosphate as from the complete commercial fertilizer. Much larger increases in crop yields must be secured if a complete fertilizer is to prove of as much value as acid phosphate, owing to its greater cost. Tests of complete fertilizers may be carried out quite readily on individual farms where there is interest in determining their value. Such tests should always compare the fertilizer with acid phosphate and if profitable results are secured from the complete fertilizer there is no objection to its use.

## DRAINAGE

Considerable areas in Greene County are inadequately drained. The natural drainage system is poorly developed and the installation of tile is necessary if the soils are to be made satisfactorily productive. On the level to depressed areas in the uplands where the soils of the Webster series are found, the drainage is generally very inadequate, and poorly developed. There are areas in some of the other upland types where the drainage is poor. On the terraces, the Fargo silty clay loam areas and the areas of the Bremer types are poorly drained. On the bottoms, the Lamoure and Wabash soils are poorly drained. The areas of peat and muck are of course particularly in need of drainage if they are to be reclaimed and utilized for crop growth.

A rather definite relationship is shown between the particular soil areas and the need for drainage. This is because of the topographic conditions which are characteristic of the individual types and series. Thus it is the Webster, Fargo, Bremer, Wabash and Lamoure soils which are in need of drainage, and they are the soils occurring in level to depressed areas and are generally heavy in texture and have rather impervious subsoils.

Where drainage conditions are poor, satisfactory crop yields cannot be secured. The basic treatment needed on such land is the securing of thoro drainage, either by the installation of tile or, if necessary, by the location of drainage ditches. There are many areas in Greene County where crop yields are not as satisfactory at the present time as they should be because of the lack of drainage and in these areas the installation of tile is highly desirable. It may prove expensive but the results secured always warrant the outlay. No fertilizing treatments will prove of value on land which is too wet. Fertilizers may be wasted if they are applied to poorly drained areas. Experimental data and considerable practical experience show the benefits from tiling out land and in many instances it means the difference between no crop at all and very satisfactory yields. Farmers in this county should see to it that their land is thoroly drained if they wish to secure the best results.

## THE ROTATION OF CROPS

There is considerable experimental evidence and much practical experience to show the undesirable effects of the continuous growing of any one crop. The fertility of the soil is very quickly reduced by such a practice and the returns from the land become low and its cultivation becomes unprofitable. In spite of the general knowledge of this fact there is still a tendency on many farms to grow one crop continuously due largely to the fact that that crop is the money crop. Evidence is available, however, which indicates that there is greater profit to be secured from following a rotation in spite of the fact that the rotation may include crops of less actual market value than is secured from the growing of one money crop continuously on the same land. From the standpoint of the permanent fertility of the soil, there is no question regarding the desirability of practicing a good crop rotation.

Numerous rotations have been followed successfully in various parts of Iowa. No one rotation can be recommended for all cases and no special rotation experiments have been carried out in this county. From among the following rotations most any one may be chosen as satisfactory for use in Greene County:



### 1. SIX-YEAR ROTATION

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

This rotation may be reduced to a five-year rotation by cutting out either the second or sixth year and to a four-year rotation by omitting the fifth and sixth years.

### 2. FOUR OR FIVE-YEAR ROTATION

*First year* —Corn.
*Second year*—Corn.
*Third year* —Wheat or oats (with clover or with clover and timothy).
*Fourth year*—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

### 3. FOUR-YEAR ROTATION WITH ALFALFA

*First year* —Corn.
*Second year*—Oats.
*Third year* —Clover.
*Fourth year*—Wheat.
*Fifth year* —Alfalfa. (The crop may remain on the land five years. This field should then be used for the four year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year system.)

### 4. FOUR-YEAR ROTATIONS

*First year* —Wheat (with clover).
*Second year*—Corn.
*Third year* —Oats (with clover).
*Fourth year*—Clover.

*First year* —Corn.
*Second year*—Wheat or oats (with clover).
*Third year* —Clover.
*Fourth year*—Wheat (with clover).

*First year* —Wheat (with clover).
*Second year*—Clover.
*Third year* —Corn.
*Fourth year*—Oats (with clover).

### 5. THREE-YEAR ROTATIONS

*First year* —Corn.
*Second year*—Oats or wheat (with clover seeded in the grain).
*Third year* —Clover. (In grain farming, only the grain and clover seed should be sold; most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop).

*First year* —Corn.
*Second year*—Oats or wheat (with sweet clover).
*Third year* —Sweet clover. (The clover may be mixed clovers and used largely as pasture and green manure.)

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

## THE PREVENTION OF EROSION

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but 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.

Erosion does not occur to any large extent in Greene County. It is evidenced, however, on the steep phase of the Carrington loam and on some areas of the Carrington loam and Clarion loam on the uplands. There is also some evidence of erosion in the Pierce sandy loam and the Carrington fine sandy loam. A washing away of the surface soil from several of these types often occurs and occasionally gullying is noted. Where this is true some means of prevention or control of this destructive action should be adopted.

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

### EROSION DUE TO DEAD FURROWS

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

*"Plowing In"*—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas this process may be quite effective. In the more rolling areas, however, it is best to supplement the "plowing in" with a series of "staked in," dams or earth dams.

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

*Earth Dams*—Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

### SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.



*Checking Overfalls*—The formation of small gullies or ditches is practically always the result of overfalls. An easy method of checking 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 are held in place by cross pieces nailed to the posts.

*"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 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 Earth Dam*—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general 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," called the surface inlet, usually extending two or three feet above the bottom of the gully. A large sized tile 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 Dickey 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.

*The Stone or Rubble Dam*—Where stones abound they are frequently used in constructing dams for the control of erosion.

*The Rubbish Dam*—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method.

*The Woven Wire Dam*—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies.

*Sod Strips*—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly.

*The Concrete Dam*—One of the more 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. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered adaptable 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.

### LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as for small gullies. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

### BOTTOMLANDS

Erosion frequently occurs in bottomlands 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.

*Trees*—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable.

### HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are valuable, 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.

*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.

*Contour Discing*—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa.

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



*Deep Plowing*—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous 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.

# INDIVIDUAL SOIL TYPES IN GREENE COUNTY * **

There are 19 soil types in Greene County and these with the steep phase of the Carrington loam and the areas of peat and muck make a total of 22 separate soil areas. They are divided into three groups on the basis of their origin and location, known as drift soils, terrace soils and swamp and bottomland soils.

## DRIFT SOILS

There are eight drift soils in the county and, including the steep phase Carrington loam, nine areas of drift types. They are classified in the Carrington, Webster, Clarion, Conover and Pierce series. Together they cover 89.6 percent of the total area of the county.

### CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil in the county and by far the largest individual type, covering 53.5 percent of the total area. It is extensively developed on the uplands in all parts of the county, being the chief type on the gently undulating, well-drained prairie upland. It occurs also on the smooth slopes bordering small stream valleys. There are no extensive individual areas of this type since in all parts of the county it is associated with the Webster silty clay loam and other Webster soils which are found in the depressions thruout the upland.

The surface soil of the Carrington loam is a dark brown to black mellow loam, about 12 inches in depth. The subsoil is somewhat more compact, being a light brown loam, grading at 24 inches into a yellowish-brown, gritty clay loam. The surface soil is mellow and friable and well supplied with organic matter. Boulders occur occasionally on the surface and thruout the soil section. Small glacial pebbles are quite commonly found.

There is some variation from the typical soil where the land is somewhat more rolling, especially in the southern part of the county where the surface soil is a yellowish-brown mellow loam and the subsoil a heavy sandy clay. In these areas erosion has been more active and there has been a larger removal of organic matter from the surface soil. Occasionally on the gentle slopes of undulating areas or at the foot of slopes, the subsoil is somewhat mottled with bluish-gray and brown.

In topography the Carrington loam is gently undulating and drainage is well established. In certain areas where the type adjoins the Webster silty

*"Greene county adjoins Webster county on the north. In certain cases the soil maps do not appear to agree along the boundaries. This is due to changes in correlation. Since the soil survey of Webster county was made a part of the Fargo soils as mapped in Webster county have been correlated with the Webster series."

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

clay loam there are certain gradations between the two types. In such areas drainage may not be entirely satisfactory.

Practically all of the Carrington loam is in cultivation. Corn occupies the largest acreage and gives an average yield of 40 bushels per acre. Oats are second in importance and average yields of 35 bushels per acre are secured from this crop. The chief hay crop consists of timothy and clover and the yields amount to $1\frac{1}{2}$ tons per acre, on the average. Wheat is grown on some farms and serves as a cash crop. Practically all of the grain and hay is fed to the work stock, hogs and cattle on the farms. The surplus crops are sold at the local markets or elevators and shipped out of the county.

Yields of the common farm crops on the Carrington loam are generally fairly satisfactory, as is indicated by the average yields given above. In many cases, however, very large increases in crops may be secured by the application of fertilizing materials and by the proper treatment of the land. The application of farm manure is very valuable and liberal amounts of this material should be used on this soil type when possible. Beneficial effects of farm manure have been shown in the experimental data given earlier in this report. The type is acid in reaction and is evidently in need of lime for the best growth of legumes and for the best yields of farm crops in general. The application of lime has been found to be of value on this soil, and it is urged that the soil be tested for its lime needs regularly in the rotation, making the application of lime as needed, prior to the growing of the legume crop. Large effects on other general farm crops are frequently secured from the use of lime on this soil.

There are many indications that applications of phosphate fertilizers are valuable on this soil. The data reported in this bulletin indicate some beneficial effects. Some experiences on the farm have likewise indicated the value from the use of a phosphate fertilizer. The results thus far obtained with acid phosphate and rock phosphate do not permit of a definite selection between these two materials. In most cases acid phosphate seems to be somewhat preferable but not in all instances. It is recommended, therefore, that farmers test both acid phosphate and rock phosphate on their particular soils so that they may determine for their own conditions which fertilizer will prove more economically profitable. The use of a complete commercial fertilizer on this soil cannot be recommended at the present time as it would seem that acid phosphate would probably be quite as satisfactory for general use. Tests of complete commercial fertilizers should be carried out, however, in comparison with acid phosphate by any farmers who are interested, before definite conclusions are reached regarding the value or lack of value of any complete brand. There is no objection to the use of a complete fertilizer if it is proven to be more profitable for use than acid phosphate.

### CARRINGTON LOAM, (steep phase) (57)

The steep phase of the Carrington loam is a minor type in the county and the total area is small. It occurs on the eroded slopes and bluffs along the Raccoon River and its tributaries and in some areas along Cedar Creek and Buttrick Creek. The most extensive development of this soil is along the Raccoon River south of Jefferson, extensive areas occurring on both sides of the river, to the county line. There is also a large area just east of Scranton and a smaller area in the northwestern part of the county along Cedar Creek.



The surface soil of the steep phase Carrington loam is a black to brown friable loam, 6 to 8 inches in depth. The subsoil is a yellowish-brown compact silty clay loam or clay. Along the steeper slopes considerable erosion has occurred and the subsoil has been exposed in many places. Here there are small areas of light colored soils. The surface soil varies to a sandy loam along the steeper slopes.

Practically all of this type is too steep for profitable cultivation. Some areas, along Cedar Creek and the Raccoon River bluffs, are very steep and the land has no agricultural value whatever. The most profitable use of this soil is for growing timber and for pasture purposes in the cleared areas. The phase is mainly in forest consisting of bur oak, red oak, bass wood, black walnut and some hickory and hard maple.

### WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the second largest soil type in the county and the second most extensive drift soil. It covers 26.2 percent of the total area of the county. It is extensively developed in all parts of the county, occurring in the level to depressed areas of the upland. The largest areas are found in the northeastern part of the county in Dawson and Highland Townships. In the western and southern parts of the county, the areas are smaller individually and are more closely associated with the Carrington soils. It is found along the intermittent drainage ways and in flat to depressed areas. Many of the areas of the type are small and more or less isolated.

The surface soil of the Webster silty clay loam is a very dark brown to black silty clay loam, 12 inches in depth. The subsoil consists of a rather compact layer of a silty clay loam, yellowish or rusty brown and gray mottled in color. At 25 inches it grades into a brownish-gray or brown and gray mottled silty clay loam. The subsoil generally has a grayish cast and contains small quantities of drift material. Glacial boulders and pebbles are occasionally found on the surface.

In topography the Webster silty clay loam is flat to depressed. Natural drainage is poor. Tiling out of such land is very necessary before it can be made satisfactorily productive. Many of the areas of the Webster silty clay loam have already been tiled to the great advantage of crop growth.

The type is practically all in cultivated crops, the principal crops being corn, oats, clover and timothy. Corn averages 40 bushels per acre, but in favorable seasons yields may be as high as 60 to 70 bushels. Oats will average 35 to 40 bushels per acre. Frequently in favorable seasons the growth of oats will be very rank and the crop will lodge before ripening. Clover and timothy hay yield $1\frac{1}{2}$ to 2 tons per acre.

The yields of general farm crops are quite satisfactory on this soil type but as has been indicated by the experiments referred to previously, increases may be secured in crop yields by certain soil treatments. The soil should first of all be thoroly drained before it can be made most highly productive. When drainage is accomplished, small applications of farm manure applied at some other place in the rotation than just preceding the small grain crop will bring about profitable increases in yields. The surface soil may be acid and in such cases the use of lime will be desirable. In general, however, the type is well supplied with lime and additions are not necessary. The use of a phosphate fertilizer has been found to be of considerable value on this type. Whether acid phosphate or rock phosphate should be used must be determined by tests carried out on individual farms.

### CLARION LOAM (138)

The Clarion loam is the third most extensive drift soil in the county and the third most important soil type. It covers 7.1 percent of the total area. It is found mainly in small areas on low sloping land, bordering the Webster soils. Numerous rather extensive areas of the type are found in Dawson and Paton Townships. Smaller areas occur in other parts of the county.

The surface soil of the Clarion loam is a very dark brown to black friable loam, 15 inches in depth. The subsoil is a dark brown silt loam to about 24 inches at which point it grades into a yellowish-brown to yellow silty clay loam. The lower subsoil contains lime and will effervesce with acid.

In topography the Clarion loam is level to undulating and, in general, drainage conditions are highly satisfactory. In a few instances where the type is closely associated with some of the more poorly drained Webster soils, tiling would be of value.

The soil is practically all in cultivated crops, corn, oats, clover and alfalfa being the chief crops grown. Yields of corn amount to 45 to 50 bushels per acre on the average. In good seasons much higher yields are secured, often going as high as 60 to 70 bushels. Oats yield 45 to 50 bushels per acre on the average. Clover and timothy hay averages 1½ tons per acre. Alfalfa yields amount to 2½ to 3 tons per acre.

The Clarion loam is naturally a fertile soil and good crop yields are normally secured. The addition of fertilizing materials proves valuable on this type, however. Applications of manure bring about large increases in crop yields as has been shown in some of the experiments referred to earlier in this report. While there is lime in the subsoil, the surface soil of the Clarion loam is acid and applications of lime in small amounts may be necessary, in order to secure a good growth of a legume. The use of phosphate fertilizers is recommended on this soil and either acid phosphate or rock phosphate may be employed to advantage. Tests of the two materials on individual farms are recommended. Complete commercial fertilizers may be of value in some cases but in general it would not seem that they will be as profitable for use as acid phosphate, inasmuch as they do not bring about sufficiently larger crop increases, to warrant their greater cost.

### WEBSTER LOAM (55)

The Webster loam is a minor type in the county covering only 1.2 percent of the total area. It occurs in a number of very small areas scattered thruout the northeastern and central parts of the county, closely associated with the



Carrington loam and the Webster silty clay loam. The chief developments of the type are along the county line in Dawson Township and in Junction Township. It occurs extensively along the county line in the eastern part of the latter township.

The surface soil of the Webster loam consists of 4 to 8 inches of a black mellow loam. Below this point there is a more compact layer of silty clay loam, extending to an average depth of 24 inches. At from 15 to 36 inches the soil passes into a dark drab to pale yellow silty clay loam. The subsoil is calcareous, containing considerable amounts of lime and numerous pebbles. Occasionally lime is found thruout the soil section.

In topography the Webster loam is flat to depressed. Drainage is naturally poor on this soil and tiling is necessary for the most satisfactory crop production. In most cases drainage of these areas is now provided.

Practically all of the type is under cultivation. Corn yields about 45 bushels per acre, oats, 40 bushels, and clover and timothy, about 1½ tons.

The needs of the Webster loam for more satisfactory crop yields are very much the same as those noted for the Webster silty clay loam. First of all, adequate drainage must be provided, if it has not already been secured thru proper tiling. The application of manure has been found to bring about considerable increases in crop yields on this soil. Manure should not be applied preceding small grain crops but small amounts applied at other points in the rotation prove very valuable. The type is usually basic in reaction and not in need of lime. When the surface soil is acid, lime should be used for the best growth of legumes. The application of a phosphate fertilizer is very desirable on this soil and either acid phosphate or rock phosphate should be employed. Which material will prove most desirable for use can only be determined by tests on individual farms.

### CONOVER SILT LOAM (167)

The Conover silt loam is a minor type in the county, covering only 0.7 percent of the total area. It occurs along the higher bluffs along the Raccoon River and some of its tributaries. There are several rather large individual areas of the type, the most extensive being found along the Raccoon River in sections 22 and 29 of Washington Township. Another large area is found in sections 25 and 26 in Kendrick Township. This is larger than the area in Washington Township, mentioned above. A long narrow area of the type is found on the east side of the Raccoon River south of its junction with Buttrick Creek and extending along the east side of the latter creek, for several miles. Numerous other small areas of the type are found in the county.

The surface soil of the Conover silt loam is a grayish-brown to brownish-gray silt loam, 12 inches in depth. In the lower part of the 12-inch section there is a distinct layer of a grayish silt loam. The subsoil is a yellowish-gray silt loam underlaid below 20 inches by a very heavy tough dark brown silty clay or clay loam. The texture of the surface soil varies from a silt loam to a fine sandy loam. The lighter soil occurs on the sides of very steep slopes and in pockets on the hillsides.

Practically none of this type is in cultivation. Most of it is covered with a virgin forest of bur oak, red oak, bass wood, black walnut, hickory, elm and hard maple, with an undergrowth of sumac and hazel brush. The land is utilized somewhat for pasture purposes but the growth of native grasses is rather poor.

The type is probably most suitable for forest use and for pasture purposes. It is low in fertility, low in organic matter, acid in reaction and therefore, in need of lime, in need of organic matter in the form of manure and in need of phosphate fertilizers if it is to be brought under cultivation.

### CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county, covering only 0.3 percent of the total area. Only a few small areas of the type have been mapped. They occur principally in section 18 of Jackson Township, in section 29 of Willow Township, and in section 19 of Kendrick Township, the latter area being the largest.

The surface soil of the Carrington fine sandy loam is a dark brown fine sandy loam, 12 inches in depth. The subsoil is a brown or yellowish-brown sandy loam, grading in places into a loose sand below 36 inches. The type occurs on hills and on sloping land bordering the streams. In topography, it is gently rolling and well drained. It is subject to erosion to some extent.

The type is mostly utilized for pasture purposes. It supports a thin stand of grass, consisting mainly of sand reed grass, little bluestem, sedges and spear grass. This type is low in fertility and if it is to be made more satisfactory for crop production, it should receive applications of farm manure, lime to remedy acidity, and the use of phosphate fertilizers. If it is to be used only for pasture purposes more satisfactory growth of grasses may be secured by proper treatments.*

### WEBSTER CLAY LOAM (56)

The Webster clay loam is a minor type in the county, covering only 0.3 percent of the total area. It is found only in a few small areas, chiefly in the northeastern part of the county and the north central part of the county along the county line in Dawson and Paton Townships. The largest area of the type is in Dawson Township.

The surface soil of the Webster clay loam is very dark brown to nearly black clay loam, extending to a depth of about 15 inches. The upper subsoil is a dark brown or grayish-brown compact clay loam. The lower subsoil beginning at a depth of 24 inches is a gray or mottled gray and brown tough clay. The surface soil is high in organic matter and in some areas approaches a muck. Occasionally boulders are found on the surface and thru the soil section. In some areas the surface soil may be composed mainly of material washed in from the surrounding higher land. The soil and upper subsoil rarely shows a lime content. The lower subsoil is high in calcareous material.

In topography the Webster clay loam is level to flat. It is found in flat areas or slight depressions in the upland and in shallow stream valleys. The type is naturally poorly drained and in some cases at the present time the installation of tile would be highly desirable.

*Circ. No. 89. The Pasture Problem in Iowa.



Crop yields are very satisfactory on this soil and nearly all of it is in cultivation. Corn yields from 50 to 60 bushels per acre in years of average rainfall. Other farm crops give equally large yields in good seasons.

The type is particularly in need of thoro drainage, if this has not already been brought about. When the soil has been drained, large crop yields may be secured. The application of small amounts of farm manure is of value in some cases altho this material should never be applied preceding the small grain crop of the rotation. When the type is acid in the surface soil, the use of lime may be desirable for the best growth of legumes. The application of a phosphate fertilizer would undoubtedly bring about profitable increases on this soil in many instances. Whether acid phosphate or rock phosphate should be used can only be determined by tests on individual farms. Farmers are urged to test the use of these two materials and determine which will give them the more profitable returns.

### PIERCE SANDY LOAM (191)

The Pierce sandy loam is a minor type in the county, covering only 0.3 per cent of the total area. It occurs in a number of small areas in the county, the most extensive being found on the morainic hills in Willow Township. The largest area is in section 31 of Scranton Township and section 6 of Willow Township.

The surface soil of the Pierce sandy loam consists of four inches of a dark brown sandy loam. The subsoil consists of a shallow layer of gravelly loam underlaid by beds of stratified gravel. In some areas there is a bed of yellowish-brown fine sandy loam, beneath the surface soil. The subsoil is high in lime content.

The topography of the Pierce sandy loam is hilly to rough. It occurs thruout the county on gravelly knolls. Some of the areas are too small to be shown on the map. Owing to the droughty character of the soil, cultivation would not be warranted except in such small areas as could be farmed along with other soils. In the larger areas the soil is used chiefly for pasture purposes and is most satisfactory for use in that way. More desirable pasture conditions can be secured on this soil by proper methods of treatment. Discing and reseeding would undoubtedly be of value and the application of certain fertilizing materials would prove of value in increasing the growth of pasture grasses on this soil.

## TERRACE SOILS

There are six terrace types in the county classified in the O'Neill, Fargo, Waukesha and Bremer series. Together they cover 5.2 percent of the total area of the county.

### O'NEILL SANDY LOAM (26)

The O'Neill sandy loam is the most extensive terrace soil in the county and the fifth largest soil type. It covers 2.2 percent of the total area. It is developed extensively along the Raccoon River and along Buttrick Creek, and Hardin Creek. The largest individual area is along Buttrick Creek in Junction Township. Rather extensive areas occur along the Raccoon River on both sides thruout the central and southern townships.

The surface soil of the O'Neill sandy loam is dark brown to dark grayish-brown sandy loam, 7 or 8 inches in depth. Below this point, there is a light brown to brown loamy fine sand, which at 24 inches grades into a dark brown coarse sand and gravel. In topography the type is level to gently rolling and drainage is good.

Practically all of the O'Neill sandy loam is under cultivation. Corn yields 25 to 35 bushels per acre, oats 20 to 30 bushels, and timothy and clover 3/4 to 1 ton per acre.

Profitable increases in crop yields on this soil may be secured by proper methods of treatment. The type is droughty in dry seasons because of the porous nature of the subsoil. The application of farm manure will improve the physical condition of the soil and prevent the injurious effects of dry weather being so great. Liberal applications of farm manure should be made to this soil for the best crop yields. The type is acid and would be benefited by liming. The application of phosphate fertilizers is very desirable. Probably acid phosphate would prove most profitable for use but tests on individual farms of rock phosphate and acid phosphate are urged to determine the response of the soil to a phosphate fertilizer and also determine which fertilizer should be employed.

### FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is the second largest terrace soil in the county covering 1.5 percent of the total area. It occurs in a number of small areas in various parts of the county, the largest development being found in Willow Township. There is one rather extensive area in Hardin Township and another in Scranton Township. Numerous other areas are found in different parts of the county, occurring in low depressions or in basins in the uplands.

The surface soil of the Fargo silty clay loam is a black heavy silty clay loam, 18 inches in depth. The subsoil is similar in texture, becoming lighter in color at a lower depth. Below 26 inches, it is a yellowish and grayish mottled heavy silty clay loam. Both soil and subsoil are high in lime content. In topography the type in level to depressed. Drainage is usually poor and tiling is necessary if the soil is to be made satisfactorily productive.

About 50 percent of the soil is under cultivation, the remainder being utilized for pasture and hay. About 80 percent of the area is drained by tile or open ditches. Corn is the chief crop grown, yielding 50 to 60 bushels per acre. Small grains produce a rank growth and frequently lodge before the grain is mature. When the soil is well drained, yields of 1½ to 2 tons of hay per acre are secured and excellent pasturage is afforded.

The type needs first of all to be thoroly drained if it is to be made more satisfactorily productive. When this is accomplished good crop yields may be secured. Small amounts of farm manure would prove of value on this soil, provided the applications are made at some place in the rotation other than preceding the small grain crop. The application of phosphate fertilizers would



be of value and tests on individual farms are recommended, both of acid phosphate and of rock phosphate.

### WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the third largest terrace type in the county but it is of minor importance, covering only 0.6 percent of the total area. It is found in a number of small areas along the Raccoon River, the most extensive areas being in section 5 of Jackson Township and in sections 10, 14 and 25 of Kendrick Township.

The surface soil of the Waukesha silt loam is a dark brown to black heavy silt loam about 15 inches in depth. The subsoil is a yellowish-brown silty clay loam underlaid at 28 inches by a brown silty clay loam. In topography, the type is flat but drainage is excellent. All of the Waukesha silt loam is in cultivation and corn, oats, clover and timothy are grown. Corn yields 45 to 50 bushels per acre, oats 40 to 45 bushels and clover and timothy 1½ tons per acre.

Crop yields on this soil may be increased considerably by proper methods of treatment. The application of farm manure will prove valuable. The type is acid and will respond to applications of lime. The use of a phosphate fertilizer is very desirable and tests of acid phosphate and rock phosphate are recommended.

### WAUKESHA SANDY LOAM (127)

The Waukesha sandy loam is a minor type in the county, covering only 0.5 percent of the total area. It is found in a number of small areas on the higher terraces along the Raccoon River. The largest areas of the type are in sections 31 and 32 of Bristol Township. A number of small areas of the type are found along the Raccoon River and along some of the tributaries of this river.

The surface soil of the Waukesha sandy loam consists of 8 inches of a dark brown to black sandy loam. The subsoil is a light brown material, heavier in texture and slightly compact, passing at 24 inches into a friable silty clay loam. The topography is level and drainage is good.

Practically all of the type is under cultivation and good yields of general farm crops are secured. The soil will respond, however, to applications of farm manure, lime and a phosphate fertilizer. Large increases in crop yields are secured from the application of manure, from the use of lime as the type is generally acid in reaction, and from the use of a phosphate fertilizer. Tests of rock phosphate and acid phosphate are recommended.

### BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is minor type in the county, covering only 0.2 percent of the total area. It is found on low terraces along the Raccoon river, and along Willow Creek. The largest development of the type is in sections 31 and 32 of Washington Township, and sections 32 and 33 of Cedar Township.

The surface soil of the Bremer silty clay loam is a black silty clay loam, 12 inches in depth. The subsoil to a depth of 28 inches is a heavier silty clay loam of a similar color. The lower subsoil is a dark drab and yellow mottled clay loam. In topography it is flat to level occupying former bottomland areas, which are now above overflow. In general, it is poorly drained.

All of the type is under cultivation and good yields of general farm crops are secured in favorable seasons. Corn averages 40 to 50 bushels per acre, oats 40 to 45 bushels and clover 1½ tons.

The type needs first of all to be adequately drained to be more satisfactorily productive. Small amounts of farm manure would be of value, provided they are not applied preceding the small grain crop of the rotation. The use of lime is necessary as the type is acid in reaction, and the application of a phosphate fertilizer would undoubtedly prove of value. Either acid phosphate or rock phosphate should certainly be used on this soil.

### BREMER SILT LOAM (88)

The Bremer silt loam is a very minor type in the county, covering only 0.2 percent of the total area. It is found on the low terraces chiefly along the Raccoon River in the southeastern part of the county. The largest areas occur in section 26 of Grant Township and in sections 18 and 19 of Washington Township.

The surface soil of the Bremer silt loam is a dark brown to black silt loam, 7 inches in depth. The subsoil is a silty clay loam to a depth of 20 inches. Below that point it is a dark drab and yellow mottled silty clay to clay loam. Drainage of the type is adequate in most cases. The soil is level to flat in topography.

All of the Bremer silt loam is under cultivation, the chief crops grown being corn and oats. The yields are very much the same as on the silty clay loam. The type will respond to applications of small amounts of farm manure. It is acid in reaction and lime should be added, in order to secure the best growth of legumes. Phosphate fertilizers would prove of value and applications of rock phosphate or acid phosphate are desirable. Tests on individual farms of these two phosphates should be carried out in order to determine which will yield the larger returns.

## SWAMP AND BOTTOMLAND SOILS

There are seven areas of swamp and bottomland soils in the county including the areas of peat and muck. The soil types are classified in the Wabash, Sarpy and Lamoure series. Together the bottomland soils cover 5.2 percent of the total area of the county.

### WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the most extensive bottomland type in the county and the fourth largest soil type, covering 2.4 percent of the total area. It is developed in all parts of the county along the various streams. The largest areas are found along the smaller streams of the county, chiefly along Hardin Creek, and Buttrick Creek. There are no large areas along the Raccoon River. The most extensive individual area of the type occurs along Buttrick Creek in section 36 of Hardin Township and section 1 of Grant Township, extending along the creek, both to the north and to the south. Most of the other areas of the type are narrow, and in many cases occupy the entire bottoms along the streams.



The surface soil of the Wabash silty clay loam is a very dark brown to almost black silty clay loam. The subsoil at 18 inches is a dark gray or mottled gray and brown silty clay loam. The texture of the subsoil becomes heavier at the lower depths until it reaches a heavy clay. Iron stains and iron concretions occur in many places in the lower subsoil. In topography the type is flat and it is subject to overflow at periods of high water. Drainage is slow because of the nearly level topography and the impervious character of the subsoil.

A large part of the Wabash silty clay loam is not under cultivation but is used for pasture. Pasture grasses, including blue grass, grow very well on it. The soil is productive and where drainage is good and it is protected from overflow, good yields of general farm crops may be secured. In many cases, the type should undoubtedly be left in pasture. When it is cultivated it will respond to applications of phosphate fertilizers and tests of acid phosphate and rock phosphate are very desirable. If legumes are to be grown the use of lime is necessary as the type is acid in reaction. Small applications of farm manure would be of value where the type is newly brought under cultivation. This material should not be applied, however, preceding the growing of a small grain crop.

### SARPY FINE SANDY LOAM (102)

The Sarpy fine sandy loam is a minor bottomland type in the county, covering only 0.7 percent of the total area. It is found in narrow strips on the bottoms along the Raccoon River. The type is most extensively developed in the southern part of the county along this river, in Grant, Franklin and Washington Townships.

The surface soil of the Sarpy fine sandy loam consists of seven inches of a grayish-brown fine sandy loam. The subsoil is a light gray fine sand, grading at 20 inches into loose sand and gravel.

Practically all of the type is utilized for pasture purposes. A few areas along the Raccoon River are forested with elm, hard maple, poplar and willow. Willow and cottonwood trees border the edge of the stream channel where the surface is more sandy. The type is subject to frequent overflow and most of it should undoubtedly be left in pasture. If it is to be cultivated, it needs to be protected from overflow and it would then respond to applications of manure, lime, and a phosphate fertilizer.

### WABASH LOAM (49)

The Wabash loam is a minor type in the county, covering only 0.6 percent of the total area. It is found in a number of small areas along some of the minor streams in the county. The largest development is along Buttrick Creek a few miles west of Dana. Many areas of the type which are too small to show on the map are included in the heavier soils of the Wabash series.

The surface soil of the Wabash loam consists of a dark brown to nearly black mellow loam, gradually grading into a silt loam. The subsoil to a depth of 18 to 30 inches is a silty clay loam, containing considerable amounts of fine sand. Generally there is little change in color through the three foot section but in some places the subsoil may change to a dark gray or mottled gray and brown. In topography the type is level and subject to overflow but it is well drained.

Only a small part of the Wabash loam is cultivated, the greater part being utilized for pasture. Blue grass does very well and there is usually a heavy growth of grass on the type. The most of it should probably preferably be kept in pasture. If cultivated it would respond to applications of manure, lime and a phosphate fertilizer.

### PEAT (21)

There is somewhat over 2,000 acres of peat in the county, making up a total of 0.5 percent of the total area. It occurs in several small areas in various parts of the county, the largest area being found in Bristol Township in the bed of what was originally Goose Lake.

The surface soil of peat to a depth of 10 to 14 inches consists of brown to black organic matter much of which is undecomposed and the original plant materials may be recognized. The remainder of the material consists of very fine sand, silt and clay. The surface soil gradually merges into a silty clay which becomes heavier at the lower depths. Yellowish-brown and gray mottlings occur below 24 inches and gray predominates below 30 inches. Lime occurs in the subsoil and generally thruout the surface soil.

The treatments which are needed to make peat a productive soil have been discussed earlier in this report. Drainage is the first essential and when this is thoroly accomplished, then the treatments required include proper cultivation and the growing of well selected crops. The seeding of timothy and alsike clover and using the crop for pasture purposes is recommended in order that the decomposition of the peat may proceed before general farm crops are grown. Ordinarily the growth of general farm crops will not be satisfactory on new peat. Certain truck crops may sometimes be grown to advantage and in such cases fertilizer treatments may be of value.

### WABASH VERY FINE SANDY LOAM (192)

The Wabash very fine sandy loam is a minor type covering only 0.5 percent of the total area. It is found in a number of small areas along the Raccoon River and there is no extensive development of the type.

The surface soil of the Wabash very fine sandy loam is a dark brown to almost black friable very fine sandy loam. Generally there is very little change in color or texture within the three foot section. In some places the lower subsoil is lighter colored and somewhat more compact. About three-fourths of the type is in cultivation. Corn is the principal crop, yielding about 40 bushels per acre. Oats yield about 35 bushels per acre.

The soil is well drained and when protected from overflow may be used satisfactorily for growing general farm crops. It will respond to applications of farm manure. It is acid and lime should be applied and the use of a phosphate fertilizer would undoubtedly be of value.



### LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is a minor type in the county, covering only 0.3 percent of the total area. It is found on the low bottomlands along the minor streams of the county. The most extensive areas of the type lie along Willow Creek in Willow Township.

The surface soil of the Lamoure silty clay loam is a dark brown to black silty clay loam, 12 inches in depth. The subsoil is somewhat heavier in texture and lighter in color at the lower depths. In some places there is little change in the character of the soil thru the three-foot section. Lime occurs in considerable quantities in the subsoil which always shows an effervescence with acid. Occasionally the lime extends thru the surface soil. Drainage of the type is very poor. Occasionally there is an accumulation of so-called alkali in the soil. This, as has been noted earlier in this report, consists mainly of a high concentration of calcium carbonate in the soil solution.

Many of the areas of the type appear like swamps and show a rank growth of slough grasses and cattails. The type is used mainly for pasture. Grasses make a heavy growth but in the late season are of little use for feeding purposes. What this soil needs primarily is better drainage in order to provide better pasturage. Most of it should undoubtedly be left in pasture. It is naturally a rich, productive soil. Good crop yields might be secured with thoro drainage and protection from overflow.

### MUCK (21a)

There is a small area of muck in the county covering only 0.2 percent of the total area. It is found in several small narrow strips, chiefly associated with the Webster silty clay loam in the depressions in the uplands. Some of the areas of muck are too small to show on the map and have been included with the Webster soils.

The surface soil of muck is a black, light, fluffy organic material, extending to a depth of 8 to 10 inches. It contains 15 to 30 percent of well decomposed organic matter, a small proportion of fine sand and the remainder consists of silt and clay. At a depth of 12 inches the soil gradually changes to a dark brown to black silty clay loam, becoming heavier with depth and changing to a silty clay at about 30 inches. Below this point, yellowish-brown and gray mottlings occur. Lime occurs in abundance in the subsoil and frequently extends thru the surface soil.

The needs of muck to be made productive are the same as those which have been mentioned in the case of peat. Muck represents peat in an advanced stage of decomposition. When well drained it may be made productive thru proper cultivation and the use of certain crops. Applications of fertilizing materials might be of value in some cases on this material, especially if truck crops are grown.

# APPENDIX

## THE SOIL SURVEY OF IOWA

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

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

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

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

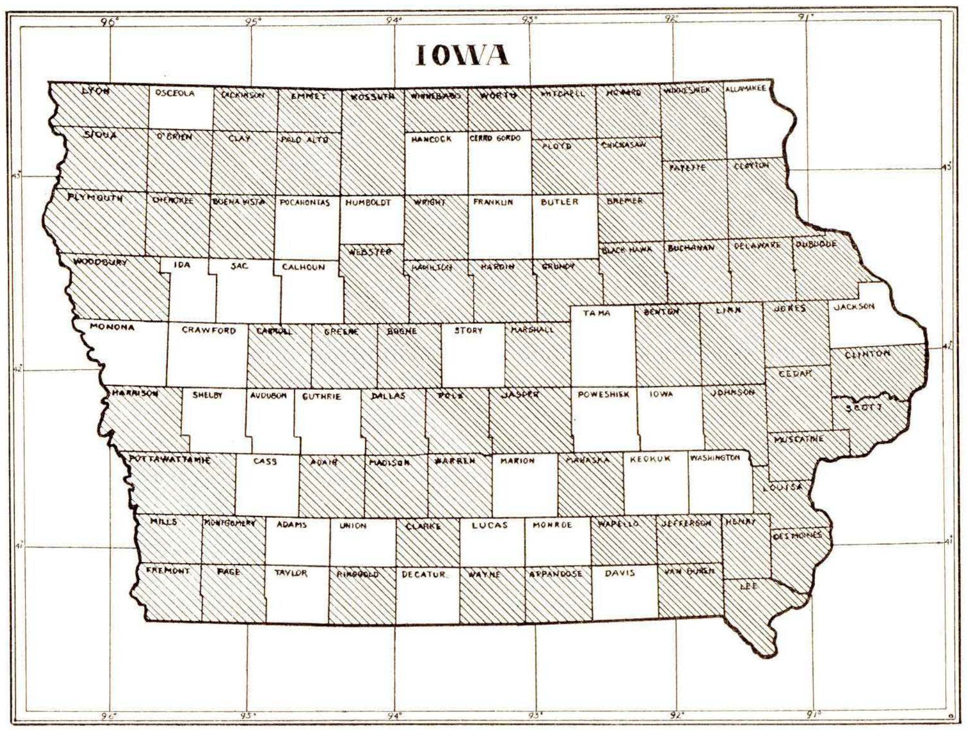


Fig. 9. Map of Iowa showing the counties surveyed.



## *PLANT FOOD IN SOILS*

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

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

### THE "SOIL DERIVED" ELEMENTS

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

### AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

### REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho 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 the soil

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO^3$) ), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl).

| Crop | Yield | Plant Food, Lbs. | | | Value of Plant Food | | | Total Value of Plant Food |
|---|---|---|---|---|---|---|---|---|
| | | Nitrogen | Phosphorus | Potassium | Nitrogen | Phosphorus | Potassium | |
| Corn, grain | 75 bu. | 75 | 12.75 | 14 | $12.00 | $1.52 | $0.84 | $14.37 |
| Corn, stover | 2.25T. | 36 | 4.5 | 39 | 5.76 | 0.54 | 2.34 | 8.64 |
| Corn, crop | ...... | 111 | 17.25 | 53 | 17.76 | 2.07 | 3.18 | 23.01 |
| Wheat, grain | 30 bu. | 42.6 | 7.2 | 7.8 | 6.81 | 0.86 | 0.46 | 8.13 |
| Wheat, straw | 1.5 T. | 15 | 2.4 | 27 | 2.40 | 0.28 | 1.62 | 4.30 |
| Wheat, crop | ...... | 57.6 | 9.6 | 34.8 | 9.21 | 1.14 | 2.08 | 12.43 |
| Oats, grain | 50 bu. | 33 | 5.5 | 8 | 5.28 | 0.66 | 0.48 | 6.42 |
| Oats, straw | 1.25 T. | 15.5 | 2.5 | 26 | 2.48 | 0.30 | 1.56 | 8.28 |
| Oats, crop | ...... | 48.5 | 8 | 34 | 7.76 | 0.96 | 2.04 | 14.70 |
| Barley, grain | 30 bu. | 23 | 5 | 5.5 | 3.68 | 0.60 | 0.33 | 4.61 |
| Barley, straw | 0.75 T. | 9.5 | 1 | 13 | 1.52 | 0.12 | 0.78 | 2.42 |
| Barley, crop | ...... | 32.5 | 6 | 18.5 | 5.20 | 0.72 | 1.11 | 7.03 |
| Rye, grain | 30 bu. | 29.4 | 6 | 7.8 | 4.70 | 0.72 | 0.46 | 5.88 |
| Rye, straw | 1.5 T. | 12 | 3 | 21 | 1.92 | 0.36 | 1.26 | 3.54 |
| Rye, crop | ...... | 41.4 | 9 | 28.8 | 6.62 | 1.08 | 1.72 | 9.42 |
| Potatoes | 300 bu. | 63 | 12.7 | 90 | 10.08 | 1.25 | 5.40 | 17.00 |
| Alfalfa, hay | 6 T. | 300 | 27 | 144 | 48.00 | 3.24 | 8.64 | 59.88 |
| Timothy, hay | 3 T. | 72 | 9 | 67.5 | 11.52 | 1.08 | 3.95 | 16.55 |
| Clover, hay | 3 T. | 120 | 15 | 90 | 19.20 | 1.80 | 5.40 | 16.40 |

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

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

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

### REMOVAL FROM IOWA SOIL

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

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

## *PERMANENT FERTILITY IN IOWA SOILS*

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



the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

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

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

### CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro 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 heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

### THE ROTATION OF CROPS

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

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

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

### MANURING

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

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

Three materials may be used to supply the organic matter and nitrogen of soils.

These are farm manure, crop residues and green manure, the first two being much more common.

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

### THE USE OF PHOSPHORUS

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

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

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

### LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer maytest his own soil and determine its need of lime, referred to above, or he may send a small sample to the Soils Section and have it tested free of charge.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil.

## *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. 12.

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 distinguishable 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 the fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

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

### THE SOIL SURVEY BY COUNTIES

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

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

### GENERAL CHARACTERISTICS

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

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

They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography of lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture of porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

### METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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

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

## SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

*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 per cent 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.